GEOGRAPHY FOR TTCs

STUDENT'S BOOK

3

YEAR THREE

OPTION:

SOCIAL STUDIES EDUCATION (SSE)

FOREWORD

The Rwanda Basic Education Board is honored to avail the Geography Student's Book, Year Three, for Teacher Training Colleges (TTCs) in Social Studies Education (SSE) Option and it serves as official guide to teaching and learning of Geography.

The Rwandan education philosophy is to ensure that young people at every level of education achieve their full potential in terms of relevant knowledge, skills and appropriate attitudes that prepare them to be well integrated in society and exploit employment opportunities.

The ambition to develop a knowledge-based society and the growth of regional and global competition in the job market has necessitated the shift to a competence-based curriculum. After a successful shift from knowledge to a competence-based curriculum in general education, TTC curriculum also was revised to align it to the CBC in general education to prepare teachers who are competent and confident to implement CBC in pre-primary and primary education. The rationale of the changes is to ensure that TTC leavers are qualified for job opportunities and further studies in higher education in different programs under education career advancement.

I wish to sincerely express my appreciation to the people who contributed towards the development of this document, particularly, REB staff, lecturers, TTC Tutors, Teachers from general education and experts from Local and International Organizations for their technical support.

I take this opportunity to call upon all educational stakeholders to bring in their contribution for successful implementation of this textbook.

Dr. MBARUSHIMANA Nelson

Director General, REB

ACKNOWLEDGEMENT

I wish to sincerely express my special appreciation to the people who played a major role in development of Geography Student's book for SSE Option, Year Three. It would not have been successful without the support from different education stakeholders.

I wish also to thank Rwanda Basic Education Board (REB) leadership who supervised the textbook writing process. I wish to extend my appreciation to REB staff, Lecturers, Tutors, Teachers from General Education, Experts from Local and International Organizations for their effort during the writing of this textbook.

MURUNGI Joan

Head of Curriculum, Teaching and Learning Resources Department/REB

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ACRONYMS AND ABBREVIATIONS

C: Degree Celsius

F: Degree Fahrenheit

CAES: Compressed Air Energy Storage

CCS: *Carbon Capture and Storage*

GHG: Greenhouse gas

HEP: Hydro-Electric Power

Inch/Inches: British measurement

MIDIMAR: Ministry of Disaster Management and Refugees

OM: Organic Matter

REMA: Rwanda Environment Management Authority

RURA: Rwanda Utility Regulatory Agency

TES: Thermal energy storage

GENERAL INTRODUCTION

This text book is part of the reform of the school curriculum in Rwanda: that is changes in what is taught in schools and how it is taught. It is hoped this will make what you learn in school useful to you when you leave school, whatever you do then.

In the past, the main thing in schooling has been to learn knowledge – that is facts and ideas about each subject. Now the main idea is that you should be able to use the knowledge you learn by developing competencies. These competencies include the ability to think for yourself, to be able to communicate with others and explain what you have learnt, and to be creative that is developing your own ideas, not just following those of the tutor and the text book. You should also be able to find out information and ideas for yourself, rather than just relying on what the tutor or textbook tells you.

Activity-based learning

This means that this book has a variety of activities for you to do, as well as information for you to read. These activities present you with material or things to do which will help you to learn things and find out things for yourself. You already have a lot of knowledge and ideas based on the experiences you have had and your life within your own community. Some of the activities, therefore, ask you to think about the knowledge and ideas you already have.

In using this book, therefore, it is essential that you do all the activities. You will not learn properly unless you do these activities. They are the most important part of the book.

In some ways this makes learning more of a challenge. It is more difficult to think for yourself than to copy what the tutor tells you. But if you take up this challenge you will become a better person and become more successful in your life.

Group work

You can also learn a lot from other people in your class. If you have a problem, it can often be solved by discussing it with others. Many of the activities in this book, therefore, involve discussion. Your tutor will help to organize these groups and may arrange the classroom so you are always sitting in groups facing each other.

Research

One of the objectives of the new curriculum is to help you find things out for yourself. Some activities, therefore, ask you to do research using books in the library, the internet if your school has it, or other sources such as newspapers and magazines. This means you will develop the skills of learning for yourself when you leave school.

Skills lab

Geography subject is practical than being theoretical only that is why it requires time of skills lab which is a regular time on normal time table when student-teachers are required to complete learning activities working in manageable groups.

During skills lab activity student-teachers are given an opportunity to talk more and get more involved in the lesson than tutors. Student-teachers receive constructive feedback on work done (Tutor gives quality feedback on student presentations).

The Skills Lab prepares student-teacher to complete portfolio assignments on their own after classes. So the classroom activity should connect directly to the portfolio assignment and the tutor during the skills lab makes sure that he/she links the unit with the students.

Icons

To guide you, each activity in the book is marked by a symbol or icon to show you what kind of activity it is. The icons are as follows:

Thinking icon/Introductory activity

This indicates thinking for yourself or groups discussion. You are expected to use your own knowledge or experience, or think about what you read in the book, and answer questions individually or as group activity.

Thinking icon/Introductory activity

This icon reminds you link your previous knowledge with the topic you are going to learn. As a student feel free to express what you already know about the topic. What is most important is not giving the right answer but the contribution you are making towards what you are going to learn.

Application activity

Some activities require you to complete them in your exercise books or any other book. It is time for you show if you have understood the lesson by answering the questions provided.

Skills lab

This icon indicates a practical activity, such as a role play to resolve a conflict, participating in a debate and following instructions provided by the teacher. These activities will help you to obtain practical skills which you can use even after school.

End unit Assessment icon

This icon invites you to write down the results from activities including experiments, case studies and other activities which assess the attainment of the competences. Tutors are expected to observe the changes in you as student-teacher.

UNIT 1

INTERPRETATION OF PHOTOGRAPHS AND VIDEO IMAGES

Key Unit competence

By the end of this unit, I should be able to interpret photographs, video and images.

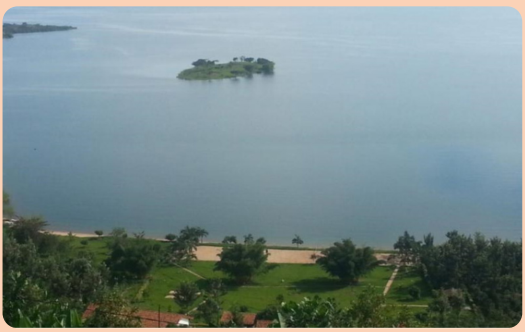
Introductory activity

In the previous units, it was shown that maps are very important tools to indicate and to describe physical and human features. Identify and describe other techniques used in geography to locate and display physical and human features.

1.1. Definition and types of photographs

Learning activity 1.1

Describe the difference between the two photographs provided below:



1.1.1. Definition

A photograph is a picture of an object or environment taken by a camera at a particular time in a given place. Photographs are techniques of recording geographical information. They enhance the understanding of reality. However, when a photograph is taken, some parts of the object or environment are seen while others may not appear clearly. A hidden ground or area which cannot be seen by a camera when a photograph is taken is called a **dead ground**.

1.1.2. Major types of photographs

There are two major types of photographs: Terrestrial / close or ground photographs and Aerial photographs.

1) Ground Photographs

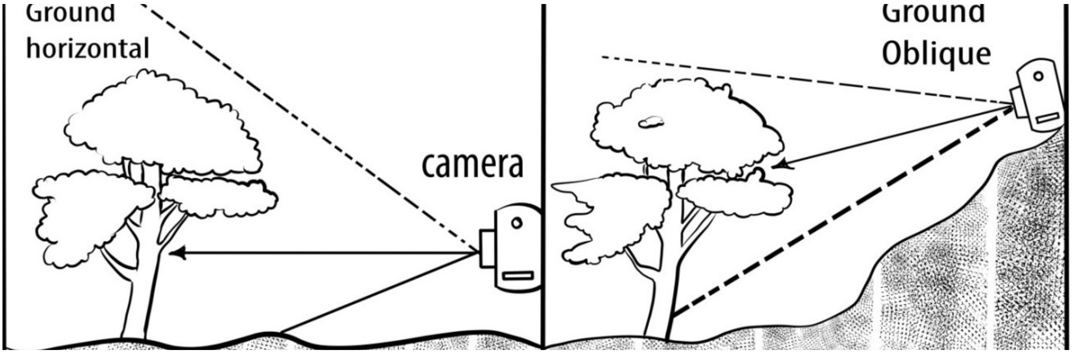
Livestock farm ground photograph

Also called terrestrial or close photographs, **ground photographs** are photographs taken from the ground level. They record targets exactly what a person would see if he or she was standing on the ground level. A ground photograph gives a horizontal view, great details of the landscape and covers a small area.

There are two types of ground photographs:

i) **Ground horizontal photograph:** This is a photograph taken when a camera is held horizontally to the ground.

ii) **Ground oblique photograph:** This is a photograph taken when the camera is titled at an angle facing the ground.



Ground photographs

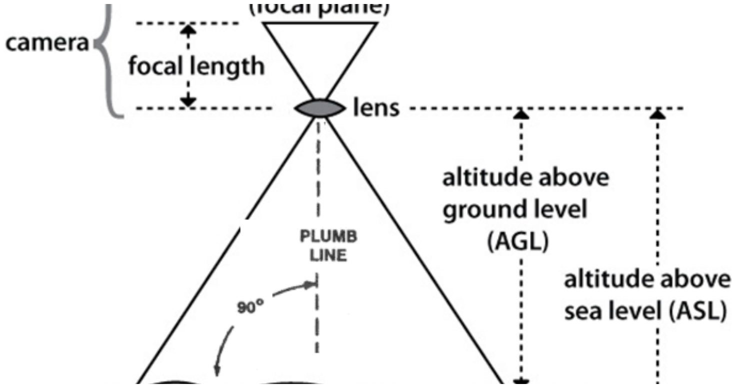
2) Aerial Photographs

Aerial photograph of Musanze

Aerial photographs are images taken from aerial station such as aircrafts, satellites and other flying objects. They cover a wide area where features are greatly reduced. They show the top of the object and do not view objects in a perfect horizontal perspective.

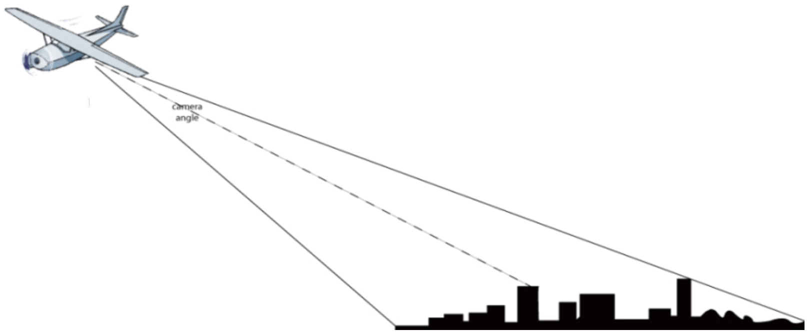
There are two categories of aerial photographs:

i) **Vertical aerial photographs** are images taken when the camera is directly located above or overheading the target objects, or when it is perpendicular to the ground.



Vertical aerial photograph

ii) Oblique aerial photographs: These are photographs taken when the camera is titled at an angle below 90 degrees.



Oblique aerial Photograph

Application activity 1.1

Identify the types of the photographs A and B below and describe them

A

B

1.2. Sections of a photograph and interpretation of physical and human aspects

Learning activity 1.2

Observe the photograph below and answer the following questions:

1) Identify the physical and human features shown on the below photograph.
2) Indicate the respective parts where these features are found in the below photograph.

1.2.1. Sections of a photograph

From a horizontal perspective, photographs have three parts described below:

- **The foreground:** It is the part of the photograph located nearest to the camera.
- **The middle ground:** It is the central part of the photograph.
- **The back ground:** It is the farthest part of the photograph that includes the horizon.

From a vertical perspective, photographs are also divided in three parts**: left, centre** and **right.**

Combining both horizontal and vertical perspectives, the photographs can be put into the following categories:

Categories of photographs depending on the position of photography

Left background	Centre background	Right background
Left middle ground	Centre middle ground	Right middle ground
Left foreground	Centre foreground	Right foreground

1.2.2. Interpretation of physical and human aspects on photographs and video images

Physical and human aspects on photographs and video images can be interpreted as follows:

A. Interpretation of physical aspects

i) **Climate:** Climate in a photograph is indicated by rainfall and temperature. Heavy rainfall can be observed by presence of dense forests and crops like sugar cane, rice and tea while high temperature may be observed by the presence of poor vegetation, people wearing light clothes etc.

ii) **Relief:** The landforms depicted on a photograph include mountains, hills, valleys, escarpments, plateaus and plains. A hilly or mountainous landscape is indicated by the presence of steep slopes, presence of terraces, snow and glaciers on the top. Plateaus and plains are identified by a uniformly flat land with sloping edges and pools of water or irrigated land. Wide valleys with meanders and flood plains also suggest the presence of plain land.

Relief on vertical aerial photographs can be interpreted by observing the following:

- Flat areas can be identifiable by the presence of meandering rivers, straight roads and gentle bends.
- Plateaus can be indicated by presence of flat topped hills.

iii) **Vegetation:** This is the plant life that covers the earth surface; it is both natural and artificial. When describing vegetation on a photograph, the aspects to consider are the type of vegetation whether grassland, scrub or thicket; the tree species such as baobab, acacia, eucalyptus; the density of the vegetation whether trees are close together or scattered; and the nature of the vegetation whether human made or natural.

iv) **Drainage:** Drainage is shown by the presence of water bodies on a photograph, such as streams, rivers, lakes, swamps, seas, and oceans. Others are man-made water features like wells, ponds, valley dams and boreholes. In photographs, drainage is interpreted in the following ways:

- Rivers appear with meandering channels with swampy vegetation along them.
- Swamps appear with luxuriant vegetation dominated by papyrus reeds.

v) **Soils:** The types of soils can be identified by observing the types of crops grown there because there are crops that grow well in specific types of soils, for example, tea and coffee grow well in fertile volcanic soils. Where erosion took place, the soils are exposed.

B. Interpretation of human aspects

Photographs and video images can be very useful in the interpretation of human activities such as:

i) **Forestry:** A forest is evidenced by the presence of both artificial and natural forests.

ii) **Agriculture:** Agricultural activities can be observed by the presence of food crops and cash crops as well as animals like cattle both exotic and traditional breeds.

iii) **Transport and communication:** Both transport and communication networks are evidenced by presence of motor vehicles, bicycles, roads, ships, airports, and communication facilities such as telephone lines and masts.

iv) **Mining:** This is shown by Open pits, people undertaking mining or a mineral processing plant show that there is mining taking place in that area.

v) **Industry:** Industrialization is shown by the presence of industries emitting smoke from huge chimneys.

vi) **Trade or commerce:** the commerce is evidenced by trading centers with congested buildings and at times presence of markets.

vii) **Settlement:** It is evidenced by the presence of houses in different patterns.

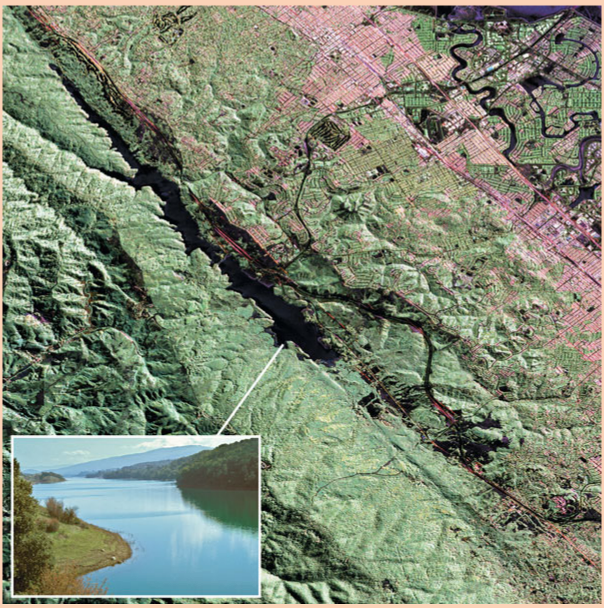
Application activity 1.2

Observe the photograph below and describe the physical and human aspects represented on it.

1.3. Relationship between physical and human aspects on photographs and video images

Learning activity 1.3

Describe the relationship between physical and human features represented on the photograph below:



Photograph showing physical features (down-left) and human features (up-right)*: the arrow indicates the position of a river which drains the valley that appears on the photograph.*

Some photographs and video images help in illustrating the relationship between human and physical aspects. Basing on the figure provided above, the relationship between human and physical aspects can be explained as follows:

i) **Relief and transport:** Transport routes occur on gentle slopes and avoid steep slopes and valleys since it is very expensive to construct roads in hilly areas.

ii) **Relief and agriculture:** On steep slopes, less agriculture takes place while on gentle slopes most agricultural practices are observed. The low lands are usually reserved for growing of vegetables, sugar cane, rice, and other crops that need enough water.

iii) **Relief and settlement:** Settlements are commonly found in gentle slopes and are few in steep slopes and valleys because of the problem of severe soil erosion and flooding in valleys.

iv) **Drainage patterns and settlement:** Settlement occurs in well drained areas and avoids lake shores or river banks because of floods and associated problems.

v) **Drainage and transport:** Transport routes are usually found in well drained areas. For example, roads cannot be constructed in swampy areas due to excessive water. Water transport occurs on water bodies like rivers, lakes, oceans and seas.

Application activity 1.3

Observe the photograph below and describe how physical features have influenced human activities in the area.

Skills Lab

With help of the knowledge, skills, attitudes and values acquired in this unit, suggest ways of conserving the physical features and promoting economic activities in your school environment for sustainable development.

End unit assessment

Study the photograph provided below and answer the following questions:

1) Identify the economic activities taking place and describe their importance to the people living in the area.
2) Suggest ways of conserving the area in the background of the photograph for environmental sustainability.
3) Identify the human features which are predominant in the foreground of the above photograph

UNIT 2

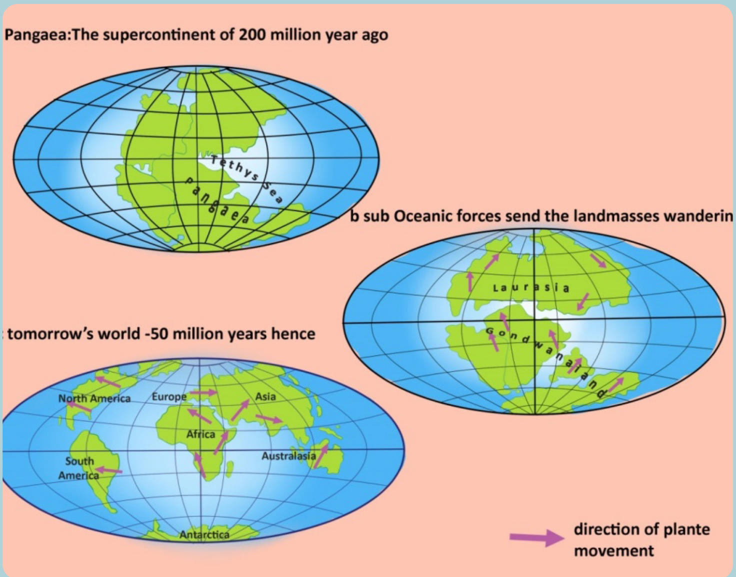
THE ORIGIN AND DISTRIBUTION OF THE CONTINENTS

Key Unit competence:

By the end of this unit, I should be able to discuss theories of the origin and the distribution of continents.

Introductory activity

Observe carefully the maps provided below and answer the following questions:



1) How many oceans do you find on map a
2) How many continents do you see on map b
3) How many continents do you see on map c
4) Explain the processes which led to the separation of the unique initial landmass into various continents as they appear today.

2.1. Concept and theories of continental drift

Learning activity 2.1

- Make research using books and internet to explain the theory of Alfred Wegener on the continental drift.

2.1.1. Concept of continental drift

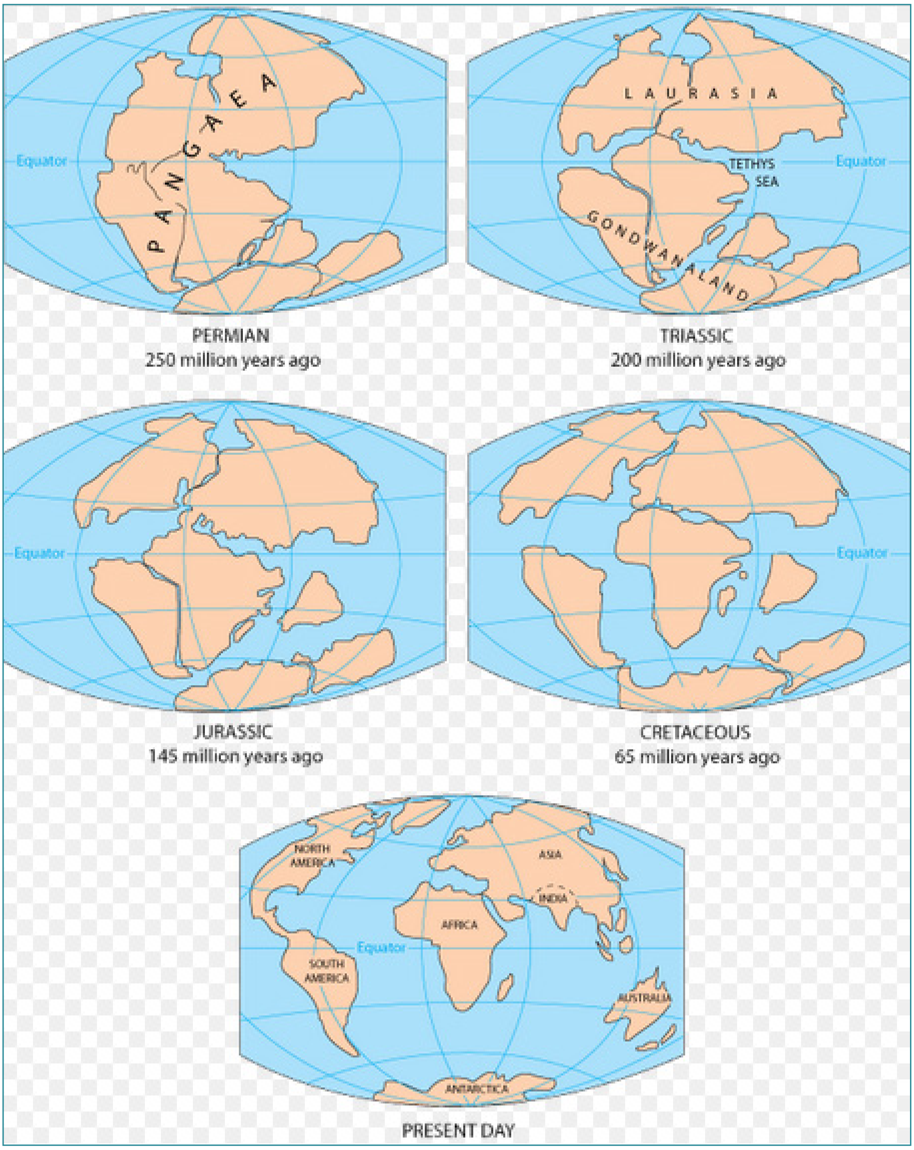
The term **continental drift** refers to the study of causes and consequences of the distribution of continents and ocean basins. It is defined as a slow movement of the Earth's continents towards and away from each other. The differential movement of the outer shell resulted into fragmentation by rifting, followed by drifting apart of individual masses of the broken outer shell.

2.1. 2. Theories of the origin and distribution of the continents and ocean basins

There are several theories of continental drift that were developed at the beginning of the 20th century. The following are the four main theories of continental drift: Alfred Lothar Wegener's theory; Maurice Ewing's theory; Harry Hammond Hess' theory and Frank Taylor's theory.

The theory of the origin and distribution of the continents and ocean basins according to Alfred Wegener

According to Wegener's theory, there was a breakup of the single super continent block called **Pangaea** "**pan JEE uh**", which means "**all land**" into multiple continents, as they appear today, that moved apart in a process called *continental drift.* That movement took place about 200 million years ago. The map provided below fits together the continents whose breaking up resulted in today's continents.



The break-up of Pangaea and periods of disintegration

The theory of continental drift traces the origin and distribution of continents through five major steps:

i) The supercontinent **Pangaea** was surrounded by an extensive water mass called the '**Panthalassa'** (***Pan*** means all and ***Thalassa*** means oceans) or the primeval Pacific Ocean. During the Carboniferous period (about 250 million years ago), the South Pole was near Natal (South African coast) and the North Pole was in the Pacific Ocean.

ii) In about 200 million years, **Pangaea** broke up to form **Laurasia** (North America, Greenland, and all of Eurasia north of Indian subcontinent), and **Gondwanaland** (South America, Africa, Madagascar, India, Arabia, Malaysia, East Indies, Australia, and Antarctica). These two blocks were separated by a long shallow inland sea called **Tethys Sea**.

iii) In about 145 million years ago, the drifting of the southern landmasses continued. India drifted northwards.

iv) In about 65 million years ago, Australia began to separate from Antarctica.

v) The present shapes and relative positions of the continents are the result of fragmentation of *Laurasia and Gondwanaland* by rifting and drifting apart of the broken landmasses following the formations of oceans and seas (see figure above). South America separated from Africa, North America separated from Europe, while Antarctica, Australia, India and Madagascar formed a single unit with South America.

However, Wegener's theory was initially criticized because he could not explain how solid continents have changed their positions. His theory has been revived by other researchers after discovering new evidences.

Application activity 2.1

1) Explain the concept of continental drift

2) Explain why Taylor's theory on the origin and distribution of the continents and ocean basins was initially criticized.

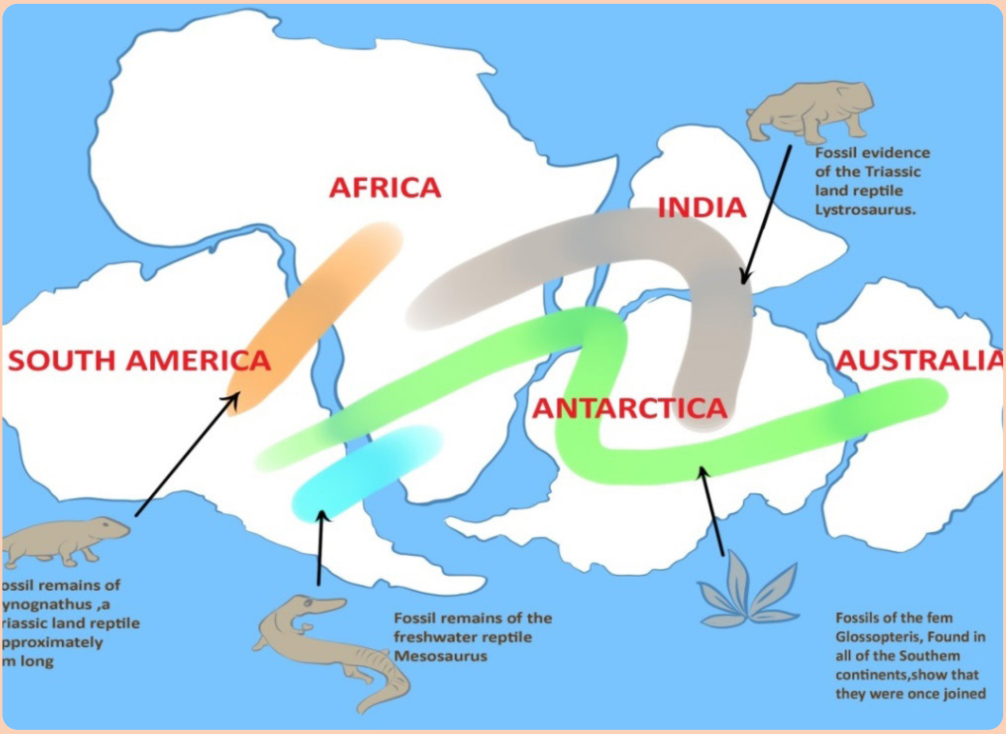
2.2. Evidences of continental drift

Learning activity 2.2

Observe the map provided below and answer the following questions:

1) Describe the edges of the continents.

2) What suggests the distribution of the same animal and vegetation species over the different continents?

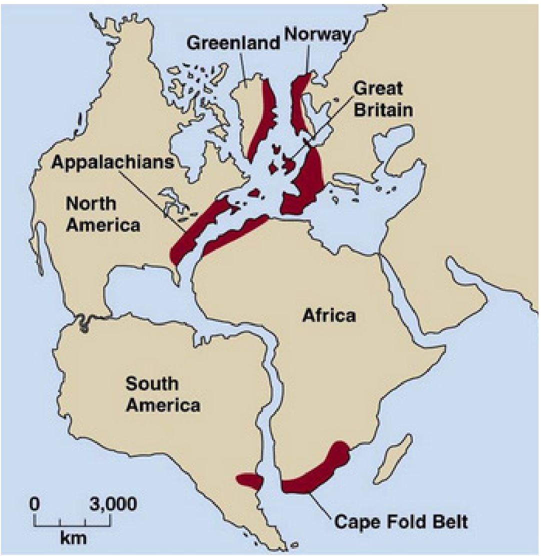


Many evidences of continental drift exist, but they can be summarized in four major categories:

i) Geological evidence

A good fit of edges of continents and similar rock structures are found on different continents. For example:

- East coast of South America and the Western Coast of Africa have good visual fits, both at the surface (1000 m) and depth (2000 m).
- Both Africa and South America are composed of rocks of varying ages and there is a convincing boundary joint across the two continents between Accra and Sao Louis in Brazil and, dividing Pan-African rocks and Elaurean rocks. This evidence constitutes what is commonly known as “matching geology”
- Parts of Appalachian Mountains of the United States of America are similar to those found in Greenland and Western Europe;
- The fact that rock particles have magnetic properties allowed geophysicists to reconstruct the position of the poles in past times and also the probable climatic lay belts of the past. From this, it appears that Southern Africa and South America lay within the Arctic circle of Permian and carboniferous times and that during the Triassic period, the continents had moved some 40° closer to the Equator.

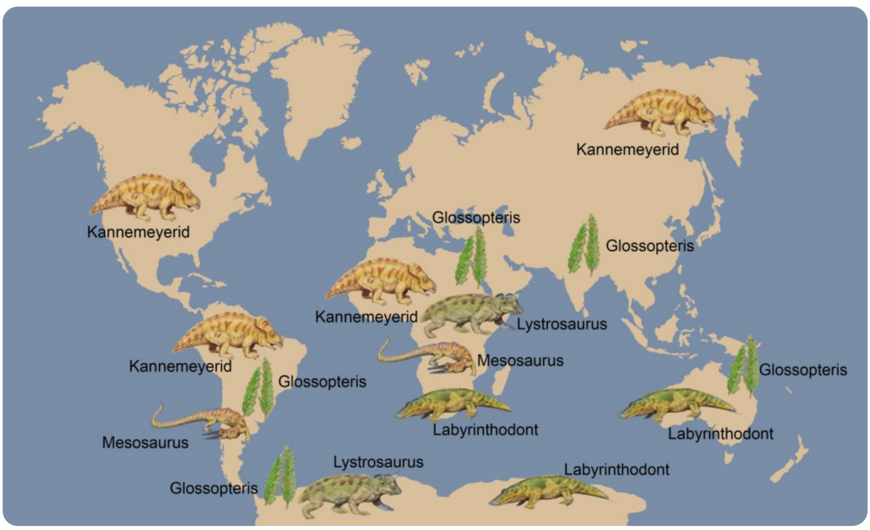


Matching ancient rock assemblage and continental shelf

ii) Biological evidence

There is similarity in the fossils and vegetation remains found on the eastern coast of South America and the Western coast of Africa. For example;

- Mesosaurus was small reptile living in Permian time (280 million of years before present); its remains have been found only in South Africa and Brazil.
- Remains of Glossopteris, a plant which existed when coal was being formed has only been located in India and Antarctica. These animals and plants could not have swum across oceans if continents were separated by water bodies, so continents must have been close together for them to occur on different continents which probably had a similar climate.

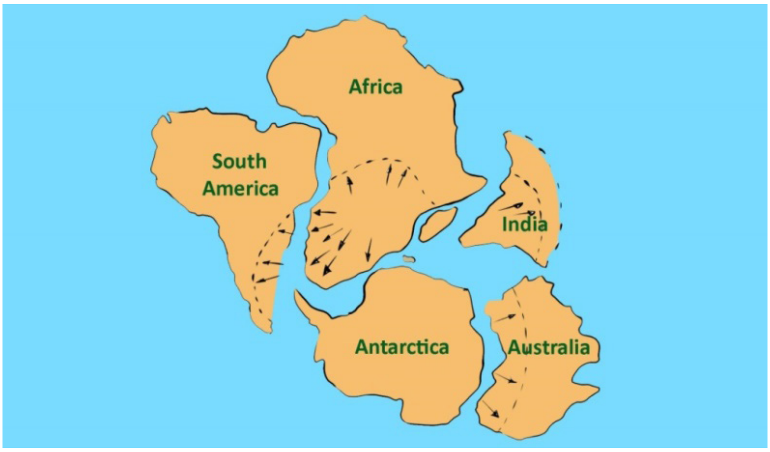


Fossils of old animals that support Wegener's hypothesis of continental drift

iii) Climatic evidence

Coal formed under warm and wet conditions was found beneath the Atlantic ice-cap, and evidence of carboniferous glaciation had been noted in tropical and central India. For example;

- Coal could not have been formed in Britain with its present climate.
- Peninsular India, Australia and Antarctica further prove the unification of all landmasses in one landmass (Pangaea) during carboniferous period.
- Groves curved on rocks by glaciers in the southern parts of landmasses forming Gondwanaland shown by arrows on the figure below provided evidence for continental drift.



Grooves curved by ancient Glaciers

iv) Geodetic evidence

Geodetic evidence has revealed that Greenland is drifting westward at the rate of 20 cm per year. This is one of the scientific evidences arising from measurement and representation of the earth that confirm the spread of the sea floor.

Application activity 2.2

1) Describe the rocks at the edge of the continents and show how all continents formed a unique block.
2) Using some examples, compare the fossils of animal species and vegetation species found on different continents by showing how they indicate the continental drift.

2.3. Effects of continental drift on the evolution of physical features

Learning activity 2.3

Make a research and describe at least four major effects of continental drift.

The continental drift has had many effects on the evolution of physical features but the most important are the following:

- Pangaea split apart into a southern landmass, ***Gondwanaland*** and the northern landmass called ***Laurasia***; later the two super continents split again into land masses that look like present day continents.
- Continental drift has also affected the earth's climate. The climate of different parts of the world has changes throughout the year;
- Continental drift has affected the evolution of animals. The rearrangement and displacement of huge landmasses has helped create the diversity which we see present in modern day animals.
- Collision of earth crusts. The collision of the Indian subcontinent and Asian continent created the Himalayan mountain range, home to the world's highest mountain peaks.
- Formation of rift valleys. Rift valleys are sites where a continental landmass is ripping itself apart. Africa, for example, will eventually split along the western Great Rift Valley system.
- Continental drift is the major cause of earthquakes, volcanoes, oceanic trenches, mountain range formation, and other geologic phenomenon which created the new landscapes on the earth's surface;

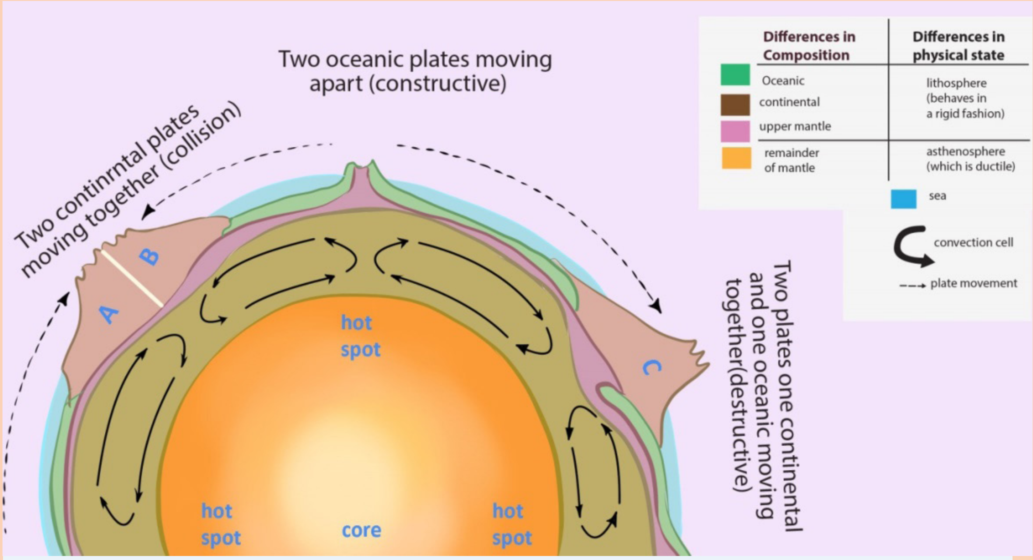
Application activity 2.3

Explain the effects of continental drift on the evolution of physical landscape of the earth.

2.4. Plate Tectonics

Learning activity 2.4

Observe the illustration below and answer the following questions:



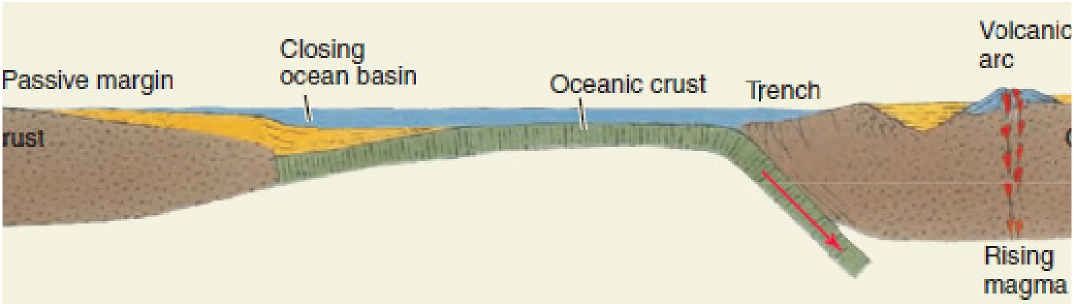
1) Identify the types of crust found on the map
2) Describe the difference between lithosphere and asthenosphere
3) Differentiate collision, constructive, and destructive processes
4) Determine the position of plate movements
5) Explain how convection cells cause the movement of plates

2.4.1. The concept of plate tectonics

The concept suggests that earth's crust and upper mantle (lithosphere) are broken into sections, called plates that slowly move on the mantle.

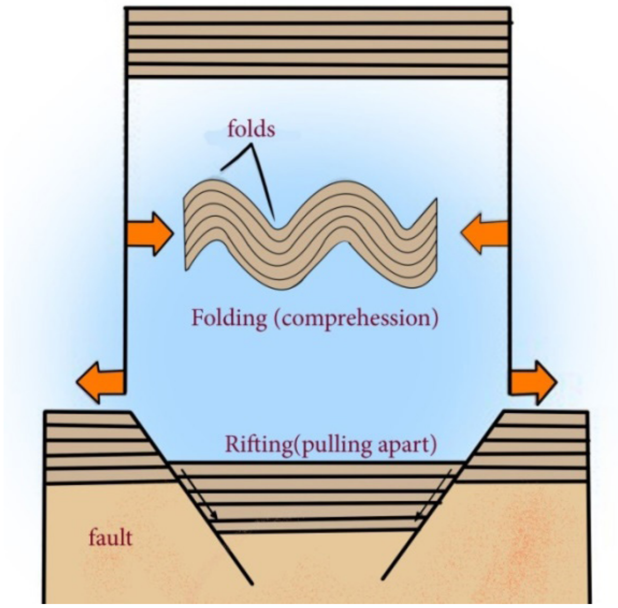
The word tectonic comes from the Greek word 'tektonikos' meaning building or construction; this means how the earth crust is constructed. Therefore, plate tectonics refers to the deformation of the earth's crust, because of internal forces, which can form various structures in the lithosphere.

The plate size can vary greatly, from a few hundred to thousands of kilometers across. Plates are moved by the energy originating from the earth interior. This energy is a result of convection currents which form convection cells. Tectonic plates are irregularly shaped slabs of solid rocks, generally presenting two types: **Continental** crust and **Oceanic** crust, as shown on the figure below.



Continental crust and oceanic crust

Tectonic processes include tension when plates diverge and compression when plates converge. These processes result in deformation of the earth crust. Tension causes fracturing and faulting of the crust while compression produces folds and over thrust faults.



Two basic deformations resulting from tectonic activity

2.4.2. Types of Plate Tectonics

There are two types of plate tectonics: continental plate and oceanic plate.

i) Continental crust is composed of older, lighter rock of granitic type: Silicon and Aluminum (SIAL).

ii) Oceanic crust consists of much younger, denser rock of basaltic composition: Silicon and Magnesium (SIMA). The major differences between the two types of plates are summarized in the table below:

Difference between continental plate and oceanic plate

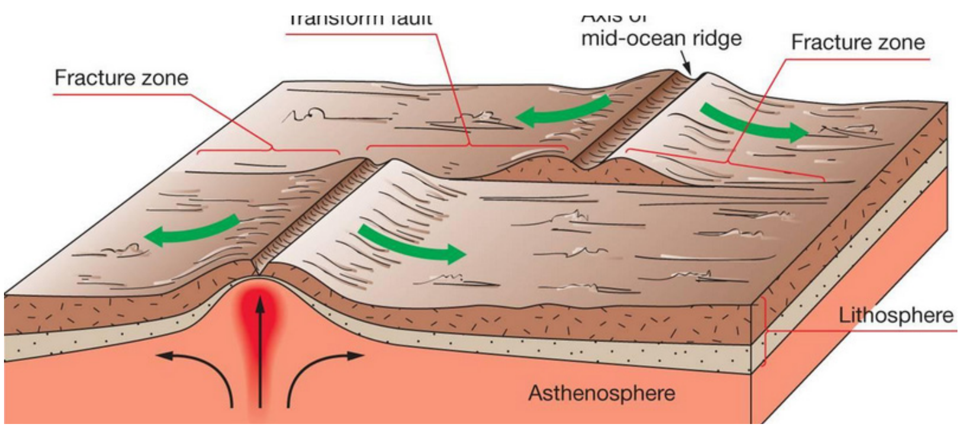
Factor	Continental plate (SIAL)	Oceanic plate (SIMA)
Thickness of rock	35-40 km on average, reaching 60-70 km under mountain chains	6-10 km on average
Age of rocks	Very old, mainly over 1500 million years	Very young, mainly under 200 million years
Weight of rocks	Lighter, with an average density of 2.6gm/cc	Heavier, with an average density of 3.0gm/cc
Nature of rocks	Light in color, many contain silica and aluminum; numerous types, granite is the most common	Dark in color; many contain silica and magnesium; few types, mainly basalt

2.4.3. Boundaries and movement of tectonic plates

i) Tectonic Plate boundaries

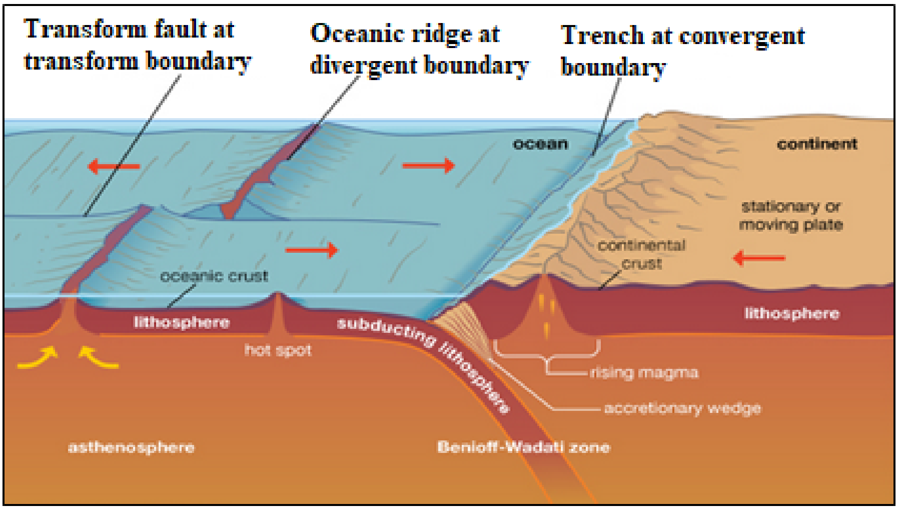
Boundaries of plate tectonic include the subduction zone, the mid-ocean ridge and the transform boundary.

- **Divergent boundary (Mid-ocean ridge):** It is an underwater mountain range which is formed when forces within earth spread the seafloor apart. It is created when convection currents rise in the mantle beneath where two tectonic plates meet at a divergent boundary, thus forming the oceanic ridge.
- **Transform boundary (Transform fault)**: It is a boundary which exists between two plates that are sliding horizontally past one another, thus forming the transform faults (see the figure below).



Mid-ocean ridge and transform fault

- **Convergent boundary (Subduction zone)**: This is the area where an ocean-floor plate collides with a continental plate and the denser oceanic plate sinks under the less dense continental plate, thus forming the oceanic trench.

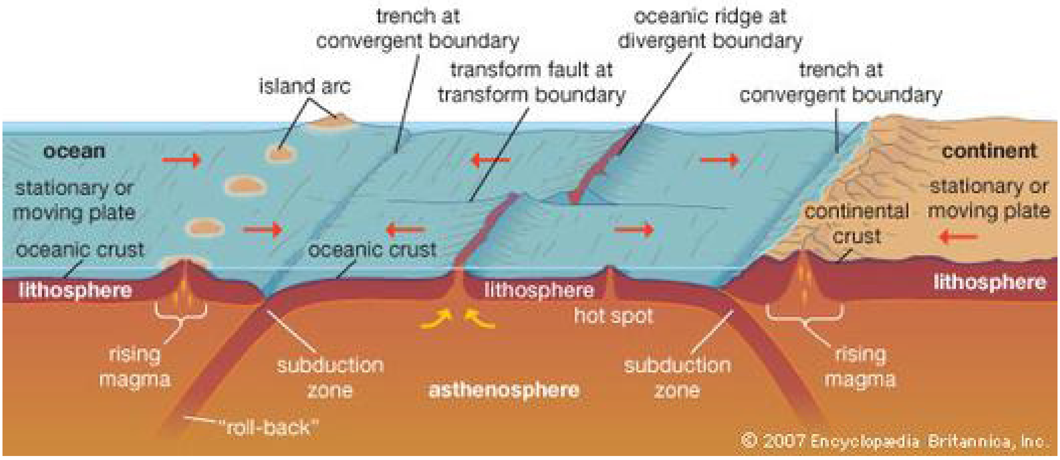


Subduction zone corresponds to trench at the convergent boundary

i) Tectonic plate movements

Plate movements include **convergence**, **divergence** and **way past** movement along the transform fault.

- **Convergence** is a movement whereby two crustal plates are colliding or one subsiding beneath the other. The margin where this process occurs is known as a destructive plate boundary. This boundary is a region of active deformation.
- **Divergence** is a movement whereby two crustal plates are moving away from each other. The margin where this process occurs is known as a constructive plate boundary. It initially produces rifts which eventually become rift valleys.
- **Way past** is plates' movement predominantly horizontal, where crust is neither produced nor destroyed as the *plates* slide horizontally *past* each other.



Types of plate movements

The plate movements are characterized by the following:

- Due to its relatively low density, continental crust does not sink; but it is the oceanic crust which is denser that can sink. Oceanic crust is then formed and destroyed, continuously;
- Continental plates, such as the Eurasian plate, may consist of both continental and oceanic crust;
- Continental crust may extend far beyond the margins of the landmass;
- Plates cannot overlap. This means that either they must be pushed upwards on impact to form mountains, or one plate must be forced to downwards into the mantle;
- No gap may occur on the earth's surface so, if two plates are moving apart new oceanic crust originating from the mantle is formed;
- The Earth is neither expanding nor shrinking in size. Thus, when the new oceanic crust is being formed in one place, older oceanic crust is being destroyed in another;
- Plate movement is slow and is usually continuous. Sudden movements are detected as earthquakes;
- Most significant landforms (folded mountains, volcanoes, insular arcs, deep sea trenches, and batholith intrusion) are found at plate boundaries.

Major landforms resulting from plate movements:

Plate movement	Description of changes	Example of landform
Divergent	**Spreading**: Two plates move away from each other, new oceanic crust appears, forming mid-oceanic ridges with volcanoes	**Mid-Atlantic Ridge** formed by American plates, moving away from Eurasian and African plates.
Convergent	**Subduction**: Oceanic crust moves towards continental crust but, being denser, sinks and is destroyed to form deep sea trench and islands arcs with volcanoes,	**Andes fold mountain** chain formed by Nazca which sinks under South American Plate **Rocky mountain chain** formed by Juan de Fuca, sinks under North Americas Plate, Island arcs of the West Indies and Aleutians Examples of trenches: Mariana trench, Peru-Chile-trench (Pacific ocean), Puerto-Rico trench in the Atlantic ocean.
Convergent	**Collision**: two continental crust collide and, as neither can sink, are forced up into fold mountains	**Himalayas** formed by Indian plate collided with Eurasian Plate, **Alp mountains** formed by African Plate collided with Eurasian Plate,
Transform	**Lateral sliding**: Two plates move sideways past each other. Land is neither formed nor destroyed	**San Andreas fault** in California

Application activity 2.4

1) Describe SIAL and SIMA in terms of thickness, age, weight and nature of rocks
2) Explain the difference between convergent movement, divergent movement and way past movement.
3) Describe the subduction, collision, spreading processes and give their effects and corresponding motions in relation to plate tectonic movements.

2.5. Major plates and effects of plate tectonics

Learning activity 2.5

1) Make research using books and a printed hand out and represent on the world map the major tectonic plates.
2) Identify the effects of the plate tectonic.

2.5.1. Major tectonic plates of the world

The following are the major tectonic plates of the world:

i) The **Pacific plate** which covers a large part of the basin of Pacific Ocean.

ii) The **Eurasian plate** located between the northern mid-ocean ridge of the Pacific Ocean and the Pacific and Philippines Plates margins.

iii) The **North American plate** bordered by the eastern margin of the Pacific plate in the West and mid-ocean ridge of the Atlantic Ocean in the East.

iv) The **South American Plate** located between the subduction zone of Nazca plate in the West and the mid-ocean ridge of the Atlantic Ocean in the East.

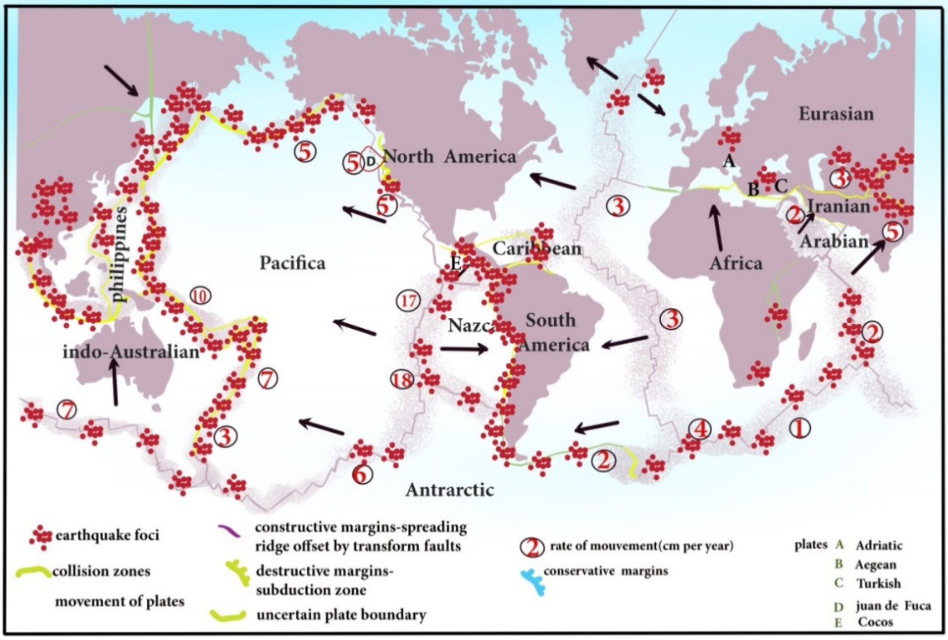
v) The **African plate** located between the mid-ocean ridge of the Atlantic Ocean in the West and the mid-ocean ridge of Indo-Australian plate in the East.

vi) The **Indo-Australian** plate extends around the Australian subcontinent, between the Pacific plate and the African Plate.

vii) The **Antarctic plate** corresponds with the Antarctic continent around the South Pole.

viii) The **Nazca Plate** which is located between the Pacific plate and the South American plate.

However, several minor plates, about 20 have been identified (e.g. *Arabian plate, Bismarck plate, Caribbean Plate, Carolina plate, Cocos plate, Juan de Fuca plate, Nazca or East Pacific plate, Philippines plate, Scotia plate* among others).



Distribution of tectonic plates and their margins

2.5.2. Effects of plate tectonics

The following are the main effects of plate tectonics:

i) Earthquake

This is a series of vibrations induced *in* the earth's crust by the abrupt separation and echo of rocks *in* which elastic strain has been slowly accumulating. This sudden violent shaking of the ground typically causes great destruction, because of movements of seismic waves within the earth's crust.

Most earthquakes occur as the result of the sudden movement along a fault line between two adjacent tectonic plates. These have several impacts like landscape modification, destruction of houses, tsunamis, etc.

Effects of earthquake on road network in Haiti 2010

ii) A volcanic eruption

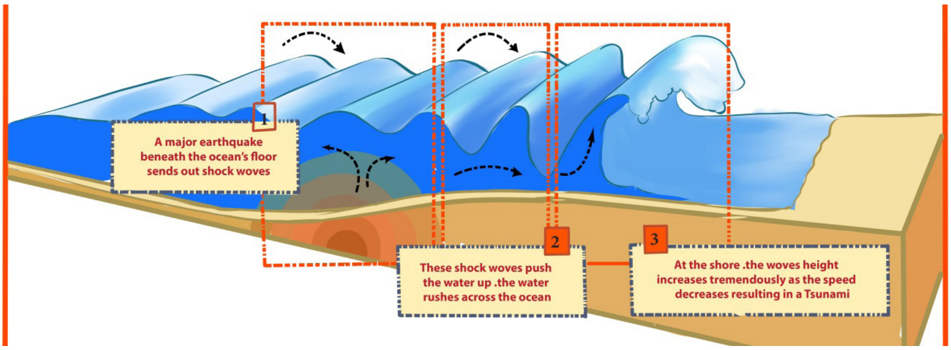
A volcanic eruption occurs when hot materials (molten materials) are thrown out of a volcano. Lava, rocks, dust, and gas compounds are some of these materials which are ejected out during volcanic eruption. Volcanic eruption take place when a plate moves over the top of another plate, then the energy and friction melt the rock and push it upwards.

Volcanic eruption

iii) Tsunamis

Tsunamis are giant waves, often generated at destructive plate margins that can cross oceans. They occur when a sudden, large scale change in the area of an ocean bed leads to the displacement of a large volume of water and the subsequent formation of one or more huge waves. When a major seismic tremor occurs underneath a body of water, the energy from that tremor is released into the surrounding liquid. The energy spreads out from its original site, traveling through the water in the form of a wave.

Tsunamis have exceptionally long wave-length up to 10 km and can cross oceans at speeds of up to 700 km/hour but can sometimes be imperceptible when their magnitude is low.



Movement of tsunami shock waves

Application activity 2.5

1) Conduct your own research to identify the minor tectonic plates of the world and locate them geographically.

2) Apart from the distribution of the continents, what are other effects of plate tectonics?

3) Identify the major seismic and volcanic zones in the world and explain the impact of those natural hazards referring to the tectonic plates.

4) Our country, Rwanda, is in a region which is tectonically active and subjected to earthquakes events. The more documented earthquake is the one which occurred on 3rd and 4th February 2008. It occurred on Sunday about 09h31 with the magnitude of 6.1 and 5, and on Monday the 4th February 2008 and affected mostly Nyamasheke and Rusizi Districts, Western Province. 37 people died, and 643 injured including 367 traumatized. Many houses were destroyed in these two Districts where 1,201 families were rendered homeless:

   Knowing the causes of the earthquake, explain how Rwandans can cope with it and its impacts and other resulting natural hazards.

Skills Lab

Basing on the distribution of continents and oceans basins, discuss the geological evidences of continental drift.

End unit assessment

1) What is the contribution of Wegner's theory on the distribution of continents?

2) Basing on the knowledge acquired in this unit, explain the relationship between the earthquakes which occur in the region of the western rift valley of Africa where Rwanda is located with the continental drift.

3) Using a map, represent graphically the main tectonic plates of the world map.

4) Discuss the consequences of the plate tectonics on population in some specific areas of the world.

UNIT 3

EXTERNAL LANDFORM PROCESSES AND RELATED FEATURES

Key Unit competence:

By the end of this unit, I should be able to demonstrate an understanding of different landforms resulting from the external processes.

Introductory activity

Observe the photographs below and explain the processes that affected the rocks that appear on them.

3.1. Definition, types and process of weathering

Learning activity 3.1

1. Differentiate physical weathering from chemical weathering
2. Outline the processes of chemical weathering

3.1.1. Definition of weathering

Weathering refers to the process of disintegration and decomposition of rocks into small particles by the action of weather and living organisms.

Agents of weathering include the temperature, rainfall (water), wind, animals and plants (vegetation).

3.1.2. Types of weathering and processes

There are three types of weathering namely **physical or mechanical weathering, chemical weathering** and **biological weathering** which cuts across each of the physical and chemical weathering.

i) Physical weathering

Physical weathering refers to the breaking down or disintegration of rocks, without any change in the chemical or mineral composition of the rock being weathered. Rocks disintegrate into smaller particles but maintain their previous chemical characteristics. Only the physical size and shape change. Physical weathering is mostly influenced by temperature changes.

Processes of physical weathering include:

1) **Thermal expansion or insolation weathering:**

This process is caused by the changing of temperature ranges which causes differential heating of minerals forming the rock. When heated dark minerals expand, faster than others resulting in cracking and fragmentation of the rock

Block disintegration due to change in temperature

2) Exfoliation

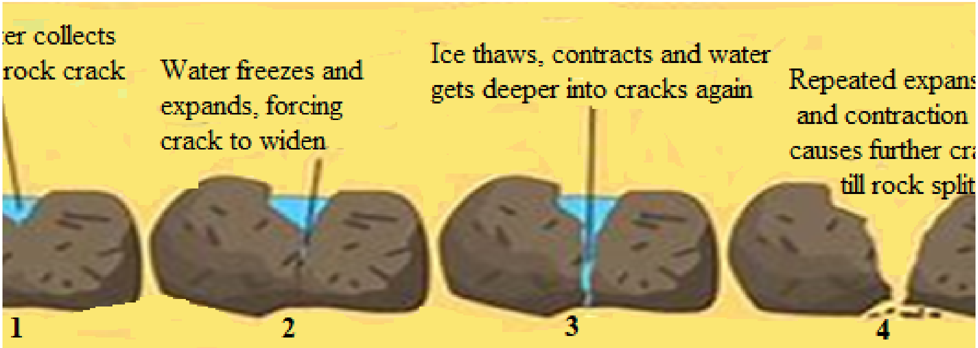
Exfoliation occurs when there is expansion of rocks during the day and contraction of rocks during the night due to repeated temperature changes. This process is common in arid and semi-arid regions. This results into rocks of a few centimeters thick to start peeling off (breaking away) leaving behind exfoliation domes.

Exfoliation

3) Freeze thaw

This process also called frost weathering (or frost shuttering) occurs due to water that enters into the cracks of the rocks; this water freezes and expands exerting pressure within cracks. Water from rain or melting snow and ice is trapped in a crack or joint in the rock.

If the air temperature falls below freezing point, the water freezes and expands. As a result, the rock becomes weak and breaks. This process is common in cold regions, especially glacial, periglacial and high mountainous zones. The figure below shows steps from infiltration of water into the rock to the condensation within rock fissure which result in the fragmentation.



Steps of frost weathering

4) Pressure release

The process of ***pressure release*** known as the ***unloading*** or dilatation weathering occurs when materials on top are removed by erosion. This releases (decreases) pressure, which causes the materials below to expand and crack parallel to the surface.

Fractures of rock due to the pressure release

5) Salt crystallization

The process of salt crystallization weathering illustrated on the figure below occurs when saline water (or water carrying salts in solution) passes through cracks and joints in rocks. As it evaporates, the dissolved salts change into salt crystals. These crystals expand within cracks as they are heated up and apply pressure on the rock leading to its breaking up.

Salt crystallization in rock joints

6) Shrinkage weathering

Some clay rocks expand after absorbing water. For instance, there are some clays which swell when they absorb water during rainy seasons. This results in increase in their volume. During dry seasons, they massively lose this water through evaporation and they contract. This process of alternation of expansion of these rocks during the wet season and contraction of clay during the dry season is known as shrinkage. This creates stresses and weakness of rocks causing cracks within the rock.

7) Granular disintegration

This takes place almost in the same way as exfoliation except that in this type, rocks disintegrate into small particles called granules. It is produced either by differences in thermal expansion and contraction, or through the frost heaving process (congeliturbation).

ii) Chemical weathering

This is a type of weathering which involves a complete change in the chemical and mineralogical composition of the rock resulting into the disintegration of rocks. It is common in areas which experience alternating wet and dry seasons.

The following are the chemical reactions that take place during weathering:

1) **Oxidation:** oxidation is one of the varieties of chemical weathering in which oxygen dissolved in water reacts with certain rock minerals, especially iron, to form oxides.

E.g.: $4FeO \quad + \quad O_2 \qquad\qquad 2Fe_2O_3$

(Ferrous oxide) (Oxygen) (Hematite)

Oxidation

2) **Carbonation:** This is the process through which rain water dissolves the atmospheric gases of carbon dioxide (CO_2) to form a weak carbonic acid which reacts rocks to wear (weather) them away especially in limestone areas. After reaction, new compounds are produced as it is shown by the following equation:

$H_2O + CO_2 \quad H_2CO_3$ (weak carbonic acid)

This reacts with calcium carbonate (the limestone) to form calcium bicarbonate which is soluble in water.

$CaCO_3 \quad + \quad H_2CO_3 \qquad\qquad Ca\,(HCO_3)_2$

(Limestone) (Carbonic acid) (Calcium bicarbonate)

Carbonation

3) **Dissolution:** Dissolution is one of the less important forms of chemical weathering, in which solid rocks are dissolved by water. When water (e.g. rainwater) mixes with carbon dioxide gas in the air or in air pockets in soil, a weak acid solution, called carbonic acid, is produced. When carbonic acid flows through the cracks of some rocks, it chemically reacts with the rock causing some of it to dissolve.

4) **Hydrolysis:** Hydrolysis involves water combining with rock minerals to form an insoluble precipitate like clay mineral. Compared to hydration - a physical process in which water is simply absorbed, the hydrolysis process involves active participation of water in chemical reactions to produce different minerals.

e.g. $K_2Al_2O_3\ 6SiO_2 + H_2O$ $Al_2O_3\ 2SiO_2\ 2H_2O$

(Feldspar) (Water) (Kaolin)

Hydrolysis

5) **Hydration:** Hydration is one of the major processes of mechanical weathering, involving the addition of water to a mineral, causing it to expand and thereby initiate stress within the rock. For example the conversion of hematite to limonite. Once minerals have experienced hydration, they become more susceptible to the effects of chemical weathering, especially those of carbonation and oxidation.

e.g. $2Fe_2O_3 + 3H_2O$ $2Fe_2O_3\ 3H_2O$

(Hematite) (water) (Limonite)

The area that experienced the hydration

6) **Solution:** is a process in which the minerals in the rock directly dissolve in water without their chemical and mineralogical composition being altered. e. g. olivine, Rock salt (calcium chloride) and calcium bicarbonate are easily weathered in solution.

   e.g. NaCl $^{+}$ H2O → Na^{+}, Cl^{-} (dissolved ions with water).

7) **Chelation:** Chelation is a form of chemical weathering by plants. It is a complex organic process by which metallic cations are incorporated into hydrocarbon molecules. In fact, the word chelate means a coordination compound in which a central metallic ion is attached to an organic molecule at two or more positions.

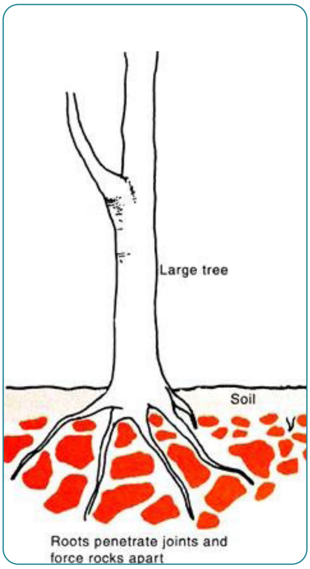
Chelation

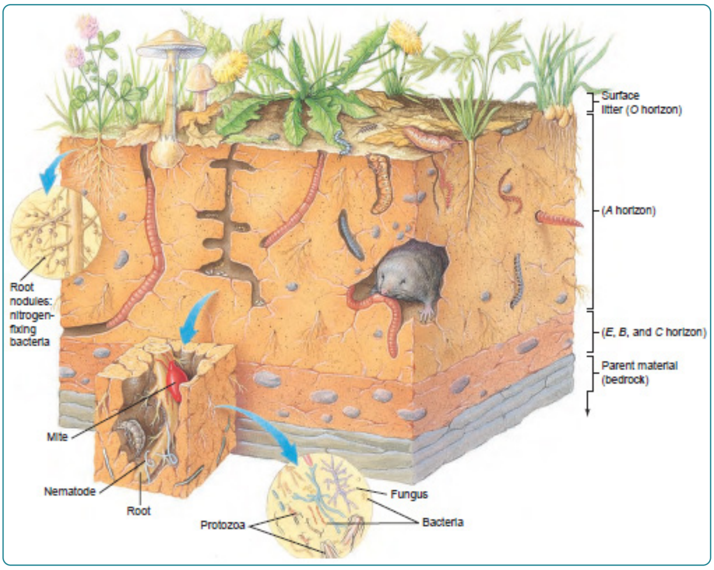
iii) Biological weathering

Biological weathering is a process of rock disintegration (decay) due to the influence of living organisms both growing plants and animals. The diversity of life in soil includes plants, algae, fungi, earthworms, flatworms, roundworms, insects, spiders and mites, bacteria, and burrowing animals.

Plants wear away the rocks by their roots which widen the rock joints hence allowing in other weathering agents like water to disintegrate the rocks. Some plant roots also have chemicals at the tips of their roots which are acidic and hence cause rock weathering.

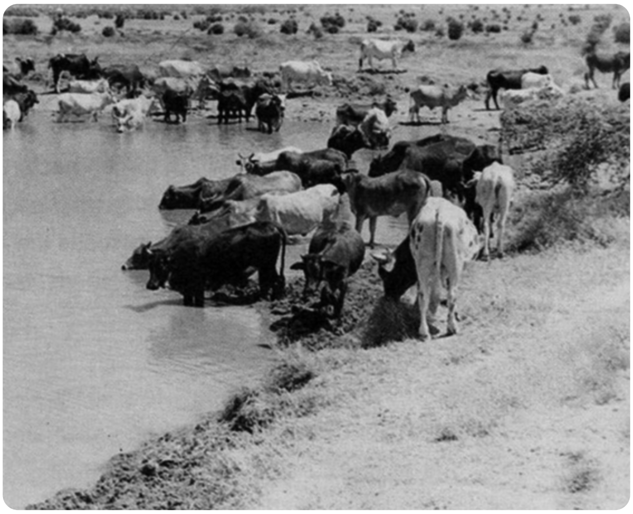
Tree roots find their way into cracks or joints in the rocks. As they grow, they cause the joints to become bigger. The end result is that the rocks break into smaller pieces at some points.





Impact roots of trees and earth animals on weathering of rocks

Burrowing animals like rodents and moles, warthogs (wild pigs) and wild animals in game parks like the chimpanzee, excavate the rocks and as such, they break up the rocks hence weathering them. Man also disintegrates rocks through his activities.



Animals create bores into a rock

Man's activities such as mining, construction, quarrying, agriculture, etc. result in such a fast rate of disintegration of rocks.

Human activities cracking the rocks

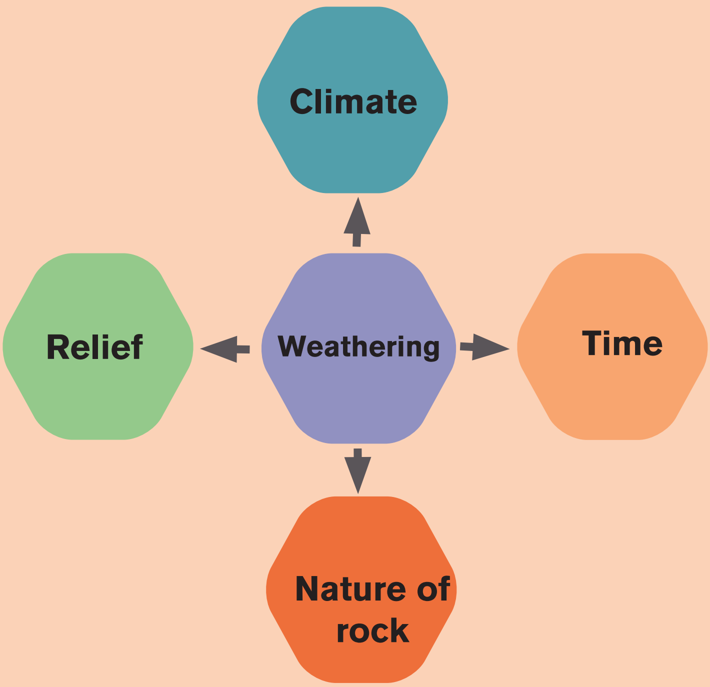
Application activity 3.1

Use your local environment to identify the evidences of biological weathering.

3.2. Factors influencing weathering and interdependence of physical and chemical weathering

Learning activity 3.2

Using the diagram below, explain how these elements influence the rate of weathering in your local area.



A number of factors are required for weathering to occur in any environment. The major factors of weathering include relief, living organisms, time, climate and rock (parent material),

i) Relief

The term relief refers to the nature of landscape or topography. It influences significantly the weathering process because it controls the flowing of run-off and infiltration of water through slope exposition, steepness and length. In mountainous regions, the windward slopes receive heavy rainfall which may speed up chemical weathering, whereas the leeward sides receiving little amount of rain becoming arid. This favors physical weathering to dominate on the leeward part.

ii) Living organisms

Living organisms include plants and animals. They both contribute to weathering in a number of ways. Growing roots of trees widen and deepen into the ground and open up joints. Animals ranging from the big to small, including man affect the rate of weathering both mechanically and chemically. Animals and micro-organisms mix soils as they form burrows and pores, allowing moisture and gases to move about.

iii) Time

The longer a rock is exposed to agents of weathering, the more weathered it is likely to be and vice-versa. Young rocks such as solidified volcanic rock after a fresh volcanic eruption are likely to be less weathered than rocks formed long ago.

iv) Climate

The key components of climate in weathering are ***moisture*** and ***temperature***. The type and amount of precipitation influence soil formation by affecting the movement of ions and particles through the soil, and aid in the development of different soil profiles. High temperatures and heavy rainfall increase the rate of chemical weathering. Arid and semi-arid areas are associated with physical weathering since there is low rainfall and high temperature. As the rocks expand during a period of high temperature and contract during a period of low temperature, they develop cracks. In addition, equatorial regions with high rainfall and high temperature experience fast and deep chemical weathering.

v) Nature of rocks

Nature of the rock determines the rate at which it may break down. Their nature depends on rock forming minerals. Some minerals are easily soluble. Also environmental condition such as organic acids and temperature may increase the rate of weathering of rocks. Soft rocks, for example, break down more easily than hard rocks. Similarly, jointed rocks (rocks with cracks) break down faster than rock substances without joints.

vi) The interdependence of physical and chemical weathering

There is interdependence between mechanical and chemical weathering. Chemical weathering to occur needs first mechanical process which provides fragmented pieces of rocks. These rock fragments are then attacked by the chemical process of weathering. Many reasons can be advanced to justify their interdependence:

- The joints and crack found in a rock as a result of physical weathering allow deeper penetration of water which leads to chemical weathering.
- Some rocks are dissolved in water and weathered away in solution. The solutions formed may later undergo precipitation leading to the formation of crystal. These crystals will exert a lot of pressure that will disintegrate the rocks physically.
- Hydration (chemical process) results in a high rate of absorbing water by rocks .e.g.: hematite, limonite which makes these rocks to peel off in a physical process called spheroidal weathering.
- The physical process of frost shattering opens up cracks in the rock and when these cracks are occupied by water, chemical weathering process takes place. e.g. carbonation.
- Roots of plants which expand within bedding planes of rocks and burrowing animals which drill holes in rocks allow water entry into these rocks which accelerates chemical weathering.

Application activity 3.2

Visit your local environment and explain how relief and climate have influenced the rate of weathering.

3.3. Landforms associated with weathering and their importance

Learning activity 3.3

1. Identify the features associated to weathering
2. Analyse the importance of the following weathering features
   a) Cave
   b) Oasis

Landforms processes may be similar of different depending on whether rocks have the same or different mineralogical compositions. The major landforms in different geological structures are briefly presented in the following paragraphs.

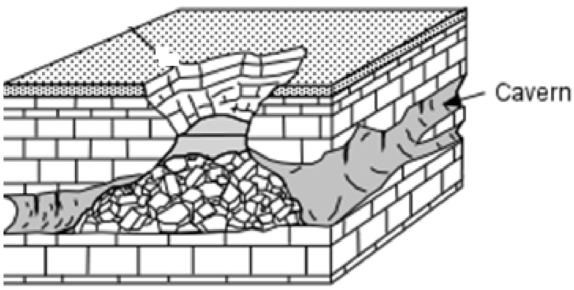
3.3.1. Landforms associated to weathering in limestone regions

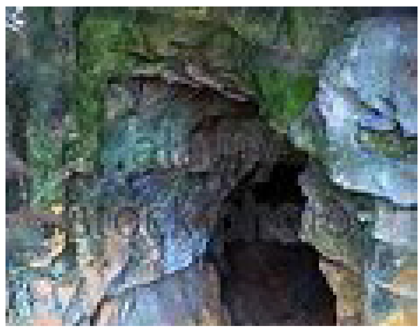
Limestone is a sedimentary rock in which calcite (calcium carbonate: $CaCO_3$) is the predominant mineral, and with varying minor amounts of other minerals and clay. Limestone rocks are very sensitive to organic acids derived from the decomposition of living organisms.

The major landforms associated with weathering in limestone regions are Karsts landforms that include: caverns, stalagmites, stalactites, pillar, dolines, limestone pavements (uvalas), poljes.

1) Caverns

Caverns or caves are also one of the important characteristic features of groundwater in limestone regions. Caverns are formed in several different ways. The rocks in which most caverns occur are salt, gypsum, dolomite and limestone, with the latter by far the most important.





Caverns

2) Doline

Doline also called Dolina is a round or elliptical hollow on the surface of a limestone region which is formed when several small hollows merge. The small hollows are formed when water starts acting on the points of convergence of joints on the surface.

3) Uvala

Uvala is a large surface depression (several km in diameter) in limestone terrain (karst region). It is formed by the coalescence of adjoining dolines and has an irregular floor which is not as smooth as that of Polje.

Uvala

4) Polje

Polje is a large depression in a karst region with steep sides and flat floor. If it is drained by surface water sources, it is termed as open Polje.

5) Stalactites

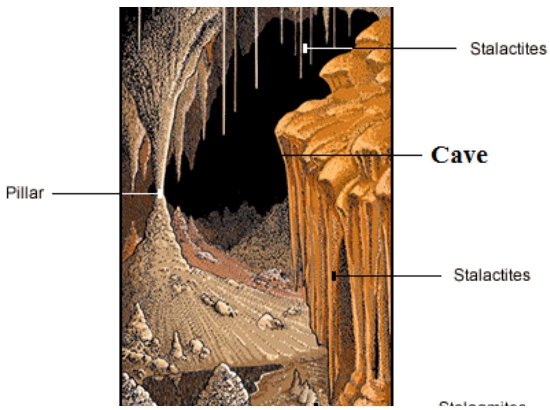
Stalactites are protrusions on top of limestone cave formed as results of water dissolving some rocks which form a solution that leaks from the roof.

6) Stalagmites

Stalagmites are formed like a columnar concretion ascending from the floor of a cave. It is formed from the re-precipitation of carbonate in calcite form perpendicularly beneath a constant source of groundwater that drips off the lower tip of a stalactite or percolates through the roof of a cave in a karst environment. It may eventually combine with a stalactite to form a pillar.

7) Pillars

Pillars are formed within the weathered limestone cave after the joining together of stalactites from up and stalagmites from down. The two may finally meet forming a pillar.



Stalagmite, stalactite and pillar

For karst land forms to be formed the following conditions must be in place:

- **Precipitation**: the major types of precipitation which contribute to groundwater are rainfall and snowfall.
- **Slope:** infiltration is greater on flat areas since water is likely to remain in one place for a long time given that other factors are favorable. On steep slopes, a lot of water is lost through surface run-off with little infiltrating in the ground.
- **Nature of the rock**: For groundwater to percolate and accumulate there must be spaces within the rocks for it to pass through as well as to occupy further beneath.
- **Vegetation cover:** the presence of vegetation increases the rate of infiltration.
- **Level of saturation of the ground:** The rate of water infiltration is high when the ground is very dry and the soil is dry; all the air spaces in it are wide open.

3.3.2. Landforms associated with weathering in arid regions

The features formed in these regions as a result of weathering are both erosional and depositional.

a) Erosional features

1) Inselbergs

An **inselberg** (island hill or mountain in German) called ***Monadnock*** in the United States, is an isolated hill, knob, ridge, or small mountain that rises abruptly from a gently sloping or virtually level surrounding plain. These forms are characterized by their separation from the surrounding terrain and frequently by their independence of the regional drainage network.

Inselberg

2) Bornhardts

These are dome-shaped and steep-sided rocks that rise up to 30 meters. They are massive rock, commonly granite comprised of bare rock that stretches several hundred meters. They take many shapes such as oranges. A good example of where Bornhardts are found is Central Australia.

Bornhardts

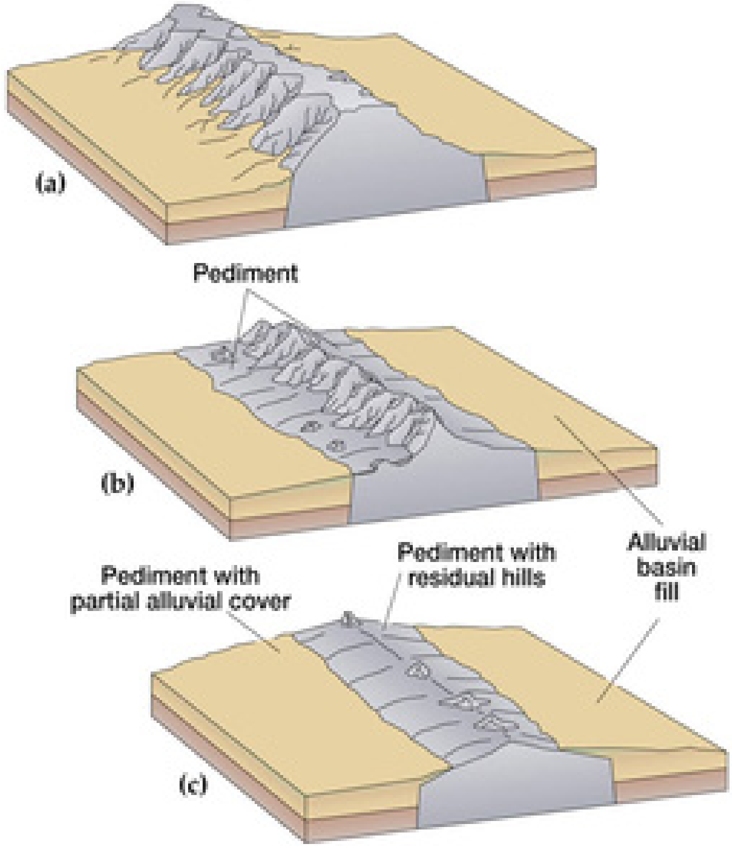
3) Tor

A tor is a pile like hill of rocks or rock peak. It is a product of massive weathering and comes in all manner of shapes.

Tor

4) Pediment

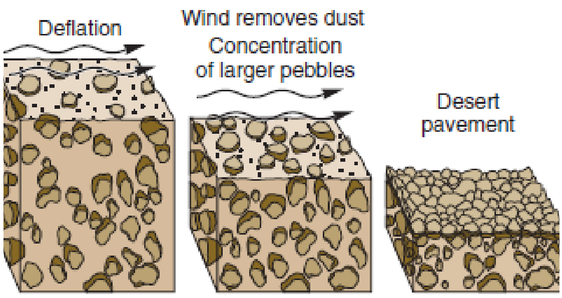
This is a rock that is gently inclined at an angle of 0.5 to 7 degrees. It is concave in shape and is found at the base of hills where rainfall is heavy and falls over a short period of time.



Pediment

5) Deflation basins

Deflation is the process whereby loose or non-cohesive sediment are blown by the wind. Depressions formed in the deserts due to removal of sand through the process of deflation are called ***Deflation Basins***. They are also called ***blow-outs*** or ***deserts hollows***. The depth of deflation is determined by groundwater table.

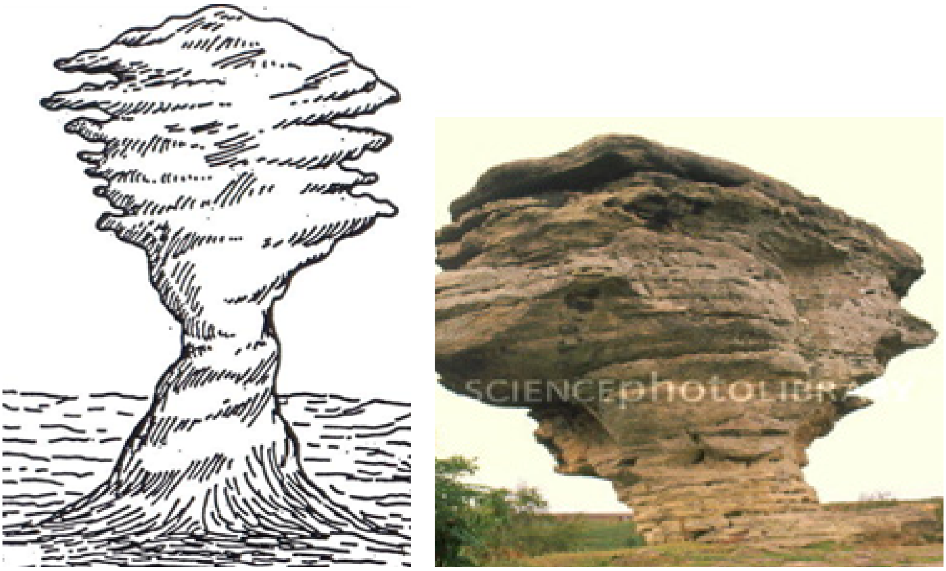


Deflation process

Deflation basin

6) Mushroom rock

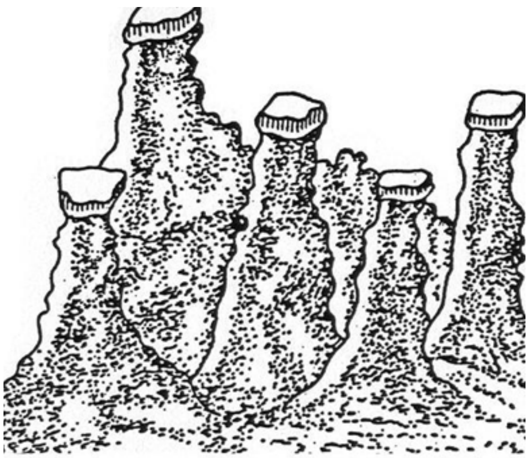
The rocks having broad upper part and narrow base resembling an umbrella or mushroom are called mushroom rocks or pedestal rocks. These undercut, mushroom-shaped pedestal rocks are formed due to abrasive works of wind.



Mushroom rock

7) Demoiselles

Demoiselles represent rock pillars having relatively resistant rocks at the top and soft rocks below. These features are formed due to differential erosion of hard rocks (less erosion) and soft rocks (more erosion). The demoiselles are maintained so long as the resistant cap rocks are seated at the top of the pillars.



Demoiselles

8) Zeugen

Rock masses of tabular form resembling a capped inkpot standing on softer rock pedestal of shale, mudstone is called Zeugen. The bases of such features are broader than their tops.

9) Yardangs

These are formed always in the same way as Zeugens except that yardangs only develop on landscapes which have alternating rock layers with different resistance to erosion parallel to the direction of prevailing winds. Winds enter and scour up rock particles from the soft bands, thus digging depressions within the soft bands. The resistant hard bands therefore remain standing high up as raised ridges.

Yardangs

10) Reg

Reg is a desert surface covered with a pebble layer, resulting from long continued deflation; found in the Sahara Desert of North Africa. Often the winds blow off all the smaller fragments, and leave the bigger size pebbles and gravels over an extensive area.

Reg

11) Oases

These are depressions that have water in deserts. These are created by strong winds which remove rock particles from a particular place until a depression is excavated (created).

Oases

b) Depositional features in desert

1) Dunes

Dunes are mounds or ridges of wind-blown sand. They are depositional features of the sandy deserts and are generally mobile. They vary in size and structure. The main types of sand dunes are Barchan, Transverse Dunes, and Seifs.

– **Barkhans**

Also called Barchans, these are typical crescent shaped sand dunes. The windward slope of barchans is gentle and convex, and the leeward slope is steep and concave. Barchans move slowly, at a rate of meters per year in the direction of the prevailing winds.

Barchans

– **Seifs**

These are long and narrow sand ridge which grow parallel to the direction of the prevailing or dominant wind.

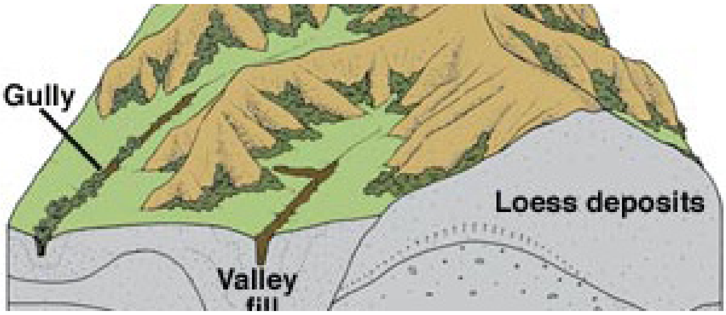
Seifs

– **Transverse dune**

Transverse dune is an alongated dune lying at right angles to the prevailling wind direction. They have a gentle sloping windward side and a steep sloping leeward side, they are commmon in areas with enough sand and poor vegetation.

2) Loess

Loess is a wind-blown deposit of fine silt and dust. It is unstratified, calcareous, permeable, homogenous and generally yellowish in colour.



Loess

3) Erg

Erg is also called sand sea or Dune Sea. It is a large, relatively flat area of desert covered with wind-swept sand with little or no vegetative cover.

Erg

3.3.3. Importance of landforms resulting from weathering

- This soil supports poor scrub vegetation as well as some shrubs and grasses.
- Chalk landscapes are characterized by undulating topography.
- The surface and underground landforms of karsts appearance are beautiful to attract tourists.
- Limestone blocks are used for building houses.
- They are also raw materials for cement manufacturing.
- Weathering results into soil formation.
- It produces a number of landforms which modify the nature of landscape
- It produces lateritic soils, which are important in road construction.
- It helps to expose mineral rock on the surface.
- It produces clay which is important in pottery industry.

Application activity 3.3

1. Examine the contribution of weathering on human activities
2. Humid tropical regions are the most affected by weathering. Discuss

3.4. Mass wasting

3.4.1. Definition and types of mass wasting

Learning activity 3.4

Study the photograph below taken in northern part of Rwanda and describe the cause of the phenomena which happened.

i) Mass wasting

Mass wasting, also called ***mass movement***, is defined as the creeping, flowing, sliding or falling of rocks and weathered materials down slope under gravity. It is different from erosion in a sense that, in erosion water physically transports away the soil particles, in mass wasting water does not wash away but assists the rock to slide down under the influence of gravity.

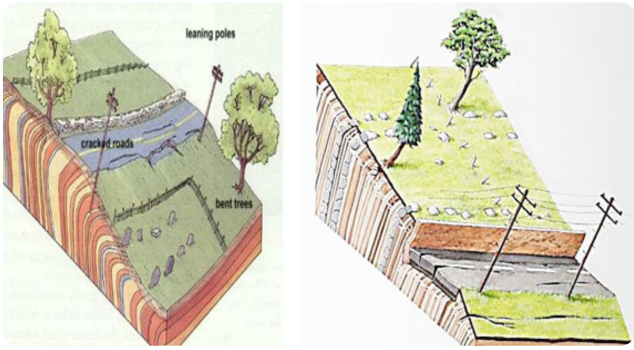
ii) Types of mass wasting

Mass wasting is classified into two major categories: **Slow movement and rapid movement**.

1) Slow movement

Also called creep movements, they are very slow in their motion and they may occur without being noticed. These slow movements include:

- **Soil creep:** This is the most common and the most widely spread type, because it is found in both tropical and temperate climates**.** The movement of materials is so slow that they may move a few centimeters per day. It can be detected by leaning of trees, electric poles and fencing poles in the direction of the slope.



Soil creep

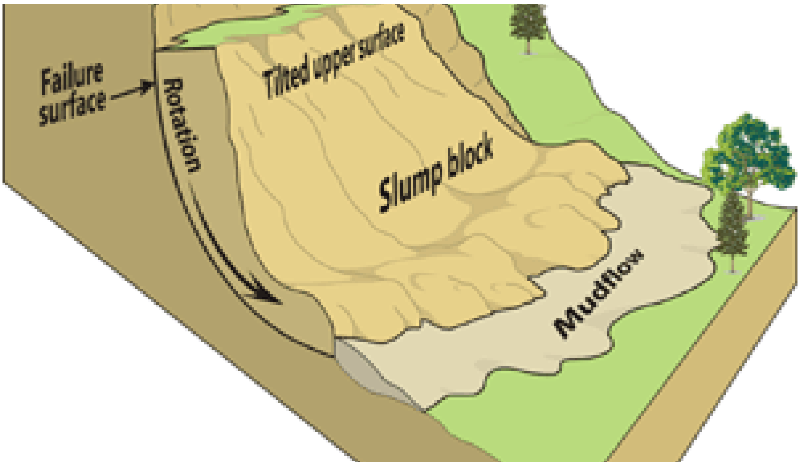
- **Solifluction**: This is limited to glaciated mountainous regions and cold climatic areas where thawing causes the saturated surface layer to creep as a mass over underlying frozen ground.

Solifluction

- **Talus creep**: This is a down slope movement of mainly screes that are relatively dry. It occurs almost in the same way as soil creep and it also occurs under tropical and temperate climate.
- **Rock glacier creep**: This is a slow process of slope failure in which individual rock boulders with very little soil but with some ice embedded within them slowly move down slope confined within a channel.
- **Rock creep**: This is the movement of individual rock boulders slowly down slope

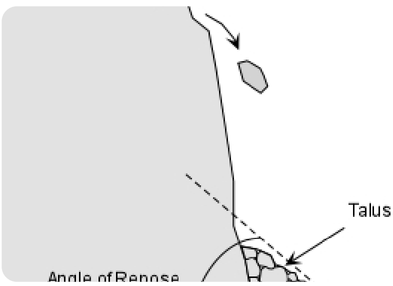
2) Rapid movement

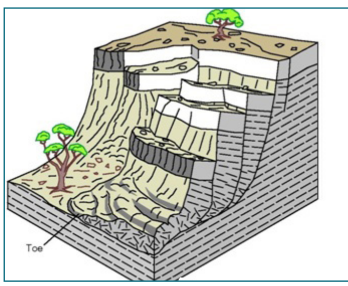
- **Earth flows**: These are the rapid down ward movements of clayish or silty soils along a steep slope.
- **Mud flows:** These are similar to earth flows but they are muddy and occur on slopes that receive heavy rainfall. They are very fast. In Rwanda they are common in the Northern and Western-provinces.

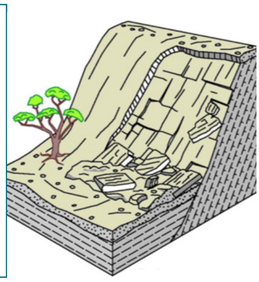


Mud flow

- **Debris avalanches**: This is the most form of rapid flowage due to the fact that slopes are very steep and there is enough rain to soak slopes. It occurs on very steep slopes that occur in humid climate.
- **Slumping:** This is the downward slipping of one or several units of rock debris, usually with a backward rotation with respect to the slope over which movement takes place. Undercutting of slopes by streams and man are the main causes of slumping. The surface of the slumped mass has a number of step-like terraces.
- **Rock slide:** This is the type of sliding in which individual rock masses fall from vertical cliffs or faces of slopes or jointed cliffs.
- **Rock fall**: Here, individual boulders fall freely from a steep rock face.

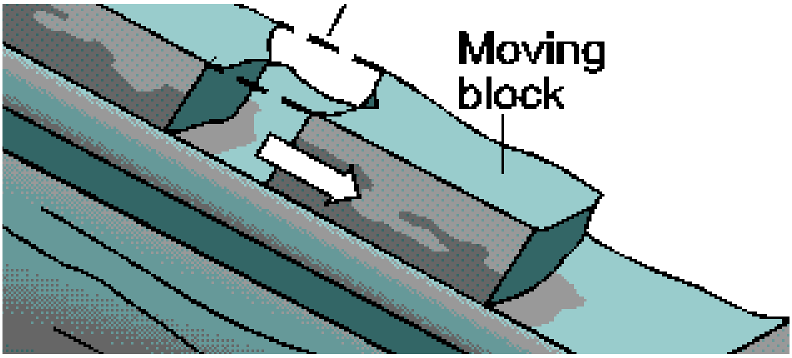






Slump *Rock slide* *Rock fall*

Landslides: These are also called landslips. They are down-slope gravitational movements of a body of rock or earth as a unit. It may be induced by natural agencies (like heavy rain, earthquake) or it may be caused by human interference with the slope stability.



Landslide

3.4.2. Causes of mass wasting

The following are the major causes of mass wasting:

- **The degree of slope**: The steeper the slope, the higher are the chances of material movement. Mass wasting is almost nil in gentle and flat areas.
- **The structure and lithology of rocks**: Alternating hard and soft rock layers on a slope can be a cause of slope fall. For example, a layer of clay on top of limestone layer can easily slide down.
- **The degree of lubrication**: Most mass wasting processes occur after a heavy down pour. Water assists to lubricate rock particles and the layers of rock on top of a slope. Therefore, water provides a medium of sliding because it reduces internal friction between rock particles and layers.
- **The amount of load on a slope**: Slopes which are light rarely fall compared to those which are heavy. Therefore, additional load on a slope increase chances of slope fall.
- **Tectonic movements:** Earthquake and Volcanic eruptions cause vibrations of the earth which often trigger off widespread movements of materials such as landslides.
- **Climate:** The amount and nature of rainfall received in an area determines the kind of movement that occurs.
- **Grazing**: The grazing of cattle, movement of elephants and other animals can cause some tremors on slopes hence making them fall.
- **Nature of soil:** soils which are infertile and therefore unable to support vegetation in enough quantities, are more susceptible to mass wasting compared to soils, which are fertile and therefore able to support dense vegetation.
- **Influence of vegetation:** Vegetation help to hold rock materials together thus reducing their movement on the surface.

- **The work of animals:** Animals and micro-organisms facilitate deep weathering which results into the reduced cohesion of the rock particles on slopes. This therefore leads to easy movement.
- **Vulcanicity:** Volcanic eruption on the ice capped highlands cause ice to melt and therefore soak the slopes. This lubrication greatly increases the chances of slope movement.

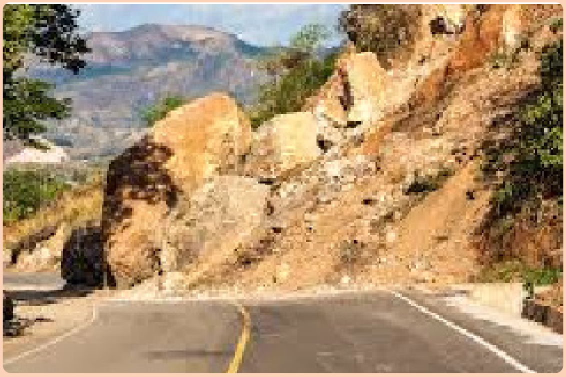
Application activity 3.4

1. Examine the major causes of mass wasting
2. Using diagrams distinguish between slumping to rock fall

3.5. Effects and control measures for mass wasting

Learning activity 3.5

Observe the photograph below showing the effects of mass wasting and answer questions:



1. Analyse the effects of mass wasting.
2. Suggest any three measures to control mass wasting.

3.5.1. Effects of mass wasting

The following are some of the effects of mass wasting:

- **Threat to life and property:** There are several serious incidents of landslides and rock slides every year. They cause loss of life and property. In a minor incident they may block only one line of a road, but in severe cases entire blocks of buildings collapse.
- **Loss of vegetation:** Mass wasting and soil erosion result in the loss of surface topsoil which is essential for vegetation. As a result, more areas become barren.
- **Scars and Gullies**: In areas where topsoil and vegetation are removed, bare spots form scars in the landscape. Gullies form on weathered slopes through rain action and mass wasting in areas with little or no vegetation. Intense gully cuts up the landscape into large-scale gullies and ridges and destroys the area. Gullying is common in the bare, granitic areas.
- **Pollution of water:** large amounts of geologic materials enter streams as sediments as a result of this landslide and erosion activity, thus reducing the potability of the water and quality of habitat for fish and wildlife.
- **Wildlife destruction:** Although most kinds of wildlife are able to retreat fast enough to avoid direct injury from all but the fastest-moving landslides, often are subject to habitat damage by landslides.

3.5.2. Control measures for mass wasting

Mass wasting, especially landslides, has severe impacts on humans and environments. For this reason, measures have to be taken for preventing or mitigating them. Some of the measures are highlighted below:

- Gradients of steeper slopes could be reduced by constructing terraces.
- Retaining walls can be built to stabilize the slope.
- Steep slopes should be inspected regularly, especially during periods of intense or prolonged rainfall to identify areas prone to mass wasting for preventive measures.
- More surface drainage channels and ditches can be constructed to reduce overflowing discharge
- Legislation can restrict development and building in zones prone to mass wasting.
- Trees can be planted on steeper slopes to stabilize the soil and the slope.
- Appropriate instruments can be installed to monitor slope stability, providing early warning in areas of concern.
- Mass education of people

Application activity 3.5

Make a field trip to observe different areas affected by mass wasting. Analyse the causes of mass wasting and propose the sustainable measures to control it.

Skills Lab

Identify any area mostly affected by mass wasting, examine how the Community Work / Umuganda may help you to fight against it.

End unit assessment

1. Give the reasons why highlands are the most affected by mass wasting.
2. How have topography and parent rock influenced the rate of weathering in your area?
3. Explain how the weathering landforms identified in your area affect positively and negatively human activities.

UNIT 4

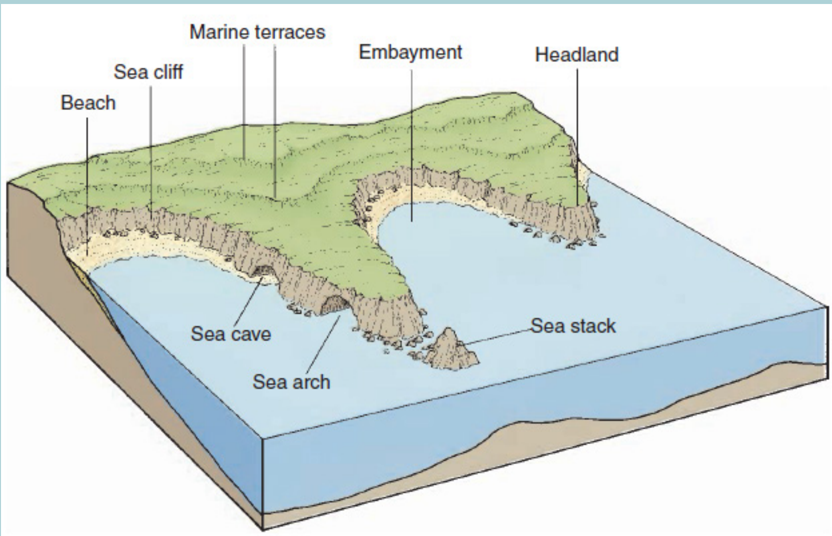
WAVE EROSION AND DEPOSITION

Key Unit competence

By the end of this unit, I should be able to categorise different features resulting from the wave action and their relationships with the human activities.

Introductory activity

Use the pictures provided below and answer the following questions:



1) Identify the coastal landforms found on figure above.
2) Explain the factors for formation of the coastal landforms identified on the figure.

4.1. Coastal landforms: Definition of key terms and types of waves

Learning activity 4.1

1. Make a research and show the difference between the following terms related to coastal landforms:
   a. Coast
   b. Shore
   c. Wave
   d. Longshore drift
2. Mention the type of waves

4.1.1. Definition of key terms

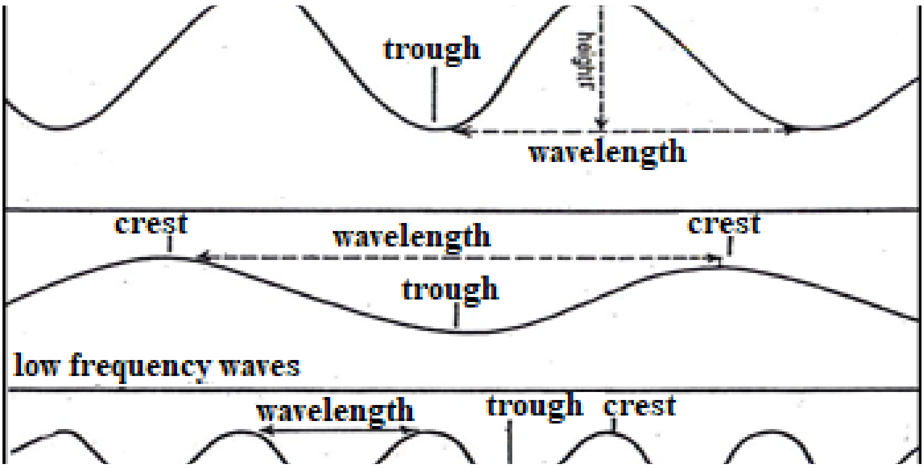
The following are definitions of some terms related with coastal landforms:

- **Coast:** A coast refers to the land that borders the sea or the ocean. It is a narrow zone where the land and the sea overlap and directly interact. Some coasts are made up of broad sandy beaches, while others form rocky cliffs or low-lying wetlands. The shape of the coastline is determined by factors such as the types of rocks present, the forces of erosion, and the changes in sea level.

Coast

- **Shore:** This is the area where land meets the sea or ocean. Different features are found in this area resulting from erosion and deposition of sediments, ocean or sea waves, as well as the effects of rivers as they join the sea. It is also called **coastline.**

- **Waves:** Waves are defined as undulations of sea/lake water characterized by well-developed crests and troughs .Waves are created by the transfer of energy from the wind blowing over the surface of the sea or from submarine shock waves by earthquakes or volcanic activities (e.g. Tsunami).
- When waves appear with high frequency they demonstrate the short wavelengths.



Waves

Structure of wave

Longshore drift, often used interchangeably with ***beach drifting***, is a general term for sediment transport parallel to shore in the nearshore zone due to incomplete wave refraction. In this process sediments transported by the river systems are moved by ocean waves and ocean currents to form beaches.

Beach drifting, also called littoral drifting, is a process in which waves breaking at an angle to the shoreline move sediment along the beach in a zigzag fashion in the swash zone. Both processes are illustrated on figure below.

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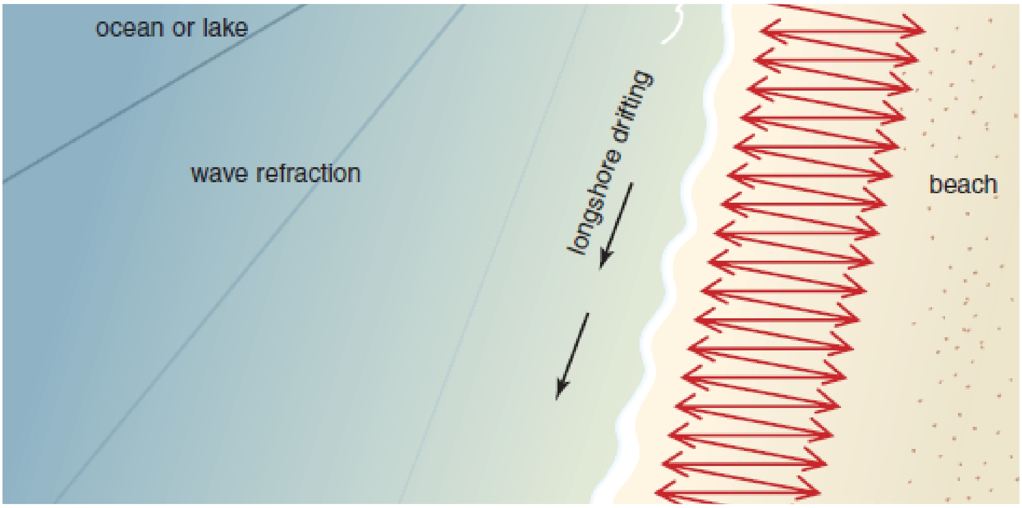


The action of longshore drifting and beach drifting

A wave approaching a straight coastline at a large angle will have velocity progressively decreasing. This will cause the wave to swing around, but it may not have enough time to conform fully to the shape of the shoreline before breaking, leading to littoral drifting.

4.1.2. Types of waves

There are two main types of waves: constructive waves and destructive waves.

1. **Constructive waves:** These are waves whose swash is more powerful than backwash. They are depositional in nature.
2. **Destructive waves:** These are waves whose backwash is more powerful than swash. They are erosional in nature.

Other types of waves

- **Breaking waves:** Formed when the wave collapses on top of itself.

There are four types of breaking waves: spilling, plunging, collapsing, and surging.

Spilling Waves

Spilling waves are waves that are produced when the ocean floor has a gentle slope. As the wave approaches the shore, it slowly releases energy, and the crest gradually spills forward down its face until it is all whitewater. These waves take more time to break than any other wave. Surfers usually call these waves, "mushy waves."

Plunging Waves

Plunging waves are formed when the incoming swell hits a steep ocean floor or a sea bottom with sudden depth changes. As a result, the wave's crest curls over and explodes on the trough. The air under the lip of the wave is compressed, and a crashing sound is often heard. Plungers are more common in offshore wind conditions.

Surging Waves

Surging waves are produced when long period swells arrive at coastlines with steep beach profiles. The base of the wave moves fast and does not allow the crest to evolve. As a result, the wave almost doesn't break, and there is little whitewater. Surging waves look friendly, but can be quite deadly because of the backwash associated with them.

Collapsing Waves

Collapsing waves are a blend between surging and plunging waves. The crest never completely breaks, and the bottom face of the wave gets vertical and collapses, resulting in whitewater.

- **Deep water waves/Swell waves:** Are made up of a number of waves of different lengths superimposed on each other. They are straight and long, powerful, and travel great distance.
- **Inshore waves:** These waves drain the beach as a backwash.
- **Internal waves:** Formed due to the disturbances found between two water masses of different density. They are high and become turbulent currents when they hit a landmass.
- **Kelvin waves:** Formed due to lack of winds in the Pacific Ocean. They are high and wide waves, warmer than the surrounding water.
- **Progressive waves:** Move with a steady speed, so they are called Progressive Waves. They are of two types:
- **Capillary waves:** Formed when wind creates pressure over capillarity, the binding force that holds the water molecules of the ocean surface together.
- **Orbital progressive waves:** Formed at the boundary of two liquids with different density.
- **Refracted waves:** Travel in shallow water when they approach the shore. The shallowness decreases the power of the wave and causes a curve. These are usually seen near headlands and bays.
- **Seiche waves:** Caused due to the movement within a confined space. These have long wavelengths and rarely result in any damage as their height is generally short.

- **Shallow water waves:** Move in shallow waters. They are of two kinds:
  - **Tidal waves:** Formed due to the gravitational pull of the sun and the moon on the ocean.
  - **Seismic Sea Waves/tsunami:** Caused due to earthquakes beneath the ocean. They travel extremely fast in open water, have significant height in shallow water, and are very dangerous and devastating.
- **Swell waves/Surging waves:** Intense waves generating from the center of a storm where the winds are strong. These expel little energy, travel long distance, and break on distant shores.

Application activity 4.1

1. Differentiate a constructive wave from a destructive wave.
2. If you find an occasion to visit the ocean coast as an East Africa person, describe the coastal features you would be interested to discover and explain why.

4.2. Factors determining the strength of waves and wave action processes

Learning activity 4.2

1. Analyse the factors that determine the strength of waves on the coast
2. Explain how waves can cause erosion along the coast.

4.2.1. Factors determining the strength of waves

The following are the major factors determining the strength of waves.

- **Wind strength**: Wind must be moving faster than the wave crests for energy transfer to continue;
- **Wind duration**: Winds that blow for a short time will not generate large waves;
- **Fetch:** The uninterrupted distance over which the wind blows without changing direction;
- **Depth of water or roughness of sea bed:** As waves enter shallow water, their speed, wavelength and height increase. Therefore waves tend to break in shallow water, for example over a bar at the entrance to a harbor;

– **Direction and speed of tide:** If the tide direction is against the wind, this will also increase wave height and decrease wavelength.

4.2.2. Wave action processes

The wave action includes erosion, transportation and deposition.

- **Erosion:** Several mechanical and chemical effects produce erosion of rocky shorelines by waves. Depending on the geology of the coastline, nature of wave attack, and long-term changes in sea-level as well as tidal ranges, erosional landforms such as wave-cut, sea cliffs, and even unusual landforms such as caves, sea arches, and sea stacks can form.

They erode in four ways as:

1) **Solution**: it is also called **corrosion.** It is common on coasts composed of soluble rocks such as limestone and rock salt.
2) **Corrosion or abrasion**: this is a type of wave erosion in which the load already weathered down and hence being transported drag itself on the bed of the coast and hence wears away some rock particles.
3) **Attrition**: this is a process of wave erosion which involves the reduction in size of eroded particles by themselves.
4) **Hydraulic action:** this is the direction of breaking waves that push water on a cliff. As this water retreats during a backwash, pressure is suddenly released and this generates shock waves that weaken rock particles and make them easily eroded by a backwash.

- **Transportation:** Waves are excellent at transporting sand and small rock fragments. These, in turn, are very good at rubbing and grinding surfaces below and just above water level in a process known as **abrasion**. Longshore drift, longshore currents, and tidal currents in combination determine the net direction of sediment transport and areas of deposition.
- **Deposition:** Sediments transported by the waves along the shore are deposited in areas of low wave energy and produce a variety of landforms, including ***spits, tombolo, beaches, bars and barrier islands***. Different types of pediments are deposited along a coast, sometimes in the form of an accumulation of unconsolidated materials such silt, sand and shingle.

Application activity 4.2

1) Wave erosion is done in four ways, differentiate them
2) Explain the impact of wind and tides on the strength of the waves.

4.3. Factors for Formation of coastal landforms and landforms produced by wave and their importance

Learning activity 5.3

In section 4.2, we have defined key terms related to coastal landforms. Observe carefully the following figure and answer the following questions:

1) Identify the landforms produced by wave erosion on the figure above.
2) Explain the factors that result in the formation of coastal landforms.

4.3.1. Factors influencing the formation of coastal landforms

The following are the major factors influencing the formation of coastal landform:

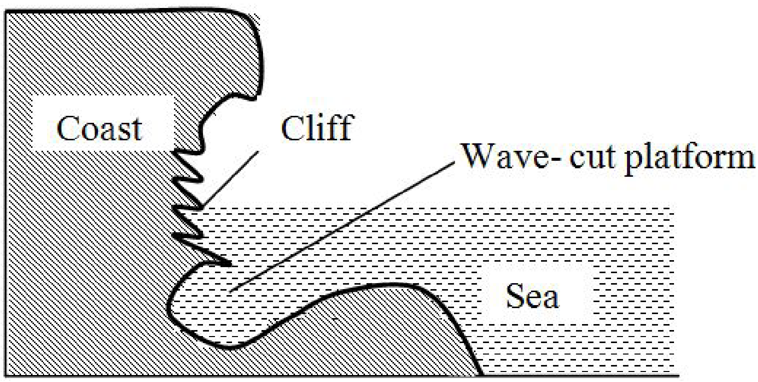
- **Tides:** Tides are greatly influencing forces of coastal landforms. They are commonly semi-diurnal (12-hour cycle). The rise and fall of water levels produce oscillating currents known as tidal streams. Tidal currents can transport large quantities of sediments, especially at the mouths of estuaries. The tidal amplitude also determines the sediments deposition or erosion and keeps redefining the shoreline of coastal landforms.
- **Nature of rocks at the coast:** Wave erosion is more pronounced on areas that are weak and soluble e.g. jointed and consolidated rocks. Rocks which are strong and highly consolidated are hard to erode. The hard and resistant rocks stand as headlands while easily eroded rocks become bays.

- **Openness of the shore to wave attack:** Coasts which are totally exposed to wave attack are easily undermined by wave attack while those which are sheltered by coastal reefs and islands are protected from direct wave attack and are hence less eroded.
- **Waves:** Waves contribute to the erosion of shore. The greater the wave action, the higher is the erosion and sediment movement. Where the shoreline is long and flatter, the wave energy gets dispersed. Wherever there are rock formations, cliffs and short shore area, the wave energy is high. Strong waves can pick up sediments from deeper waters and make them available for transportation by the coastal currents. The larger the wave, the larger the particle it can move. Storm waves can even move boulders. Even small waves can lift the sediments and deposit along the coastal shoreline.
- **Abundance and size of loads which is used as an abrasive tool:** When materials e.g.; boulders, sands, etc. are in abundance, the coast line will be easily eroded through corrosion. In the absence of such materials, wave erosion becomes meager.
- **Longshore currents**: Parallel movement of water is known as longshore current and it extends up to the zone of breaking waves from the coastal shoreline. As the long shore currents are formed by refracting waves, the direction of flow will depend upon the angle of the wave which in turn depends upon the wind directions. If the wind direction is balanced, the sediment movement is also balanced. If the wind movement and resultant wave action dominate in one direction great volumes of sediment may be moved in one direction.
- **Weather elements**: The elements of climate, such as wind, rainfall and temperature play an important role in formation of coastal landforms. Winds are directly related to the intensity of waves. Landforms like coastal dunes are created by wind action. Temperature is required for physical weathering of sediments. Rainfalls provide runoff for producing and transporting sediments from land to seashore.
- **Gravity:** Gravity is an important factor for the development of coastal landforms. Gravity is indirectly involved in the movement of wind and waves as well as in downward movement of sediments.
- **Nature of coastal rocks:** Soft rocks are easily eroded hence forming erosional features like bays while hard or resistant rocks lead to the formation of headlands.

4.3.2. Landforms produced by wave erosion (destructive wave)

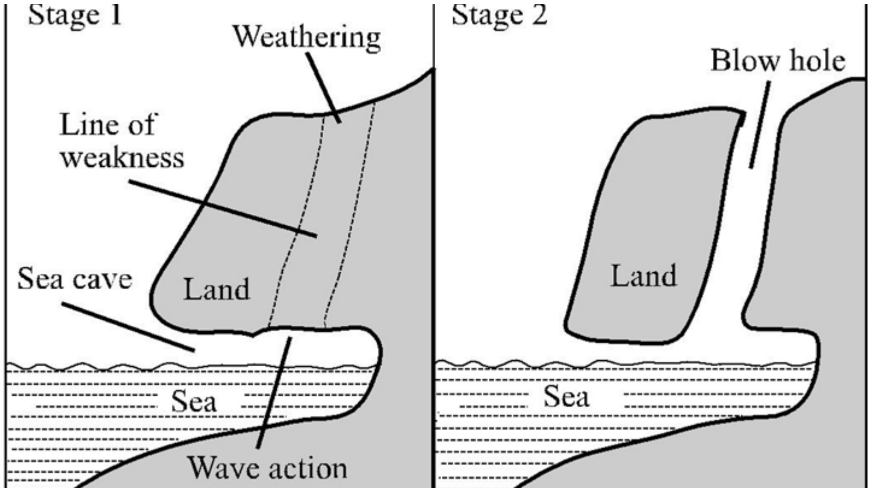
The coastal features formed due to marine erosion by sea waves and other currents and solution processes include cliffs, caves, geo, stacks, blowhole, arch, wave-cut platforms.

- **Cliffs:** A cliff is a steep rocky coast rising almost vertically above sea water. Cliffs are very precipitous with overhanging crest. The steepness of vertical cliffs depends on the following: lithology of the area, geological structure, weathering, erosion of cliff faces and marine erosion of cliff base.
- **Wave-cut platform:** Rock-cut flat surfaces in front of cliffs are called wave-cut platforms or simply shore platforms. They are slightly concave upward. The origin and development of wave-cut platforms is related to cliff recession. The plat-form is composed of bare rock or it may contain a temporary deposit or rock debris, pebbles or sand.



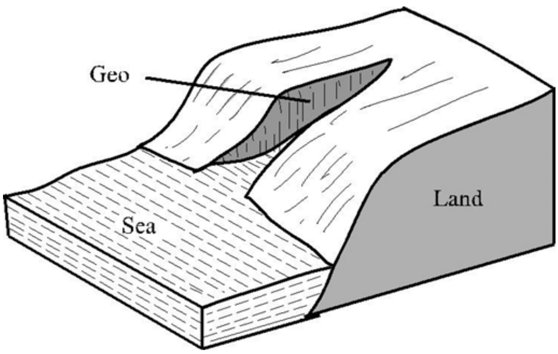
Cliffs and Wave-cut platform

- **Sea caves:** A sea cave is a natural cavity or chamber which develops along the coast due to gradual erosion of weak and strongly jointed rocks by up rushing breaker waves (surf currents). Sea caves are more frequently formed in carbonate rocks (limestone and chalks) because they are eroded more by solution processes. However, sea caves are not permanent as they are destroyed with time.
- **Headland**: Is a projection of land into the sea or lake. Where alternate hard and soft rocks occur at the coast, the weak material is eroded to form a bay while the harder rock resists erosion and remains extending out into the water as a headland.
- **Blowhole:** This is a vertical shaft linking the cave to the surface. It is formed when wave action attacks the back part of the roof of the cave. At the same time, weathering by solution acts on the line of weakness from the surface downwards to form a blowhole



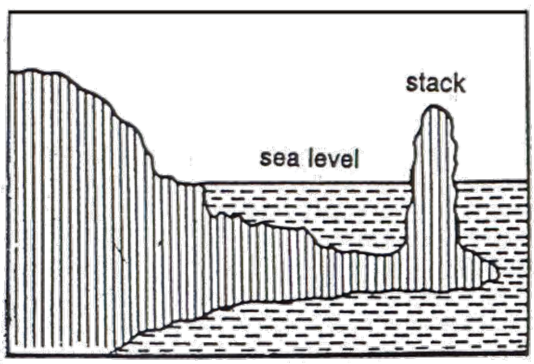
Sea cave and Blowhole

– **Geo:** Wave erosion may continue on the roof of the cave along the blowhole. Hence, the roof of the cave may collapse to form a long and narrow sea inlet known as Geo.



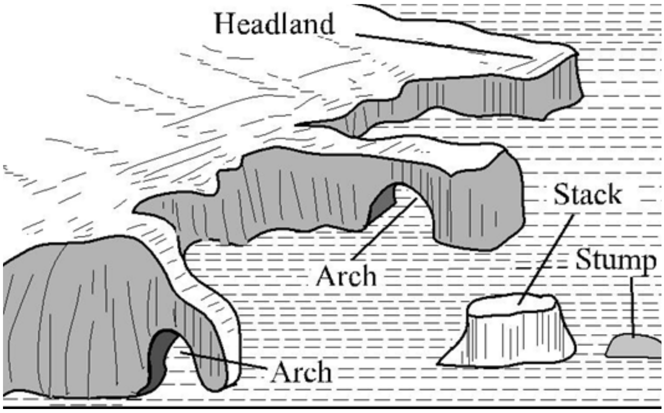
Geo

– **Stack/ Column/Pillar:** A stack is an isolated rock monolith or pillar rising steeply from the sea. It is a former part of the adjoining land that has become isolated from it by wave erosion, probably after having formed part of a marine arch.



Stack

- **Sea arch:** A **s**ea arch is a natural opening through a mass of rock limestone or boulder clay. It is most commonly seen on the sea coast where waves have cut through a promontory. When the keystone of the marine arch collapses, the feature will become a stack.

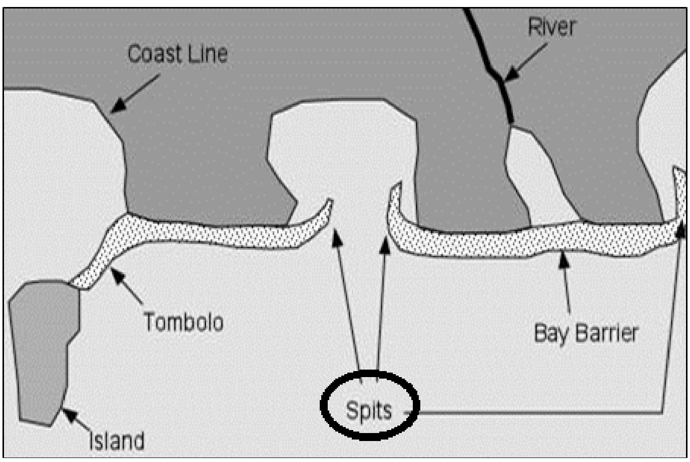


Sea arch

4.3.3. Landforms produced by wave deposition (constructive wave)

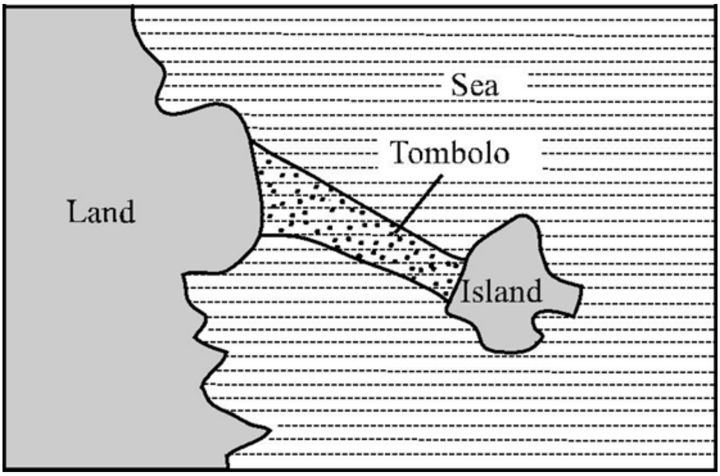
Sediments transported along the shore are deposited in areas of low wave energy. They produce a variety of landforms, including ***spits, tombolo, beaches, bars and barrier islands***. Different types of pediments are deposited along a coast, sometimes in the form of an accumulation of unconsolidated materials such as silt, sand and shingle.

- **Spits:** A spit is an embankment composed of sand and shingle attached to the land on one end and projecting seaward. It may form parallel to the coast and stretch several kilometers. It may also grow at an angle across an estuary. Spits are formed when materials are transported and deposited by the long shore drift, mostly where the orientation of the coast changes.



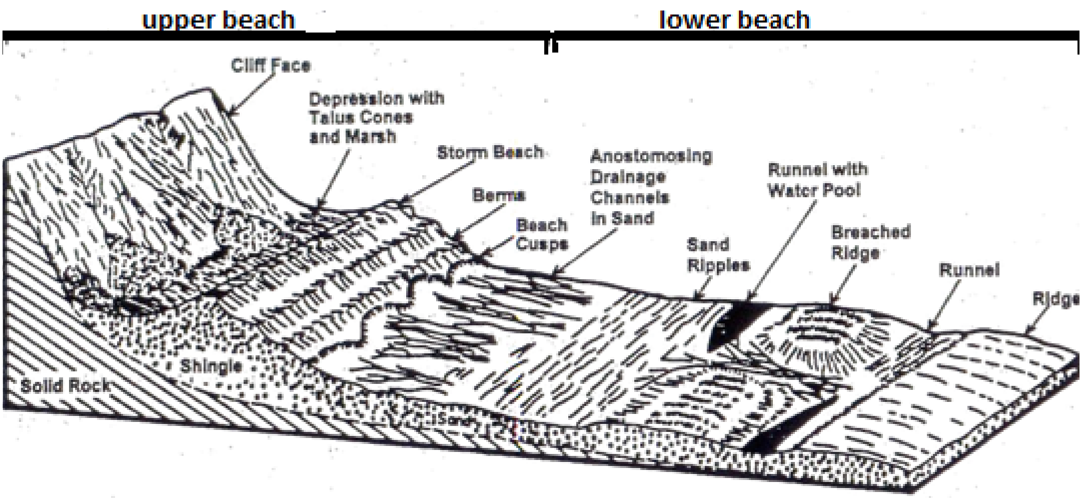
Spits

- **Tombolo:** It is a spit which grows seawards from the coast and joints to an island.



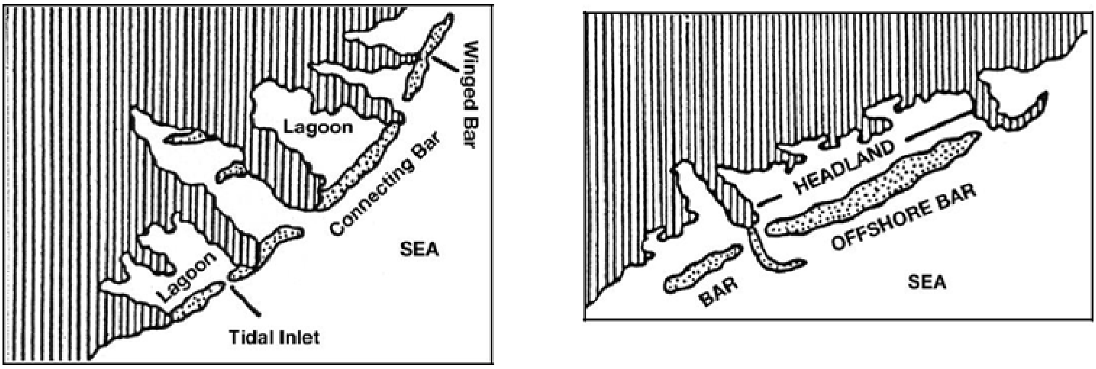
A Tombolo

- **Beaches:** A beach is located on a wave-cut platform of solid rock and is generally of a low gradient with a gently concave platform. Beaches may extend for hundreds of kilometers. Beaches are classified into: *sand beach*, *shingle beach*, and *boulder beach*.



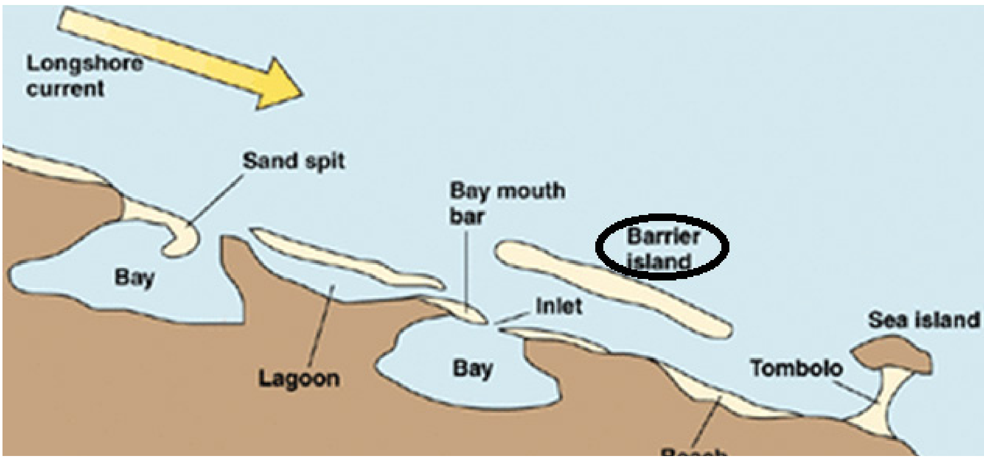
Different elements of a beach

- **Bar**: A bar is an elongated deposit of sand, shingle or mud occurring in the sea. It is more or less parallel to the shoreline and sometimes linked to it. Bars may be of submerged or emergent embankments of sand and gravel built along the shore by waves and currents. One of the most common types of bars is the *spit*.



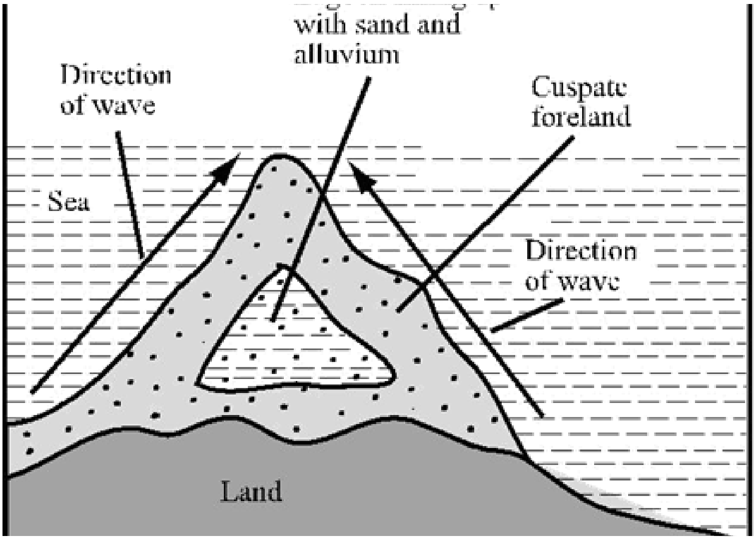
Bar

- **Barrier Islands:** Barrier Islands are long, offshore islands of sediments tending parallel to the shore. They form long shorelines adjacent to gently sloping coastal plains, and they are typically separated from the mainland by a lagoon. Most barrier islands are cut by one or more tidal waves.



Barrier islands

- **Cuspate foreland:** This is a large triangular-shaped deposit of sand, mud and shingles projecting seaward. It is a rare feature formed when two adjacent spits growing towards each other at an angle join and enclose a shallow lagoon.

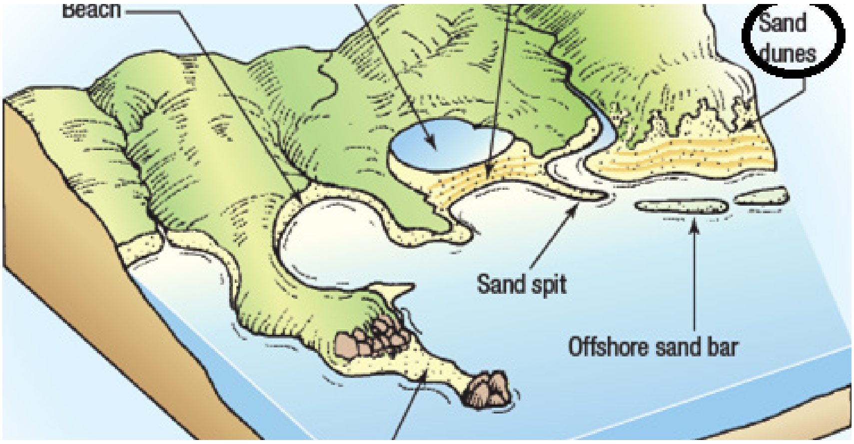


Cuspate foreland

- **Mud flats:** These are platforms of mud, silt and river alluvium kept by salt-tolerant plants to form a swamp or marshland. They are formed when tides deposit fine silts along gently sloping coats in bays and estuaries.

Mud flats

- **Coastal dunes:** These are low-lying mounds of fine sand, deposited further inland from a wide beach by strong onshore winds. They are common in arid and semi-arid coasts.



Coastal dunes

Application activity 4.3

1) Describe landforms produced by wave deposition.
2) Explain the factors influencing the formation of coast landforms.
3) According to you, which landforms are likely to be found around lakes in Rwanda ?

4.4. Importance of coast landforms produced by wave action and type of coasts

Learning activity 4.4

Study the following photograph and answer related questions:

1. Describe the types of coasts.
2. Describe the economic activities that can be carried out in this area

4.4.1. Importance of coast landforms produced by wave

Coastal landforms produced by wave action are very important in different ways as follows:

- Many of the world's major cities are located in coastal areas, and a large portion of economic activities, are concentrated in these cities.
- There are different activities that take place in coastal zones including coastal fisheries, aquaculture, industry, and shipping.
- Many of coastal landforms are very favourable for tourism that contributes to the economic development of countries.
- Marine, estuary and coastal wetland areas often benefit from flows of nutrients from the land and also from ocean upwelling which brings nutrient-rich water to the surface. They thus tend to have particularly high biological productivity.
- The world's fish production is dependent on the nature of coastal landforms like bays and headlands.
- Beaches support leisure, recreation, trade and mining of sand
- Mud flats and sand dunes have fine silt which attracts mangrove swamps used in crafts industry.
- Features produced are important in agriculture development
- Cliffs protect the land from wave attack.
- These landform features are used in study purposes.
- Cliffs may produce waterfalls important in generation of power.

4.4.2. Types of coasts

There are two types of coasts: Submerged coasts and Emerged coasts.

i) Submerged coasts

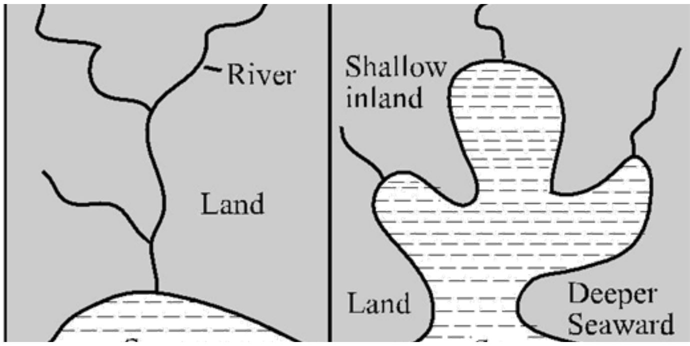
Submerged coasts fall into two categories: Submerged upland coasts and submerged lowland coasts.

A. Submerged upland coasts

When the margin of an irregular upland area is submerged, a more or less indented coastline is produced. It appears with islands and peninsulas representing the former uplands, and with inlets indicating the former valleys. The following are the three types of submerged coasts:

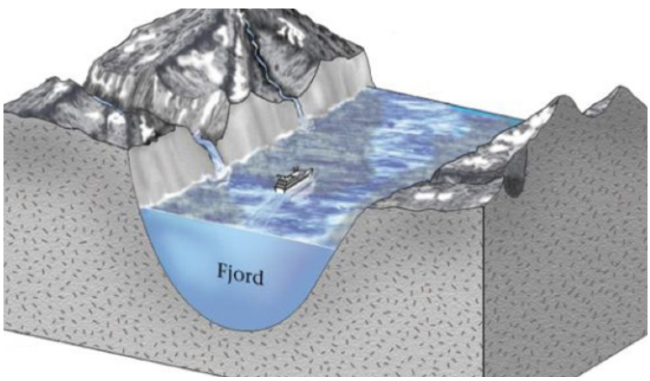
1) **Ria coasts**: *Ria* is a Spanish term widely used to describe a submerged coastal valley or estuary resulting from a rise of the sea level. In the case of a Ria coast, hills and river valleys meet the coastline at right angles. The rias are characterized by funnel-shaped which decreases width

and depth as they run inland. The head of a stream which is small is responsible for the formation of the valley at the inlet.



Ria coasts

2) **Fiord (Fjord) coasts**: A long, narrow inlet of the sea bound by steep mountain slopes. These slopes are of great height and extend to considerable depths (in excess of 1,000 m) below sea level. It is formed by the submergence of glacially over deepened valleys due to a rising sea level after the melting of the Pleistocene ice sheets. Fiords occur in western Scotland, Norway, Ireland, Greenland, Labrador, British Columbia, Alaska, Southern Chile and New Zealand. The main reason for their existence is the submergence of deep glacial troughs and that is why fiords have many characteristics of glaciated valleys.



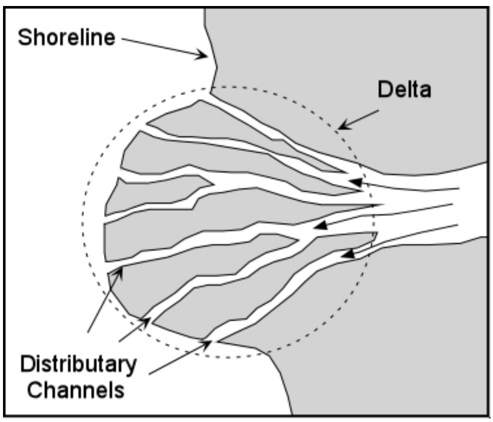
Fiord

3) **Dalmatian or longitudinal coasts:** *Dalmatian* is a term derived from the Yugoslavia Adriatic in which the coast runs parallel with the lineament of the topography and probably with the underlying geological structure. A rise of sea level (estuary) has drowned the coastal area, resulting in a coastline of narrow peninsulas, lengthy gulfs and channels and linear islands. The Dalmatian coast tends to be straight and regular.

Dalmatian or longitudinal coast

4) Submerged lowland coasts

These are formed when a rise in the sea level drowns a lowland coast. The sea penetrates deep inland along rivers to form estuaries. The rise in base level causes an increase in deposition by rivers leading to formation of mud flats, marshes, and swamps which are visible at low tides. **Delta:** Is a large, flat and low lying plain of river deposits laid down where a river flows to the sea or lake. A delta is a large area covered by river deposits (alluvium) formed at the mouth of a river



Submerged lowland coasts

Ii) Emerged coasts

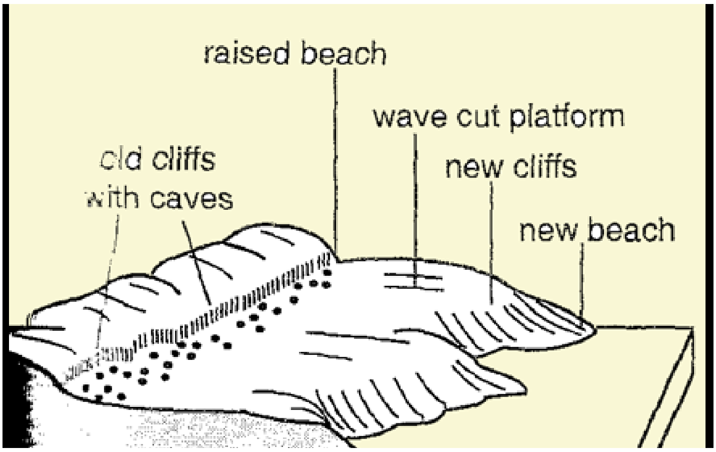
Emerged coasts comprise emerged highlands coasts and emerged lowland coasts.

A. Emerged upland coasts

Raised beaches: when the sea level drops, wave activity also drops to lower levels. The wave deposition will be at a new point of low tide level forming a new beach there, hence leaving the old beach up high at a former point of sea. These types of beaches are usually evident on land that is far away from the present edge of the water. They may have been formed at the head of a bay but they are now isolated on land. Most raised beaches are colonized by vegetation.

Raised cliffs: this is formed when there is a relative fall in the level of the sea.

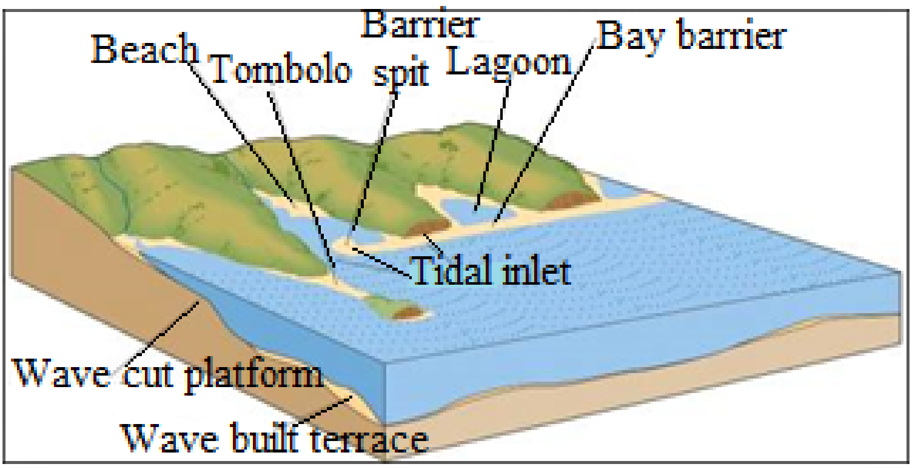
A raised terrace: the drop in sea level produces a wave cut platform down to a new level of the sea leaving the former terrace suspended up to the original level of the sea before emergence.



Emerged upland coast

B. Emerged lowland coasts

An emerged lowland coast has been produced by the uplift of part of the neighboring continental shelf. The landward edge of such coastal plain is found in the southern of USA. It is formed by the fall-line where rivers descend from the Appalachian in a series of waterfalls. Other examples of emerged lowland costs are: the northern shore of the Gulf of Mexico and the southern shore of the Rio-de-la Plata in Argentina.



Application activity 4.4

1. Give five examples of cities located in coastal areas, including at least two cities located in East African Community.
2. Indicate the type of submerged coast, and describe its characteristics.
3. Suppose that you live nearby the coast, explain the business opportunities that you may carry out there and the challenges you can face.

4.5. Coral reefs: Nature, types and formation of coral reefs

Learning activity 4.5

Observe the figure below of a coral reef and answer the following questions:

1. What do you think are the elements that constitute a coral reef?
2. Analyze the processes in which coral reefs are formed.
3. What do you think are the problems related to coral reefs formation?

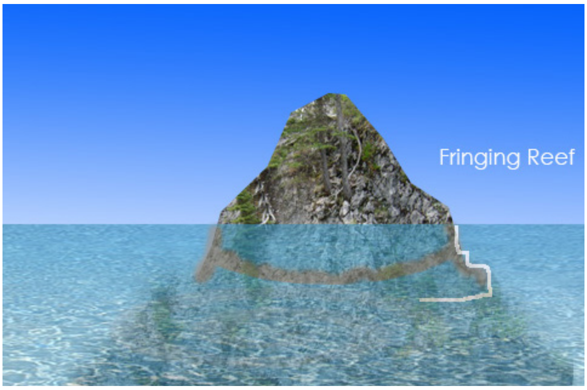
A coral is a hard limestone rock made up of the skeletons of tiny (very small) marine organisms, known as coral polyps. Also coral reefs are limestone rocks which are formed from dead animals called **corals.** Corals have a hard shell of calcite, formed by the extraction of calcium carbonate from sea water.

They are generally attached to submarine platforms or islands submerged under seawater.

A. Types of coral reefs

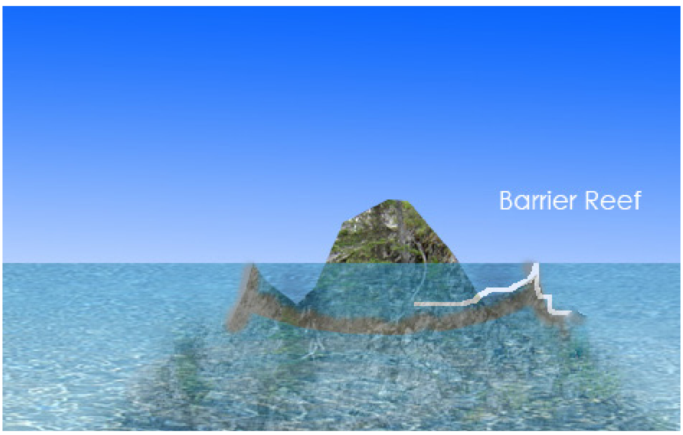
On the basis of the location of the main types of reefs, we distinguish tropical coral reefs and marginal belt coral reefs. But, by categorizing on the basis of the nature, the shape and the mode of occurrence, we have three types of coral reefs which are: fringing reefs, barrier reefs and atoll.

1) **Fringing reefs (Shore Reefs):** These are the coral reefs developed along the continental margins or along the islands. The seaward slope is steep and vertical while the landward slope is gentle. A fringing reef runs as a narrow belt which grows from the deep sea bottom sloping steeply seaward side. It is separated from the main land by a narrow and shallow lagoon.



Fringing reefs

2) **Barrier reefs*:*** Barrier reefs are extensive linear reef complexes that are parallel to a shore and are separated from it by a deep and wide lagoon.



Barrier reefs

3) **Atoll**: An atoll is a roughly circular (annular) oceanic reef system surrounding a large and often deep central lagoon. There are three types of atolls, namely, true atolls, island atolls and coral island or atoll islands.

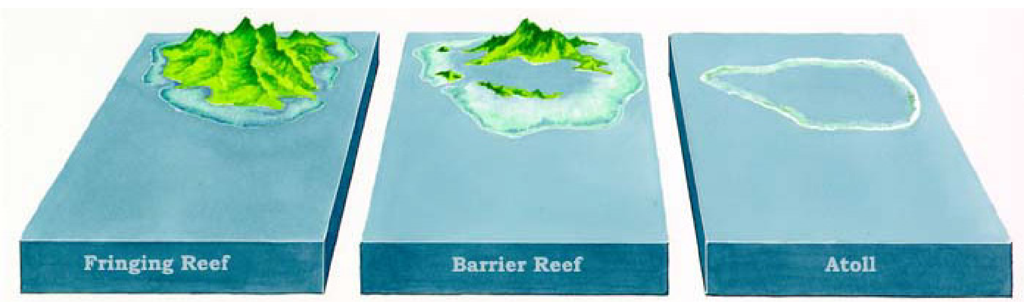
- **True atolls** are characterized by circular reef enclosing a shallow lagoon but without an island;
- **Island atolls** have an island in the central part of the lagoon enclosed by circular reefs;
- **Coral islands** or atoll islands do not have islands in the beginning but later on islands are formed due to erosion and deposition by marine waves.

Atoll

B. Formation of coral reefs

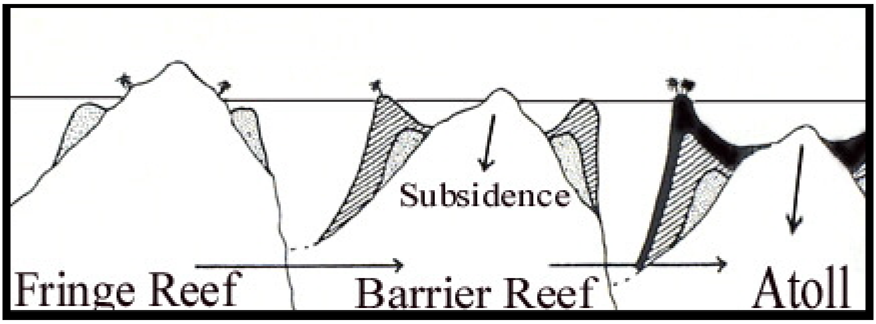
1) The process of coral reefs formation

Coral reefs start to form when the free-swimming coral larvae attach to the submerged rocks or other hard surfaces along the edges of islands or continents. This continues to grow under the influence of coral reefs conditions to grow in any types accordingly. The coral reef formation takes three stages: fringing, barrier and atoll.



Stages of coral reefs formation (fringing, barrier, atoll)

Concerning the process, a typical fringing reef is attached to or borders the shore of a landmass, while a typical barrier reef is separated from the shore by a body of water. An atoll began as a fringing reef around a volcanic island. Over time, the volcano stopped erupting, and the island began to sink. Over time, coral growth at the reef's outer edge would push the top of the reef above the water. As the original volcanic island disappeared beneath the sea, only an atoll would remain.



Formation of coral reefs

1) The general conditions influencing coral formation

- Corals are found mainly in the tropical oceans and seas because they require high mean annual temperature ranging between 20°C and 21°C for their survival. They cannot survive in the waters having either very low temperature or very high temperature.
- Corals do not live in deep waters, that is, not more than 60-77 meters below the sea level.
- There should be clean sediment-free water because muddy water or turbid water clogs the mouths of coral polyps resulting into their death.
- Though coral polyps require sediment-free water, fresh water doesn't allow their growth. This is why corals avoid coastal lands and live away from the areas of river mouths.
- High salinity is injurious to the growth of coral polyps because such waters contain little amount of calcium carbonates whereas lime is important food of coral polyps. The oceanic salinity ranging between 27% and 30% is most ideal for the growth and development of coral polyps.
- Ocean currents and waves are favorable for corals because they bring necessary food supply for the polyps.
- There should be extensive submarine platforms for the formation of colonies by the coral polyps. Besides, polyps also grow outward from the submarine platforms.
- Human activities like deforestation, industrialization cause global warming, which adversely affects corals in their habitats. Corals are

more susceptible to long-term climatic change. Corals are generally termed as rainforests of the oceans. These cannot survive in extreme warm environment.

Application activity 4.5

1) Using illustrative graphics, differentiate the types of coral reefs.
2) Explain the conditions for coral reefs formation.

4.6. Theories of the origin of coral reefs, Problems facing the development and growth of coral reefs, Impact of coral reefs

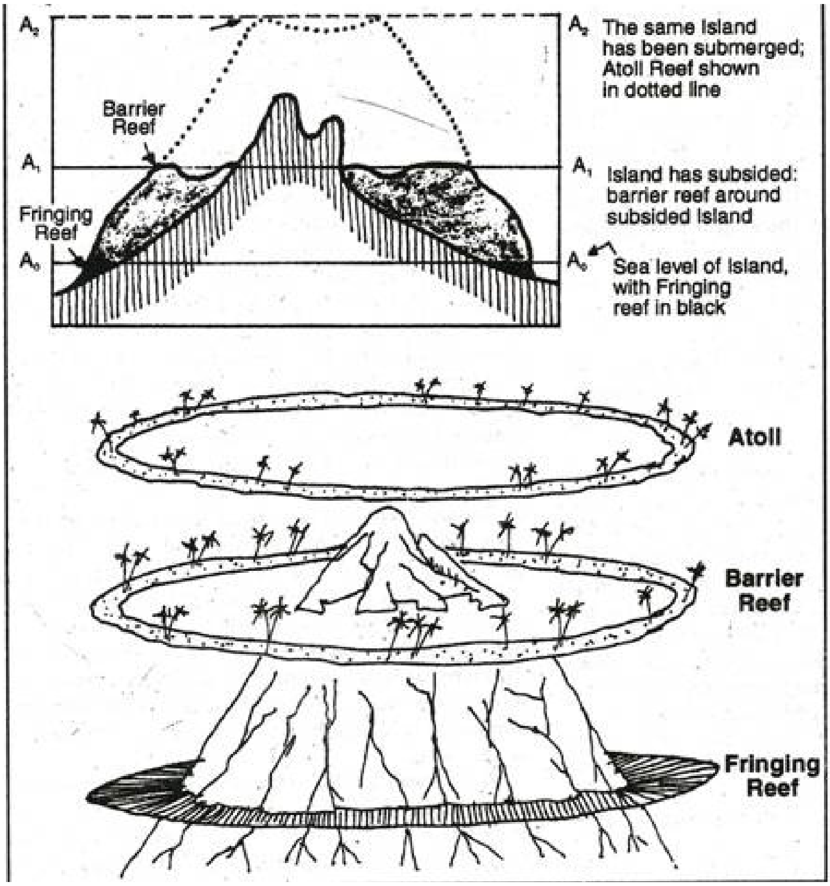
Learning activity 4.6

1. Using concrete examples, show how coral reefs are important
2. Mention the theories explaining the formation of coral reefs

4.6.1. Theories of the origin of coral reefs

There are three main theories about the origin of coral reefs that are:

- The subsidence theory by Darwin,
- Antecedence theory by Murray,
- Glaciated control theory by Daly.



Darwin's Subsidence theory of the origin of coral reefs

A. Darwin's Theory or subsidence theory

Darwin, a British naturalist developed his theory as follows:

- Darwin's theory starts with a volcanic island which becomes extinct.
- As the island and ocean floor subside, coral growth builds a fringing reef, often including a shallow lagoon between the land and the main reef.
- As the subsidence continues, the fringing reef becomes a larger barrier reef further from the shore with a bigger and deeper lagoon inside.
- Ultimately, the island sinks below the sea, and the barrier reef becomes an atoll enclosing an open lagoon.

B. Murray's theory or antecedence theory

The Antecedent-Platform or uplift theory for the origin of coral reefs stipulates that:

- Any bench or bank that is located at a proper depth within the circum-equatorial coral-reef zone is potentially a coral-reef foundation.

- If ecological conditions permit, a reef may grow to the surface from such a foundation without any change in sea-level.
- Reef foundations, or platforms, are formed by erosion, deposition, volcanic eruption, or earth movement or by combinations of two or more of these processes.
- The theory agrees that atoll coral reefs formed when the tops of islands were undergone wave action resulting to a platform.

C. Daly's theory or glaciated control theory

Daly studied the coral reefs of Hawaii and he was greatly impressed by two things:

- The reefs were very narrow and there were marks of glaciations
- There should be a close relationship between the growth of reefs and temperature.
- According to Daly's hypothesis, in the last glacial period, an ice sheet had developed due to the fall in temperature. This caused a withdrawal of water, equal to the weight of the ice sheet. This withdrawal lowered the sea level by 125-150 m.
- The corals which existed prior to the ice age had to face this fall in temperature dining this age and they were also exposed to air when the sea level fell. As a result, the corals were killed and the coral reefs and atolls were planed down by sea erosion to the falling level of sea in that period.
- When the ice age ended, the temperature started rising and the ice sheet melted. The water returned to the sea, which started rising. Due to the rise in temperature and sea level, corals again started growing over the platforms which were lowered due to marine erosion.
- As the sea level rose, the coral colonies also rose. The coral colonies developed more on the circumference of the platforms because food and other facilities were better available there than anywhere else.
- Hence, the shape of coral reefs took the form of the edges of submerged platforms, a long coral reef developed on the continental shelf situated on the coast of eastern Australia. Coral reefs and atolls developed on submerged plateau tops. After the ice age, the surface of platforms was not affected by any endogenic forces and the crust of the earth remained

4.6.2. Impact of coral reefs

Coral reef landforms have crucial impact in world economic activities. These are:

- **Tourist attraction**: Coastal features like caves, beaches and arches are tourist attractions.
- **Development of harbors**: Rias and fiords favor the development of deep sheltered harbors.
- **Industrial raw materials**: Coral limestone provides raw materials for the manufacture of cement. This is obtained from raised coral reefs.
- **Fishing grounds**: Fiords contain sheltered waters which are suitable for feeding and development of fishing ports. Continental shelves contain shallow waters which favor growth of planktons. This makes them rich fishing grounds.
- **Habitat for marine life**: Lagoons, mud flats and mangrove swamps are good habitats for marine life. This has promoted the development of research on marine life and establishment of marine parks.
- **Impact on agriculture**: emerged coasts have sand, gravel and bare rock. These inhibit agriculture, especially crop farming.
- **Transport barrier**: coastal features such as sandbars and coral reefs inhibit water transport and development of ports.

4.6.3. Problems facing the development and growth of coral reefs

The following are the major problems facing the development and growth of coral reefs:

- ***Overfishing***: Increasing demand for food fish and sea tourism has resulted in over fishing of not only deep-water commercial fish, but key reef species as well. This affects the reef's ecological balance and biodiversity.
- ***Coral disease***: coral diseases contribute to the deterioration of coral reef communities around the globe. Most diseases occur in response to the onset of bacteria, fungi, and viruses.
- ***Destructive fishing methods***: Fishing with dynamite, cyanide and other methods that break up the fragile coral reef are highly unsustainable. Dynamite and cyanide stun the fish, making them easier to catch. Damaging the coral reef habitat on which the fish rely reduces the productivity of the area.
- ***Unsustainable tourism***: Physical damage to the coral reefs can occur through contact from careless swimmers, divers, and poorly placed boat anchors. Hotels and resorts may also discharge untreated sewage

and wastewater into the ocean, polluting the water and encouraging the growth of algae, which competes with corals for space on the reef.

- ***Coastal development:*** The growth of coastal cities and towns generates a range of threats to nearby coral reefs. Coral reefs are biological assemblages adapted to waters with low nutrient content, and the addition of nutrients favours species that disrupt the balance of the reef communities.
- ***Pollution:*** Coral reefs need clean water to thrive. From litter to waste oil, pollution is damaging reefs worldwide. Pollution from human activities inland can damage coral reefs when transported by rivers into coastal waters.
- ***Marine debris:*** It is any solid object that enters coastal and ocean waters. Debris may arrive directly from a ship or indirectly when washed out to sea via rivers, streams, and storm drains. Human-made items tend to be the most harmful such as plastics (from bags to balloons, hard hats to fishing line), glass, metal, rubber (millions of tires!), and even entire vessels.
- ***Dredging operations.*** They are sometimes completed by cutting a path through a coral reef, directly destroying the reef structure and killing any organisms that live on it. Operations that directly destroy coral are often intended to deepen or otherwise enlarge shipping channels or canals, due to the fact that in many areas, removal of coral requires a permit, making it more cost-effective and simple to avoid coral reefs if possible.
- ***Global Aquarium Trade*****:** It is estimated that nearly 2 million people worldwide keep marine aquariums. The great majority of marine aquaria are stocked with species caught from the wild. This rapidly developing trade is seeing the movement of charismatic fish species across borders. Threats from the trade include the use of cyanide in collection, over-harvesting of target organisms and high levels of mortality associated with poor husbandry practices and insensitive shipping. Some regulation is in place to encourage the use of sustainable collection methods and to raise industry standards.
- ***Alien invasive species*****:** Species that, as a result of human activity, have been moved, intentionally or unintentionally, into areas where they do not occur naturally are called "introduced species" or "alien species". In some cases, where natural controls such as predators or parasites of an introduced species are lacking, the species may multiply rapidly, taking over its new environment, often drastically altering the ecosystem and out-competing local organisms.
- ***Climate change***: Rising sea levels due to climate change requires coral to grow to stay close enough to the surface to continue photosynthesis.

Also, water temperature changes can induce coral bleaching in which sea surface temperatures rose well above normal, bleaching or killing many reefs.

– ***Ocean acidification***: results from increases in atmospheric carbon dioxide. The dissolved gas reacts with the water to form carbonic acid, and thus acidifies the ocean. This decreasing pH is another issue for coral reefs.

– ***Coral mining***: Both small scale harvesting by villagers and industrial scale mining by companies are serious threats. Mining is usually done to produce construction material which is valued as much as 50% cheaper than other rocks, such as from quarries. The rocks are ground and mixed with other materials, like cement to make concrete. Ancient coral used for construction is known as coral rag. Building directly on the reef also takes its toll, altering water circulation and the tides which bring the nutrients to the reef.

Application activity 4.6

1. Establish the similarities of the subsidence, antecedence and glaciated control theories of coral reefs formation.
2. Account for the negative impacts of human activities on the coral reefs growth.
3. Describe the economic importance of coral reefs.

4.7. Sea level change

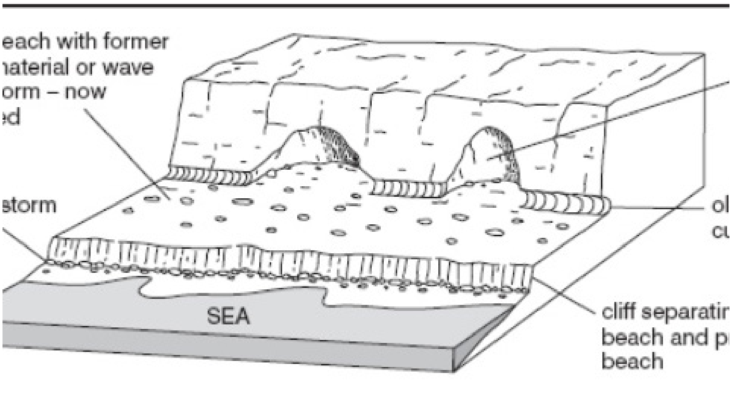
Learning activity 4.7

Observe the following picture and answer the question that follow:

1. Find evidence that the level of water on this picture changes.
2. What do you think can cause that change?
3. Describe any three features observed on this picture

4.7.1. Meaning of sea level change and its resulting features

The sea level change is the variation and fluctuation of the sea level throughout time. It can contribute to the formation of submergent landforms such as Ria (a river valley that's been flooded by the eustatic rise in sea level), fjords and dalmatian coastline, and emergent landforms such as raised beaches. These are wave-cut platforms and beaches that are above the current sea level. There are also some old cliffs (relic cliffs) behind these raised beaches with wave-cut notches, arches and stacks along them.



Raised beach

4.7.2. Types of sea level changes

There are two types of sea level changes which are:

- **Submergence or Rise of sea level**: This is referred to as an increase in global mean sea level as a result of an increase in the volume of water in the world's oceans. This leads to the formation of coastal features of submergence.
- **Emergence or fall of sea level**: This is referred to as the decrease in global mean sea level as a result of a decrease of the world's oceans. This leads to the production of emergence coastal landform.

4.7.3. Causes of sea level change

The sea level changes daily because of the following causes:

- **Eustatic variations in sea level** are the effects of external forces. Most experts agree that human induced global warming is the force behind the current global sea-level rise. There are three factors that primarily affect eustatic sea level change that are: thermal expansion of the ocean, melting of nonpolar glaciers, and change in the volume of the ice caps of Antarctica and Greenland.
- **The changes in global temperature** affect the amount of ice stored on land as water, thus changing the sea levels. A rise in temperatures causes the ice caps to melt, and sea levels rise, and vice versa.
- **The changes in sea levels are** also affected by the steric effect. This is where the density of the water increases or decreases as the temperature rises or falls. If the temperature rises the water expands and if it falls the water contracts. It is estimated that sea levels can rise up to 0.4 mm per year.
- **The mass of ice adds weight to the earth's crust** causing it to sink lower into the mantle resulting into relative rise in the sea-level during glacial period.
- **Isostatic re-adjustment;** at the end of glacial period, the mass of ice melts and the weight is lost from crust which then rises. When the ice melts the land begins to rise as the weight is removed. This process results in a relative fall in sea-level. This is called isostatic re-adjustment.
- **Uplift/mountain building** due to plate movements may also result in a relative fall in sea-level as land rises up.
- **Pre-glacial erosion of a coastline** causes the coast rise and end-up to the sea level change.

4.7.4. Evidences of sea level changes

The following are evidences of sea level changes:

- **The presence of old coastline high above the present sea level**: During the Ice Age the sea levels fall leaving the old coastline. Since the end of the Ice Age, sea levels have risen again, but not to their previous levels. The raised beaches continue to be above the present sea level by quite a distance.
- **The estuaries and inlets flooded**: Sea level rise after the last Ice Age caused estuaries and inlets to be flooded. This occurred in South West England, drowning many river valleys around the coasts of Devon and Cornwall, and creating Rias. In other more northern areas, glacial valleys were drowned to create Fjords.

- **Isostatic re-adjustment phenomenon:** Some places in Scotland still undergoing isostatic re-adjustment up to 7 mm per year in some areas.

4.7.5. Effects of the sea level changes

Rising sea level has many impacts on coastal areas. The following are some of them:

- **Erosion of beaches and bluffs:** Beach erosion is the most common problem associated with rising sea level. Depending on beach composition, beaches erode by about 50 to 200 times the rate of sea level rise. That translates a 2-millimeter (0.08-inch) per year increase in sea level eroding from 10 to 40 centimetres (3.9 to 15.6 inches) of coastline per year. Beach erosion has not only a strong ecological impact, but also a profound economic impact;
- **It increases the flooding and storm damage** caused by changes in sea level;
- **Contamination of drinking water:** as the rising sea crawls farther and farther up the shore, in many places it will seep into the freshwater sources in the ground that many coastal areas rely on for their drinking water. Saltwater is unsafe to drink, and while it is possible to remove the salt from water, doing so is an expensive and complicated process;
- **Interference with farming:** Those same freshwater sources we use for drinking also supply the water we use for irrigation. The problems here are the same: The intruding sea could make these groundwater sources saltier. Saltwater can stunt or even kill crops, but creating freshwater from saltwater is a costly and unsustainable practice;
- **Change in coastal plant life:** more saltwater hitting the shores changes the soil composition on the coast, meaning the plant life there will most likely change as well;
- **Threating the wildlife population:** Many forms of wildlife make their home on the beach. As the rising ocean erodes the shoreline and floods the areas in which coastal animals live, animals like shorebirds and sea turtles will suffer and die and others will migrate;
- **Hurting the economy:** the tourism and real-estate industries in coastal areas are likely to take a hit as prime beachfront properties and recreational areas are washed away by rising waters. This is a fact that some involved in these industries are finding hard to swallow.

Application activity 4.7

1. Explain the causes of sea level change
2. According to you, which feature is more attractive to tourism. Defend your view
3. Explain the environmental effects of sea level changes.

Skills Lab

With help of knowledge and skills acquired in this unit, suggest ways beaches may be preserved and more productive.

End unit assessment

1) Describe the major features resulting from wave erosion and deposition processes.
2) Observe the following photographs and answer the questions that follow:
   i) Examine the economic activities that should be carried out in the regions demonstrated on photographs.
   ii) According to you, what are the advantages of coast or shore to people living nearby?
3) Demonstrate the impacts of sea level change to the environment.

UNIT 5

ROCKS AND MINERALS

Key Unit competence

By the end of this unit, I should be able to compare different types of rocks and minerals and evaluate their importance.

Introductory activity

Observe the rock provided below and answer the following questions:

1. Identify the types of rocks given above.
2. In which category can they be classified?
3. Which properties can help to identify these rocks and their minerals?
4. Explain the economic advantages of the rocks and minerals.

5.1. Rocks: Definition, types and characteristics

Learning activity 5.1

Make a field trip in your environment; observe the rock and identify their types and distinctive characteristics.

5.1.1. Definition

A **rock** is a natural aggregate of minerals in the solid state; usually hard and consisting of one, two, or more mineral varieties. Rocks form the solid part of the earth's crust. Rocks may also include substances like clay, sandstones, shells and corals. Rocks which contain metallic compounds are called ores.

5.1.2. Types of rocks

There are three major groups of rocks namely igneous rocks, sedimentary rocks and metamorphic rocks. Their classification is based on the mode of formation and the nature of constituting minerals. Characteristics of each rock group are briefly described below.

i) Igneous rocks

The word igneous comes from the Latin word ignis, which means fire. Igneous rocks are rocks formed by cooling of molten material from a volcano or from deep inside the earth. This molten material from inside the earth is known as magma. Igneous rocks are also called magmatic rocks or volcanic rocks. Their formation is associated with the cooling and hardening of molten material from the interior of the earth.

ii) Sedimentary rocks

Sedimentary rocks are the result of the accumulation of small pieces broken off from pre-existing rocks (igneous rocks, metamorphic rocks and sedimentary rocks) or precipitation of dissolved minerals. Sedimentary rocks form when sediments become pressed or cemented together or when sediments precipitate out of solution.

iii) Metamorphic rocks

The metamorphic rocks get their name from "meta" (change) and "morph" (form). Metamorphic rocks are formed from pre-existing rocks due to increases in heat and pressure which alter rock structure and chemical composition. Therefore, sedimentary and igneous rocks can become metamorphic rocks.

There are four factors that contribute to the formation of metamorphic rocks:

- Heat or high temperature: this speeds up the chemical reactions that result in metamorphic rocks. The heat is from magma, steam from hot water and rocks sinking deeper into the warmer layer of the crust
- High pressure which changes the mineral and feel of the original rock.
- Nature of the parent rock which determines how resistance it is to change.
- Time which determines the period required for the chemical reactions to take place.

5.1.3. Characteristics of rocks

A. Characteristics of igneous rocks

Igneous rocks have the following characteristics:

- They are hard, and water does not pass through their joints easily, that is why they are less affected by erosion;
- Igneous rocks have a lot of minerals;
- They do not have strata or layers;
- They do not contain fossils (fossils are remains of plants and animals fixed in rocks);
- The number of joints increases upwards in any igneous rock;
- Igneous rocks are mostly associated with volcanic activities and are mainly found in the volcanic zones. That is why they are also called volcanic rocks.

Igneous rocks can also be classified based on the chemical and mineralogical compositions, texture of grains, forms and size of grains, and the mode of origin, igneous rocks are classified as follows:

1) Classification based on the amount of silica

- Acidic igneous rocks: they contain more silica: (≥65% of SiO_2);
- Basic igneous rocks: they contain low amount of silica (≤ 45% of SiO_2).

2) Classification based on the chemical and mineral composition

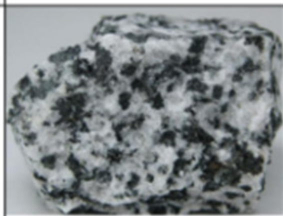
- Felsic igneous rocks: they are composed of the dominant minerals of the light group (e.g. Silicon, Aluminum).
- Mafic igneous: they arecomposed of the dominant mineral of dark group (magnesium and iron).

3) Classification based on texture of grains

- Pegmatitic igneous rocks: they are very coarse grained: (e.g. granite);
- Phaneritic igneous rocks: grains of minerals are of intermediate size;▪ Aphanitic igneous rocks: they are fine grained igneous rocks);
- Glassy igneous rocks: they don't contain a defined grain size;
- Porphyritic igneous: they have mixed graine sizes.

4) Classification based on the mode of occurrence

- **Intrusive igneous rocks**: They are formed when the rising magma, during a volcanic activity, does not reach the earth's surface but rather cools and solidifies below the surface of the earth. Intrusive igneous rocks fall into two categories:
  - ***a) Plutonic igneous rocks***: they are formed due to the cooling of magma very deep inside the earth.
  - ***b) Hypabyssal igneous rocks***: they are formed due to the cooling and solidification of rising magma during volcanic activity in cracks, pores, crevices and hollow places just beneath the earth's surface.
- **Extrusive igneous rocks**: They are formed due to the cooling and solidification of hot and molten lava on the earth's surface (examples are basalt, Gabbro). Extrusive igneous rocks are further divided into two major subcategories:
  - ***a) Explosive type***: The igneous rocks formed by a mixture of volcanic materials ejected during explosive or violent volcanic eruptions.
  - ***b) Quiet type***: The appearance of lava through minor cracks and openings on the earth's surface is called 'lava flow'. The lava forms basallic igneous rocks after cooling and solidifying.

	INTRUSIVE	EXTRUSIVE
FELSIC > 63% SiO2	 **Granite**	 **Rhyolite**
INTERMEDIATE 52 - 63% SiO2	 **Diorite**	 **Andezite**
MAFIC 45 - 52% SiO2	 **Gabbro**	 **Basalt**
ULTRAMAFIC < 45% SiO2	 **Dunite**	

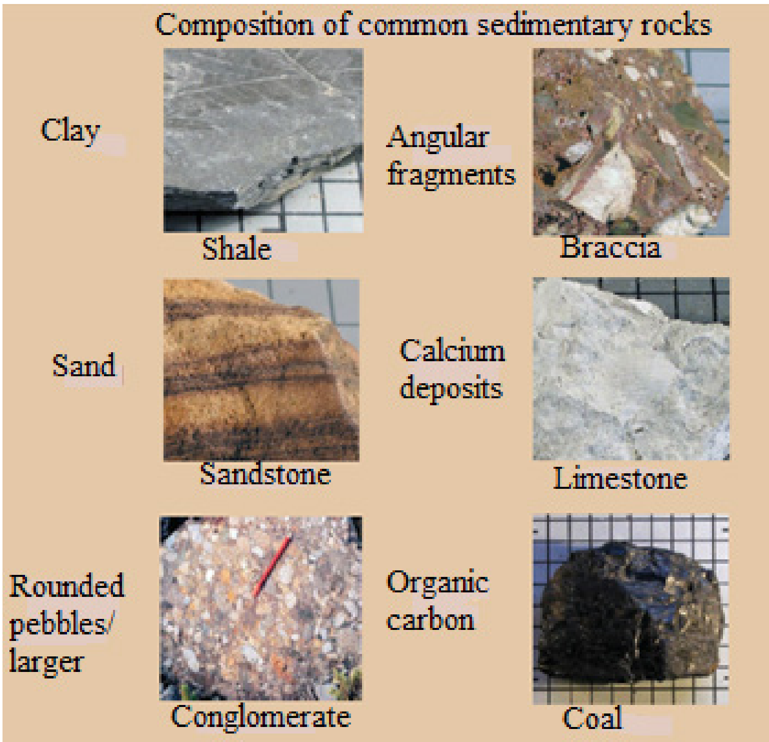
Common Igneous rocks

B) Characteristics of sedimentary rocks

Sedimentary rocks have the following characteristics:

- They are the product of other rocks that have already formed;
- They appear in the form of layers or strata;
- Sedimentary rocks are formed of fragment from materials from older rocks, plant and animal remains;
- They are found over the largest surface area of the earth;
- Sedimentary rocks have various minerals because they are a product of different sources;
- Most of the sedimentary rocks allow liquids and gases to pass through them (permeable and porous);

- Sedimentary rocks are characterized by different sizes of joints;
- Sedimentation units in the sedimentary rocks having a thickness of greater than one centimetre are called *beds*;
- As highlighted in the figure below, the composition of sedimentary rocks includes clay, sand, rounded pebbles, angular fragments, calcium deposits and organic carbon.



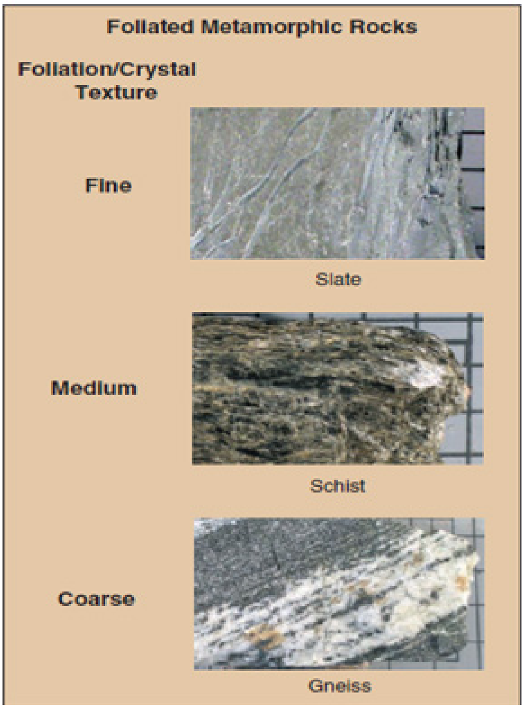
Samples of sedimentary rocks composition elements (Gabler et al, 2009)

C) Characteristics of Metamorphic Rocks

The following are the characteristics of metamorphic rocks:

- They are harder than the original rocks. Therefore, they are not easily eroded;
- They do not split easily;
- They contain minerals;
- Some are made up of just one mineral, for example, marble;
- They have a different texture or feel from the original rock.

Metamorphic rocks present two distinctive physical characteristics: **Foliated metamorphic rocks** and **Non-foliated metamorphic rocks**. Foliated metamorphic rocks such as gneiss, phyllite, schist and slate have a layered or banded appearance that is produced by exposure to the heat and pressure. Non-foliated metamorphic rocks such as hornfels, marble, quartzite do not have a layered or banded appearance.



Foliated and non-foliated metamorphic rocks

Application activity 5.1

1. In which area of Rwanda do we find igneous rocks? Explain their characteristics.
2. Observe rocks found in your environment and examine their major rock groups.

5.2. Composition, properties of rocks and Impact of rocks

Learning activity 5.2

Rocks are composed of physical and chemicals elements. describe the physical and chemical properties of rocks.

5.2.1. Composition of rocks

All rocks are composed of minerals. Composition refers to both the types of minerals within a rock and the overall chemical makeup of the rock. The mineral that compose the three types of rocks are presented in the table below.

Types of rocks and their forming minerals

Types of rocks	**Forming minerals**
Sedimentary rocks	Silicate, Clay, Dolomite, Anhydrite, Gypsum, Hematite, Limonite
Metamorphic rocks	Quartz, Muscovite, Sillimanite, Andalusite, Kynite, Garnet, Sericite, Staurolite
Igneous (magmatic) rocks	Quartz, Feldspars, Plagioclase, Micas (Muscovite, Biotite), Pyroxene, Amphibolite, Olivine.

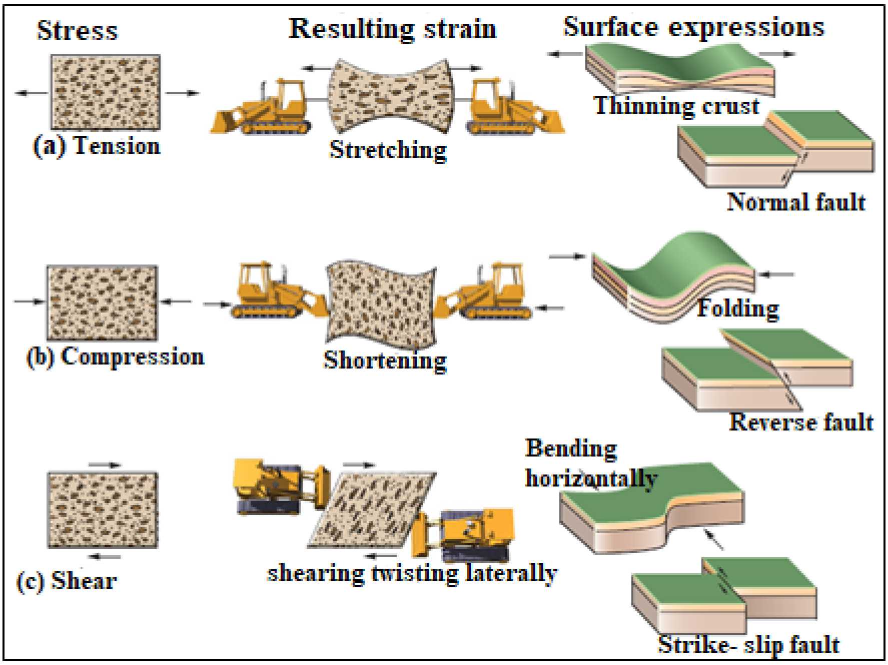
5.2.2. Properties of rocks

i) Physical properties of rocks

Physical properties of a rock can be ***intensive*** (hardness and softness) and ***extensive*** (volume, total mass and weight). Rocks, whether igneous, sedimentary or metamorphic, are subject to powerful stress or pressure by tectonic forces and the weight of overlying rocks. The physical properties of rocks determine their behaviour and respective deformations when a rock is subject to stress such as folding, faulting or warping, and their resulting landscape deformation.

- ***Stress*** refers to forces that constantly push, pull, or twist the earth crust. There are three types of stress: *tension* (stretching), *compression* (shortening), and s*hear* (twisting or tearing).
- ***Strain*** is how rocks respond to stress whether by stretching, shortening, shearing.
- ***The surface expressions*** refer to the structure of landforms resulting from the stress depending on whether the rock is brittle (hard) or ductile (pliable). Surface expressions can be folding (bending) or faulting (breaking). ***Brittle*** rock breaks (brittle deformation) while ***ductile*** rocks like clay bend or flow (ductile deformation).

The figure below presents different types of stresses that are naturally applied on rocks, their resulting strains and surface expressions.



Types of stress and resulting rock deformation

ii) Chemical properties of rocks

A) Sedimentary rocks

All water falling onto the earth as rain and running over the earth surface carries minerals in solution. These minerals may precipitate by direct evaporation of water, chemical interaction or by the release of pressure where underground water reaches the surface. Sedimentary rocks formed as chemical precipitates include halite, gypsum, silcretes, ferricretes, limestone, and dolomite. The table below gives details on their chemical composition.

Chemically formed sedimentary rocks and their composition

Rock Name	Precipitate type	Chemical composition
Halite	Sodium, Chlorine	$NaCl$
Gypsum	Calcium, Sulfur, Oxygen	$CaSO_4.2H_2O$
Silcrete	Silica	SiO_2
Ferricrete	Iron	Fe_2O_3
Limestone	Calcium, Carbonate	$CaCO_3$
Dolomite	Calcium, Magnesium, Carbonate	$CaMg\ (CO_3)_2$

B) Metamorphic rocks

Metamorphism involves the alteration of existing rocks either by excessive heat and pressure or through the chemical action of fluids. This alteration can cause chemical changes or structural modification to the minerals making up the rock. Metamorphism process results in the creation of new minerals by the substitution, removal, or addition of chemical ions. Metamorphism may consist of three minerals, kyanite, andalusite and sillimanite. These are all aluminium silicates having the same chemical formula (Al_2SiO_5) but different crystal structures and physical properties.

Below is an example of a simplified representation of sediments products and resulting metamorphic rocks from sea beaches to far shelf.

Lateral representation of metamorphic rocks form beach to far sea shelf

Location	**Beach**	**Near shelf**	**Far shelf**
Metamorphic rock	Sandstone	Shale	Limestone
Chemical composition	SiO_2	SiO_2, Al_2O_3	$CaCO_3$

Igneous Rocks

The major indicator for the chemical classification of igneous rocks is the amount of Silica (SiO_2). Igneous rocks with a high proportion of silica exceeding 65% are said to be ***acidic*** or ***felsic***, for example, the granite found on an extensive part of Muhanga District of the Southern Province. Where the amount of silica is very low (less than 45%), the rocks are said to be ***ultramafic*** or ***ultrabasic***. Rock having intermediate silica content comprised between 65% and 45% are said to be ***mafic*** or ***basic rocks***.

Igneous rocks are classified according to their forming minerals (see the table below). Mineral groups include Felsic minerals (feldspars and silica), mafic minerals (magnesium and iron), and ultramafic minerals (low silica content). Some of these rocks form underneath the earth's crust and are known as **intrusive** magmatic rocks, whereas other form from the volcanic lave that reached the earth's surface, forming **extrusive** volcanic rocks.

Families of igneous rocks and constituting minerals

Igneous rock minerals	**General characteristics** (All contain **Quartz (Silica)** (SiO_2) with varying amount)	**Mineral family**	**Coarse-grained texture** (**intrusive**, slower cooling rate)	**Fine-grained texture** (**extrusive**, faster cooling rate)
Felsic *minerals* (feldspars and silica): ***Acid rocks***	– Higher Silica content (more than 65%) – Higher resistance to weathering – Increased potassium and sodium – Lower melting temperatures – Brighter coloration	**Feldspars:** – Potassium feldspars: K, Al, Si (Orthoclase) – Sodium Feldspars : Na, Al, Si (Plagioclase) – Calcium feldspars: Ca, Al, Si	Granite	Rhyolite
Mafic *minerals* (magnesium and iron): ***Basic rocks***	Silica content (between 45% and 65%) – Intermediate silica content – Intermediate resistance to weathering – Intermediate potassium, sodium, calcium, iron and magnesium – Intermediate melting temperatures – Grey coloration	**Mica**: K, Fe, Mg, Al, Si (biotite: black; muscovite: white) **Amphibolite**: Fe, Mg, Al, Si, Ca, Na (complex) (hornblende: black)	Diorite	Andesite Dacite (sodic feldspar) (Mount St. Helens)

Ultramafic *minerals* (low silica content): ***Ultrabasic rocks***	– Lower Silica content (**less than 45%**) – Lower resistance to weathering – Increased calcium, iron, and magnesium – Higher melting temperatures – Darker coloration	**Pyroxene**: Fe, Mg, Si (dark) **Olivine**: Mg, Fe, SiO_4 (dark green) (no quartz, no feldspars)	Gabbro Peridotite	Basalt

5.2.3. Impact of rocks: advantages and disadvantages on the landscape and man

A) Advantages of rocks on the landscape and on the man

Rocks have a wide variety of uses. Many of them are used as building materials of houses and infrastructures such as roads and rail ways.

- Some rocks are more resistant to weathering and others are less resistant. This difference in rock resistances provides various landscapes such as alternation of elevated topographies (hills, mountains or interfluves) and depressions (valleys and low-lying areas) which are sometimes drained;
- Gravel and sand, being among products of rock weathering make beautiful landscape at some location of the earth. Also, the weathering of rocks provides different types of soils including sand, silt and clay which are useful at varying points for agriculture.
- Some rocks present beautiful landscapes which may attract tourists;
- Some rocks store, purify water and act as water sources to rivers.

The table below shows usages of rocks.

Sedimentary rocks	
Coal	A sedimentary rock, formed from decayed plants, is mainly used in power plants to make electricity.
Halite (Salt)	Salt is an essential nutrient for humans and most animals. It is also used in winter on roads to control the accumulation of snow and ice.
Limestone	It is used mainly in the manufacture of Portland cement, the production of lime, manufacture of paper, petrochemicals, insecticides, linoleum, fiberglass, glass, carpet backing and as the coating on many types of chewing gum.
Shale	Well stratified rock in thin beds. It splits unevenly more or less parallel to bedding plane and may contain fossils. It can be a component of bricks and cement.
Sandstone	Used principally for construction, manufacture of glasses.
Metamorphic rocks	
Quartzite	Quartzite is very hard and is used in building (houses, rail way, road,).
Marble	Marble is beautiful for statues and decorative items such as vases. Ground up marble is also a component of toothpaste, plastics, and paper.
Schist	Sometimes used as building (e.g. roofing tiles)
Slate	Most of the slate mined throughout the world is used to produce roofing slates. Slate performs well in this application because it can be cut into thin sheets, absorbs minimal moisture, and stands up well in contact with freezing water.
Clay minerals	Clay minerals are the most utilized minerals not only as the soils that grow plants for foods and garment, but also a great range of applications, including oil absorbants, iron casting, pottery, drilling fluids, waste water treatment, paint, etc.
Igneous rocks	
Granite	Granite is used in both building construction (stone for house foundation, bridges) and for statues. Some varieties of floor tiles for houses are manufactured from granite.
Peridotite	It is used in jewellery.
Pumice	Pumice is a light igneous rock which is commonly used to remove dead skin from the bottom of the feet.

Basalt	It is used as flooring, cobblestone, countertops and in construction projects. Also, you will find crushed basalt rocks in railroad track ballast.
Gabbro	It is used for making work surface, floor tiles, facing stone and cemetery markers.
Diorite	It was used for inscription, statues and for carving works. In modern time diorite is used for flooring and landscaping works. Being a hard rock, it is resistant to weathering agents, and serves as a highly durable stone slab for landscaping.
Rhyolite	It is used as an ornamental stone. It also be used as an abrasive and scouring stone.
Obsidian	This volcanic glass is used in making scalpel blades, ornamental stones and decorative specimens.

B) Disadvantages of rocks on the landscape and man

- Hard and resistant rocks hinder the penetration of plant roots hence, limiting the weathering process or hindering the growth of vegetation;
- Rock forming minerals have different colours. The difference in colours makes minerals to absorb differently the heat. Dark-coloured minerals absorb much heat during daytimes and therefore expand, causing the cracking and fragmentation of rocks.
- The sand can blow; rocks can roll risking injury to people;
- Light-coloured rocks reflect sunlight and increase the temperature around the plants during the daytime;
- Some environments such as sand rocks (dunes, erg, etc.) are not suitable for human settlement because of lack of water and soils;
- Some rocks may reflect landscape with steep slopes where human activities such as agriculture or settlement cannot be possible.

Application activity 5.2

1) Referring to the properties of rocks, explain how rocks react to the stress and the resulting landscapes?
2) Analyse a sedimentary rock in your local environment and describe the process under which it might have been formed.
3) With relevant examples, discuss the disadvantages of rocks on landscape and society.

5.3. Minerals

Learning activity 5.3

1) Account for the types and characteristics of minerals.
2) Examine the use of minerals to your society.

5.3.1. Definition, types and characteristics of a mineral

A **mineral** is a solid inorganic substance that occurs naturally in the earth's crust. A mineral deposit is a concentration of naturally occurring solid material in or on the earth's crust. Mineral resources are non-renewable.

There are five characteristics shared by all minerals.

- All minerals are ***formed by natural processes***. They can form when magma cools, when liquids containing dissolved minerals evaporate, or when particles precipitate from solution.
- Minerals are ***inorganic***. They are not alive and are not made by life processes. Coal, for instance, is made of carbon from living things. Although geologists do not classify coal as a mineral, some people do. Miners, for example, generally classify anything taken from the ground that has the commercial value as a "mineral resource".
- Minerals are ***solid*** and have a definite volume and shape. A gas such as air and a liquid such as water aren't minerals because they do not have definite shape.
- Every mineral is ***an element*** or ***a compound*** with a chemical composition unique to that mineral.
- The ***atoms*** in a mineral are arranged in a ***pattern that is repeated over and over again***.

The table below shows two examples of mineral crystals (salt and quartz) with defined shapes:

Examples of mineral crystals with defined shapes

Salt crystals	Quartz crystals
	
Salt (NaCl) (sodium chloride). These clear salt crystals were deposited near the vent of an underwater volcano. In many rocks, mineral crystals are too small to be seen without magnification.	**Quartz (Si_2O)** (silicon dioxide) is a very common mineral. It is usually found as regular six-sided crystals; and as a clear or light-coloured mineral, and it is often present in sediments such as beach.

5.3.2. Types of minerals and ores

The wide varieties of minerals that have been explored by man for general and commercial purposes to satisfy his needs are of two types: **metallic minerals** and **non-metallic minerals**.

1) Metallic minerals

Metallic minerals include:

- Industrial metallic minerals: iron ore
- Ferroalloy metallic minerals: manganese, chromium, cobalt, molybdenum, vanadium, nickel.
- Precious metallic minerals: gold, silver and platinum

2) Non-metallic minerals

This category of non-metallic minerals includes salt, tin, potash, asbestos and sulphur.

Rocks or minerals worked because they contain valuable (profitable) elements are usually called ore-deposits. Minerals are extracted in a mineral ore. For instance, Aluminum comes from the ore bauxite. The iron comes from the mineral ore Hematite. A mineral can also be called an ore, for example Hematite is a mineral that can also be called an ore. A mineral is an ore if it contains useful substance that can be mined at a high profit and be processed and refined into more useful materials. For instance, Aluminum can be refined from bauxite, and made into the useful products. These products are worth more money than the cost of the mining, so bauxite is an ore.

5.3.3. Physical properties of minerals

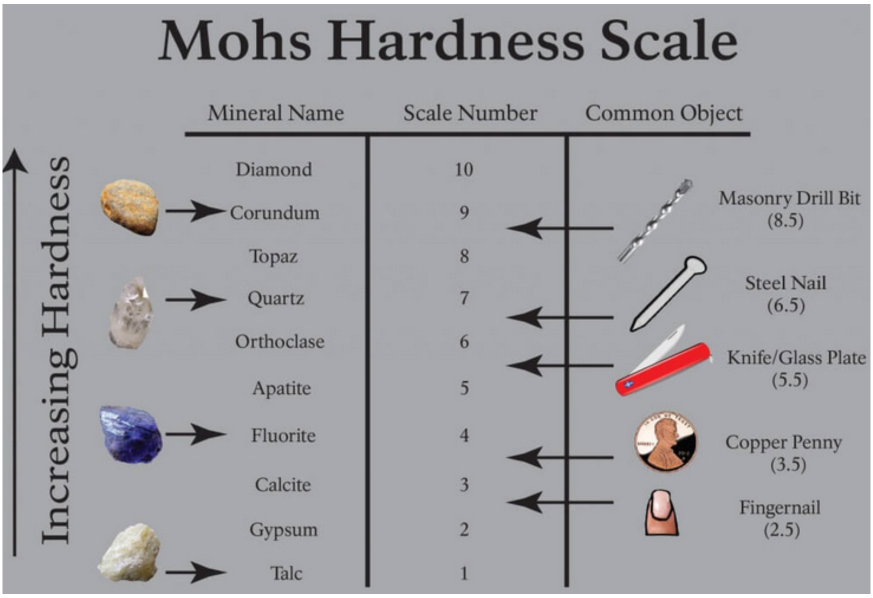
The most common minerals in earth's crust can often be identified in the field basing on their basic physical properties such as their form, hardness, fracture, cleavage, colour, streak, density, luster, mass, taste, odour, feel, magnetism as described below:

1) **Form:** Definite geometrical forms called crystals can be recognized in minerals. These are for example: cubic, acicular (needle shaped), columnar, fibrous, reniform (kidney shaped) and nodular forms.

Some examples of crystal forms

Pyrite (left) has a cubic form; Tourmaline (middle) is prismatic; azurite and malachite (right) are often amorphous.

2) **Hardness:** The hardness of a mineral can be tested in several ways. Most commonly, minerals are compared to an object of known hardness using a scratch test developed by Friendrich Mohs. He assigned integer numbers to each mineral, where 1 is the softest and 10 is the hardest. This scale is shown below.



Mohs hardness scale

If the gem minerals are excluded, the scale has only 7 numbers. Substitutes may be used when the scale minerals are not available:

- Easily scratched by nail;
- Not so easily scratched;
- Can be scratched by a piece (a copper coin);
- Scratched easily by knife;
- Can be scratched by knife with difficulty;
- Scratched by window-glass;
- Window-glass is scratched by the mineral.

3) **Fracture:** Freshly broken surfaces of minerals present characteristic fracture surfaces. The following important types are noted:
   - *Conchoidal (vitreous):* the fracture surfaces are curved with a concave or convex form; for example, quartz.
   - *Even***:** the fracture surfaces are nearly flat; for example, in chert.
   - *Uneven***:** the fracture surface is formed of minute elevations and depressions; for example, most of minerals.

4) **Cleavage:** This is how the mineral breaks. Certain minerals split easily along certain planes called cleavage-planes. These planes are parallel to certain faces of the mineral crystal, or to faces of a form in which the mineral may crystallize.

5) **Colour:** When a body absorbs all the seven colours that make up white light it appears black, and when it reflects all the colours it appears white.

When a body reflects the green vibrations of white light and absorb the other vibrations it appears green. Thus, the colour of a body depends on the selective reflection and absorption of the different vibrations of white light.

6) **Streak:** The colour of the powder of minerals sometimes differs from the mineral in mass. Different specimens of the same mineral might show variation in colour, yet the streak is fairly constant.

7) **Luster:** The amount and the type of reflection from the surface of a mineral determine its brightness.

8) **Mass:** The mass of a mineral can be used to identify its type.

9) **Density:** The density of a mineral can also be used to determine its type.

10) **Taste:** Some of the minerals which are soluble in water give distinctive taste but the character is not very useful in identification of minerals because there are only a few minerals which are soluble is water. For example, we get a saline taste in case of common salt, and alkaline in case of soda or potash.

11) **Odour:** Only a few minerals give characteristic odour, e.g. the odour of garlic from arsenic compounds.

12) **Feel**: Minerals differ in the sensation they give by touch, e.g. minerals are smooth, greasy or rough.

13) **Magnetism:** Generally, iron bearing minerals are magnetic, but not necessarily all iron bearing minerals are magnetic. Some non-magnetic minerals like monazite are also slightly magnetic. The electromagnetic minerals depend on the varying magnetism of different minerals.

5.3.4. Chemical properties of minerals

Some minerals are affected by the variations in temperature and the pressure on the earth's surface. Others vary in the structure depending on the percentage of water that they loose with the change of the temperature and the pressure. The chemical composition influences the destruction of the rocks and development of new minerals.

Chemical properties of minerals are identified from their chemical composition. We refer to two elements that are Silicon and oxygen. These are the two most abundant elements in the earth crust. They constitute approximately 90% of the crust of the earth. Then we distinguish silicate minerals and non-silicate minerals. Silicate minerals (silicates) are minerals containing Silicon and Oxygen atoms usually with one or more other elements. Non-silicates are minerals other than silicate minerals.

Chemical properties of minerals

Groups of minerals	Class	Chemical formula and or description
Silicate minerals	*Nesosilicates*	$(SiO_4)^{-4}$
	Sorosilicates	$(Si_2O_7)^{-6}$
	Cyclosilicates	$(Si_6O_{18})^{-12}$
	Inosilicates	$(Si_2O_6)^{-4}$
	Phyllosilicates	$(Si_2O_5)^{-2}$ or $(Al\ Si_3O_{10})^{-5}$
	Tectosilicates	$(Al_2Si_2O_8)^{-2}$, or $(Al_2Si_4O_{12})^{-2}$
Non-silicate minerals	*Carbonates*	Calcite: $CaCO_3$ Dolomite: $CaMg\ (CO_3)^2$
	Halides	Sodium Chloride (NaCl)
	Oxides	Hematite Fe_2O_3, Goethite $2Fe_2O_3$, Limonite $FeO(OH).2H_2O$, MagnetiteFe_2O_4
	Phosphates	$(PO_4)^{-3}$: source of phosphorus (P) for plants
	Sulphates	Gypsum: $CaSO_4$(Hydrated calcium sulphate)
	Sulphides	Sulphur (S^{-2}) Ex. Pyrite: FeS_2, Galena: PbS

5.3.5. The importance of minerals and manufactured products

Minerals provide the material used to make most of the things of industrial-based society; roads, cars, computers, fertilizers, etc. In more than 1600 minerals identified in earth crust, only 200 are extracted for commercial and industrial purposes and less than 1/3 are the most economically significant.

Some minerals have high economic value because of their uses or they are rare and beautiful. For example, germs or **Gemstones** is a mineral with a distinctive colour which makes it expensive. That is why it is used for jewellery.

The table showing manufactured products from minerals

Mineral	Manufactured products	Mineral	Manufactured products
Antimony	Batteries for storing grid power	**Cobalt**	glass and pigment
Asbestos	Fire retarding properties (electrical insulators)	**Columbite-tantalite**	Electronics (Smartphones, Laptops, etc.)
Limestone	Fertilizer	**Coal/oil**	Heating products
Slate	Roofing materials	**Clay**	Pottery
Barium	x-ray technology, fireworks, rubber and glass and rat poison	**Copper**	currency, jewellery, plumbing and electric insulators
Bauxite	Source of aluminium, used in paints and airplane parts.	**Feldspar**	Building material, used in the manufacture of porcelain
Beryllium	X-rays and fluorescent lights	**Fluorite**	Fluorescent pigment for gem material
Chromite	High polish	**Gold**	jewellery, dentistry, electronics
Gypsum	Drywall, also known as sheet rock, fertilizer and road construction materials	**Halite**	Food processing and softening water products, acids, products used in fire extinguishers and melting ice on the road
Iron Ore	Vehicle and buildings construction materials	**Lead**	Paint, pencils and eating utensils
Lithium	Electric materials, car spare parts, medicines for bipolar symptoms, batteries.	**Manganese**	steel making products, and petro-glyphs
Mica	Used in sparkle products, window glass and occurs in large flexible plates,	**Molybdenum**	Supporting all life forms products for utilizing nitrogen
Tantalum	Missiles products, aircraft parts and vacuums	**Titanium**	Human body repair products
Nickel	Currency, jewellery and utensils	**Perlite**	Potting products to lighten the soil
Platinum	Jewellery	Phosphate	Fertilizers
Potash	(Potassium) fertilizer and soap	**Pyrite**	Facial mirrors, and jewellery

Quartz	Used in glass manufacture, electronic equipment, radios, computers, watches, gemstones	**Rare Earth Elements (promethium)**	Salts
Silica	Desiccants to remove moisture from the air	**Silver**	Currency, jewellery and medicine
Sodium Carbonate	Glass, paper, detergents and for softening	**Stibnite**	Fireworks, rubber and glasses
Aggregates	Sand, gravel, and crushed stone used in construction	**Cement**	Powdered lime, clay, and other minerals, used in construction
Sulphur	Ingredients in acid rain, wine making and fruit preservation	**Tungsten**	Saw blades and products used in welding
Uranium	Highly radioactive element used in cancer treatments, X-rays, military weapons and fuel for the space shuttle	**Vanadium**	Products used in regulating blood sugar in diabetics and growing muscles for bodybuilders

Application activity 5.3

1. What are the five characteristics shared by all minerals?
2. Differentiate a mineral from an ore.
3. Identify minerals that are extracted in your district and describe their advantages and disadvantages.

Skills Lab

Show how you are going to use available rocks for the economic improvement of your society.

End unit assessment

1. Classify the different types of rocks and their characteristics.
2. Evaluate the economic importance of rock and minerals in your society.
3. Identify the physical and the chemical properties of the minerals.

UNIT 6

CLASSIFICATION OF SOILS AND SOIL FORMATION

Key Unit competence

By the end of this unit, I should be able to explain the classification of soils and factors responsible for the formation of the soil.

Introductory activity

Read the passage below and answer the questions that follow:

Soil is defined as the thin layer of material covering the earth's surface and is formed from the weathering of rocks. It is composed of mineral particles, organic materials, air, water and living organisms all of which interact slowly but constantly.

Most plants get their nutrients from the soil and they are the main source of food for humans, animals and birds. Therefore, most living things on land depend on soil for their existence.

Soil is a valuable resource that needs to be carefully managed as it is easily damaged, washed or blown away. If we understand soil and manage it properly, we will avoid destroying one of the essential building blocks of our environment and our food security.

1. Identify major types of soil in the world
2. Describe factors responsible for soil formation
3. Assess the importance of soil to man
4. Discuss the major causes of soil erosion and suggest what should be done to prevent it

6.1. Definition of the soil

Soil is a dynamic natural body capable of supporting a vegetative cover. It contains chemical solutions, gases, organic refuse, flora, and fauna. The physical, chemical, and biological processes that take place among the components of a soil are integral parts of its dynamic character.

6.2. Classification of the major types of soil in the world, factors and processes of soil formation

This section presents briefly the classification of the major types of soil in the world, factors and processes of soil formation are briefly described.

Learning activity 6.1

1. Make research on the major types of soils in the world.
2. Identify factors influencing soil formation
3. Discuss on processes leading to the formation of the soil

6.2.1. Classification of the major types of soil in the world

The classification of soils is either based on ***geographic regions***, where the soils are well-developed from the parent material by the normal soil-forming action of climate and living organisms. Another way of classifying the soil is based on the ***level of weathering***, which is related to geographic environments, but also under the ***same geographical region*** you can find different types of soils which reflect the ***level of weathering***.

A) Soil classification based on geographical regions

The soil classification based on ***geographical regions***, include three soil classes: zonal soil, intrazonal soil and azonal soil.

i) Zonal soils

These are soils that cover a wide geographic region in the world. They depend on the major climatic zones, vegetation and living organisms in areas where the landscape and climate have been stable for a long time. They are common on gentle slopes. They are found both in tropical and temperate regions.

This kind of soil has the following types: Tundra Soils, Podzols, Brown forest Soils, Lateritic Soils / Latosols / Ferralsols, Chernozem / Prairie / Steppe, Grumusol / Reddish Brown Soils, Desert (Seirozems and Red Desert) Soils.

ii) Intrazonal soils

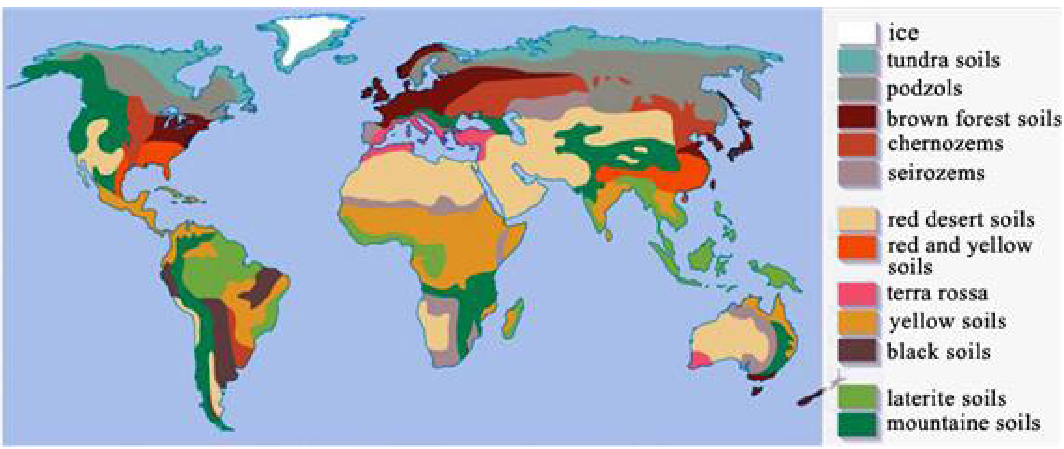
These are soils that mainly develop due to relief of the area and the nature of parent rock. These soils reflect the dominance of a single local factor, such as parent rock or extremes of drainage that prevail over the normal soil-forming factors of climate and living organisms. They are divided into three types:

- **Calcimorphic** or **calcareous soils** which develop on limestone parent rock (rendzina and terra rossa);
- **Halomorphic soils** which contain high levels of soluble salts (e.g. sodium ions) which render them saline.
- **Hydromorphic soils** that have constantly high water content which tends to suppress aerobic factors in *soil*-formation.

iii) Azonal soils

Azonal soils have a more recent origin and occur where soil-forming processes have had insufficient time to operate fully. They lack well-developed horizons because of immaturity or other factors that have prevented their development such as excessive soil erosion. They are skeletal soils resulting from erosion and deposition. They lack clear soil horizons. They are common in volcanic regions, glaciated regions and areas blown by winds. They include dry sand, loess, moraine soils, and marine soils, alluvial and volcanic soils.

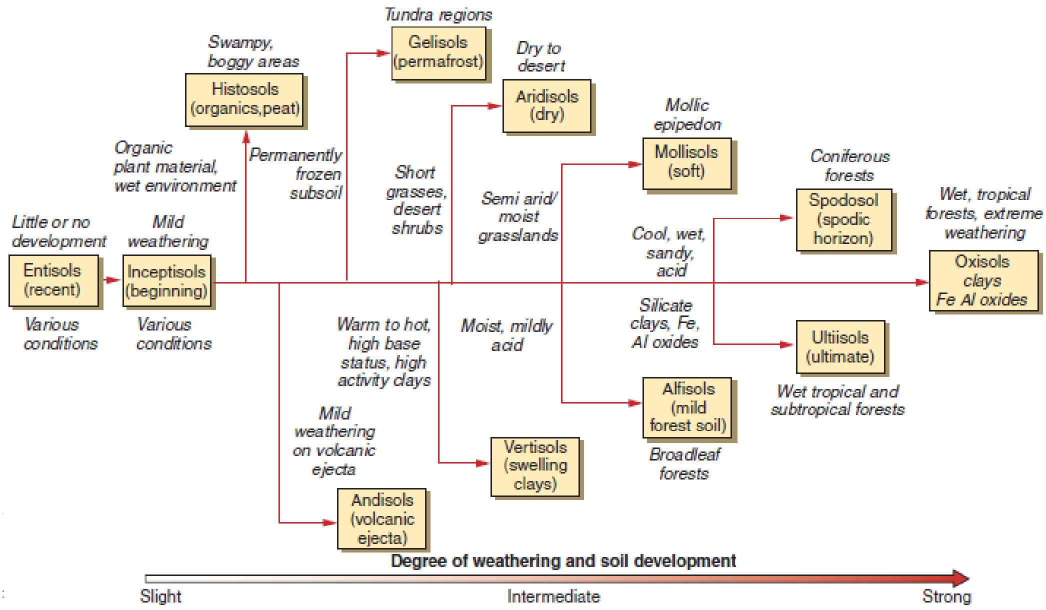
The map below shows the major soil types of the world



Major soil types of the world

B) Soil classification based on level of weathering

Basing on the level of weathering, the American soil taxonomy has classified soils into 12 soil orders which reflect the level of weathering (slight, intermediate and strong) plotted on the chart and briefly described below:



12 Soil orders according to geographical environment and degree of weathering

Table: Major soil orders according to American classification

GROUP	CHARACTERISTICS
GROUP 1: Soils with well-developed horizons or with fully weathered minerals, resulting from long-continued adjustment to prevailing soil temperature and soil-water conditions	
Oxisols	Very old, highly weathered soils of low latitudes, with a subsurface horizon of accumulation of mineral oxides and very low base status.
Ultisols	Soils of equatorial, tropical, and subtropical latitude zones, with a subsurface horizon of clay accumulation and low base status
Vertisols	Soils of subtropical and tropical zones with high clay content and high base status. Vertisols develop deep, wide cracks when dry, and the soil blocks formed by cracking move with respect to each other.
Alfisols	Soils of humid and sub-humid climates with a subsurface horizon of clay accumulation and high base status. Alfisols range from equatorial to subarctic latitude zones.
Spodosols	Soils of cold, moist climates, with a well-developed *B* horizon of illuviation and low base status.
Mollisols	Soils of semiarid and sub-humid mid-latitude grasslands, with a dark, humus-rich epipedon and very

Aridisols	Soils of dry climates, low in organic matter, and often having subsurface horizons of accumulation of carbonate minerals or soluble salts.
GROUP 2: Soils with a large proportion of organic matter	
Histosols	Soils with a thick upper layer very rich in organic matter.
GROUP 3: Soils with poorly developed horizons or no horizons, and capable of further mineral alteration	
Entisols	Soils lacking horizons, usually because their parent material has accumulated only recently.
Inceptisols	Soils with weakly developed horizons, having minerals capable of further alteration by weathering processes.
Gelisols	Soils underlain by permafrost, with organic and mineral materials churned by forest action.
Andisols	Soils with weakly developed horizons, having a high proportion of glassy volcanic parent material produced by erupting volcanoes

6.2.2. Soil formation factors

Soil formation is a function of ***five factors*** which include ***parent material***, ***climate***, ***biology*** (living organisms), ***relief*** (topography), and ***time***. They are classified ***passive*** (parent material, relief "topography" and time) and ***dynamic*** (climate and biology "living organisms)". Recent studies have shown that human activities can have an impact on soil development. These factors interact as a system to form soils. The roles of these factors are briefly hereafter described:

Parent rock

Physical and chemical weathering of rocks in the upper lithosphere provides the raw mineral ingredients for soil formation. This helps to determine the type of soil, mineral composition and texture. For instance, granite and sandstone disintegrate to form sandy soils rich in quartz, volcanic lavas form clay soils with low quartz content and plants decompose to form loam rich in humus.

Climate

The moisture (rainfall), evaporation and temperature changes determine the chemical reactions and physical breakdown of rocks. Climate also affects rate and type of weathering. For example, heavy rainfall results into deep soils due to heavy weathering and leaching, wind in deserts is responsible for formation of loess soils.

Living organisms

Plants, animals and microbes are living organisms that affects soil development. Dense vegetative cover protects a soil from being eroded away by running water or wind. . Burrowing animals and worms mix organic remains with mineral soil component. - Roots penetrate and add more porosity, improve soil depth and aeration. Micro-organisms such as bacteria cause plant and animal remains to decay into humus

Topography

The topography represents the slope of the relief. The slope of the land and its aspect (the direction it faces) all influence soil development. Steep slopes are generally subject to rapid surface runoff of rainfall and less infiltration of water, whereas on gentler slopes runoff decreases with an increasing infiltration. As a consequence, rapid runoff ***on steep slopes*** can erode soils as fast, or faster than soil can develop on them. Steep slopes result in shallow immature soils due to severe erosion and prevent the formation of a soil that would support abundant vegetation,

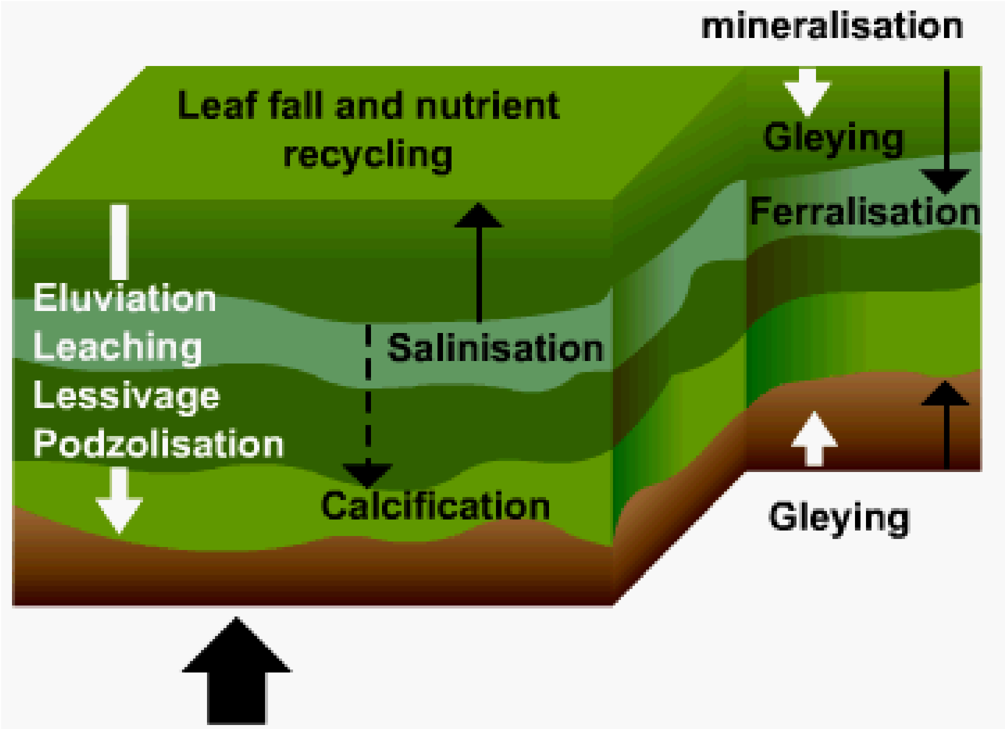
On ***gentler slopes*** there is higher infiltration and less runoff. More water is available for soil development and to support vegetation growth, so erosion is not as intense. Well-developed soils typically form on land that is flat or has a gentle slope.

Time

All of the mentioned above natural factors in soil development require time to operate. This determines the depth of weathering and the period of operation of soil formation processes. Briefly, the longer the time taken by soil forming processes the deeper and well developed soil is.

6.2.3. Processes of the soil formation

The formation of soil requires numerous processes. Soil is said to be formed when organic matter has accumulated and colloids are washed downward, leaving behind deposits of clay, humus, iron oxide, carbonate, and gypsum, producing a distinct layer called the ‘B’ horizon.



Process of soil formation

Weathering: Weathering is the process by which the rocks break down into small particles to form soil. It is the combined action of physical weathering, in which rocks are fractured and broken, and chemical weathering, in which rock minerals are transformed to softer or more soluble forms.

Mineralization: This is the process through which organic matter is further decomposed into mineral compounds. Mineral content in humus may be further converted to inorganic matter e.g. silica.

Humification: Humification is the process by which organic matter is decomposed to form humus, a task performed by soil organisms.

Eluviation: Eluviation is the downwards movement of fines particles such as clay and the leached soluble materials from upper layers of the soil ('A' horizon) to another lower layer within the soil.

Illuviation: This is the process of accumulation of clay, aluminum and iron usually from A and E horizons to B horizons.

Leaching: Leaching is the removal of soluble material in solution. It is the process by which water removes leached materials (organic and inorganic) in solution from the upper horizon to the underlying horizon. It operates vertically but not sideways.

Laterization: Laterization is leaching of soils in warm and humid climates. It is a process that occurs after the soluble mineral substances have been leached. After leaching, the insoluble mineral compounds derived from the parent rock remain on top, hence forming lateritic soils that are stony.

Calcification: This is the process in which calcium carbonates accumulates in the 'B' horizon; particularly characteristic of low rainfall areas such as arid and semi-arid climates.

Application activity 6.1

1. Soil forms continuously, but slowly, from the gradual breakdown of rocks through weathering:
   a. Explain how organisms contribute to the formation of soil
   b. Describe any three other processes leading to the soil formation
2. With reference to the knowledge and skills you have acquired in this unit, discuss the difference between zonal soils, azonal soils and intrazonal soils.
3. Based on the level of weathering, describe the soils orders according to American soil classification

6.3. Soil erosion: causes, effects, appropriate soil management and the conservation measures and importance of soil

Learning activity 6.3

1. What does soil erosion means?
2. Identify major causes of soil erosion
3. Discuss on the effects of the soil erosion

6.3.1. Cause of soil erosion

The predominant causes of soil erosion are either related to naturally occurring events or influenced by the presence of human activity. If we want to prevent soil from going away, we need to understand different factors contributing to the soil erosion. Some of the major causes of soil erosion include:

- **Overgrazing** also causes excessive loss of water from the soil causing it to become loose and fine grained and easily eroded.

- **Rainfall:** In a particular heavy rain result to excessive soil erosion and thus poorly aerated
- **Drought**: A long dry weather deprives the soil of moisture which holds the soil together causing particles to loosen making it to be easily brown by wind.
- **Some human works** in relation with excavation activities such as quarrying, open-cast mining, building of estates and road construction which loosen and expose the soil to erosion agents.
- **Slope of the landscape:** The physical characteristics of the land can contribute to the soil erosion. For example, steep slopes accelerate soil erosion while gentle slopes experience less erosion, places with rugged terrain experience gulley erosion while hilly and steep areas experience rill and gulley erosion.
- **Poor cultivation techniques** such as pulling hoe along the surface when removing weeds which loosens the soil and when it rains it's washed away, ploughing of land down slope which accelerates soil erosion, cultivation of steep slopes and along river banks which encourages soil erosion, burning which destroys vegetation covering the soil exposing it to erosion agents etc.

6.3.2. Effects of soil erosion

Some of the greatest effects of soil erosion include:

- **Loss of topsoil:** Soil erosion lowers the agricultural productivity of land when fertile top soil is eroded.
- **Desertification:** Soil erosion contributes to desertification when top soil is eroded leaving bare ground destroying vegetation.
- **Water pollution:** Serious soil erosion is responsible to water pollution when agro-chemicals and other chemicals are carried to rivers, lakes or oceans.
- **Flooding:** Another effect of soil erosion is that it contributes to flooding by blocking river channels causing them to burst their banks during the rainy season flooding the adjacent areas.
- **Alteration of the landscape:** Soil erosion can cause significant alteration to the natural shape of the land. For example, it can make huge valleys to occur on plain lands.
- **Reduced organic and fertile matter**: Removing topsoil that is heavy with organic matter will reduce the ability for the land to regenerate new flora or crops.
- **Eye and respiratory problems:** Soil erosion especially one caused by wind can cause eye and respiratory problems. The latter can happen when people inhale the dust and soil particles being carried away by

the wind into their lungs. Eye problems can also occur when the dust particles from wind erosion enter into the eyes.

- **Water siltation:** Persistent soil erosion causes siltation of water reservoirs reducing their utility. For example, H.E.P. generation, navigation and fishing
- **Destruction of properties:** It may cause collapsing of structures such as buildings and bridges when soil around them is eroded weakening their foundation.

Effects of soil erosion

6.3.3. Appropriate soil management and the conservation measures

Generally, when it comes to finding solutions for soil erosion, the most useful techniques found tend to be those that highlight reinforcing the structure of the soil, and reducing processes that affect it.

- **Careful tilling**: Due to the activity of preparing land for growing that involves break up the structure of the soil, doing less tilling with fewer passes will preserve more of the crucial topsoil
- **Crop Rotation:** If farmers want to keep their land happy and healthy, they are strongly advised to apply crop rotation. Growing crops which require different nutrients on the same piece of land on rotational basis to prevent exhaustion of particular mineral nutrients from the soil.
- **Mixed farming:** This involves growing crops and keeping animals on the same farm. Consequently, manure from animals is used to enrich the soil with minerals and improve its structure.
- **Increased knowledge:** another major factor for preventing soil erosion is education more and more people who work with the land on why it is a concern, and what they can do to help reduce it.

- **Contour Ploughing:** Ploughing across the slope rather than down the slope. This practice helps to trap water on horizontal furrows thus preventing excessive soil removal.
- **Terracing:** Through dividing the slope into a series of wide steps, crops can be grown on them. This helps to trap the soil from being carried away by running water and also traps water allowing it to gradually infiltrate into the soil.
- **Afforestation and reafforestation:** Vegetation play a big role in preventing soil erosion:
  - Leaves reduce the force of rain drops preventing soil particles from being removed.
  - Plants protect the soil, more dense plant cover yields less damage from erosion.
  - Vegetation increases the rate of infiltration of rain water into the soil thus reducing runoff.
  - Roots bind the soil particles together.
  - Decayed vegetation provides humus which binds the soil particles together.
- **Planting wind breakers:** Planting hedges or trees around plots in large fields acts as wind breakers and also trap soil being carried by water.
- **Regulating livestock numbers:** Matching the number of animals kept to the carrying capacity of land.
- **Paddocking:** Overgrazing can also be prevented by paddocking which ensures there is always pasture for animals and no area is overgrazed.
- **Constructing Gabions:** Construction of wire mesh boxes which are filled with soil. This allows water to pass through but trap the soil then vegetation gradually grows on the trapped soil.
- **Planting Cover Crops:** Planting crops which cover the soil properly and holds the soil in place e.g. sweet potato vines.
- **Mulching:** This practice consist of covering the soil with crop residues.
  - It helps reducing the impact of rain drops on the soil.
  - Decays enriching soil with nutrients.
  - Reduce the rate of moisture evaporation from the soil.

6.3.4. Economic importance of the soil

- Soil provides physical support for the rooting system of plants and protects root system from damage.
- It is a conducive habitat for burrowing animals and bacteria necessary for breakdown of organic matter into humus.

- Soil acts as a medium through which nutrients and air are made available to plants.
- It provides mineral elements to plants e.g. nitrogen, calcium, phosphates, etc.
- Serve as a construction material for building and other infrastructure. Example, clay is used for making bricks and tiles.
- Clay soil is used in ceramics such as making pots.
- Source of minerals especially to expectant mothers.
- Soil contains valuable mineral elements such as alluvial gold.
- Soil supports plant life which is a source of food for people and animals especially herbivores. Soils are used for medicinal purposes e.g. clay is mixed with some herbs for medical purpose in some communities.

Application activity 6.3

Study carefully this photograph and answer the questions that follow

1. Suggest what could be the cause of the colored river
2. Examine the effects of soil erosion
3. If you had a chance to become a chairperson in charge of environmental conservation, what would you suggest to handle the above cases?

Skills Lab

Identify any area affected by soil erosion and explain to the local people what should be done to slow down the washing away of soil.

End unit assessment

1. With reference to your knowledge and skills, show difference between three categories of the soil in the world.
2. Explain how soil erosion is one of the major problem challenging agriculture.
3. Soil is one of the amazing products of nature and without which there would be no life. Justify
4. Most farmers in the northern province of Rwanda use terracing as a measure of soil conservation.
   a. Explain why terracing is mostly used in this area.
   b. Describe other soil conservation techniques used in your area.
   c. Show how these techniques are helpful to environmental sustainability.

UNIT 7

CLIMATE CHANGE

Key Unit competence

By the end of this unit, I should be able to discuss the climate change and its impact on Rwanda and the other countries

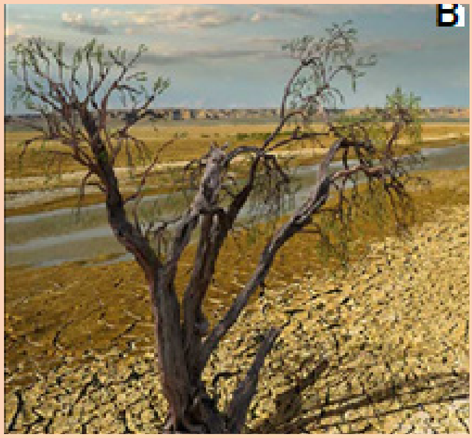
Introductory activity

1) Using internet research and other geographical materials make a research to establish relationship between the following concepts:
   i) Climate change and global warming
   ii) Green house phenomena and desertification
2) Basing on the knowledge acquired from the question 1, assess the consequences of climate change on Rwanda.
3) Which area of Rwanda is likely to experience the desertification? Give reasons supporting your answer.

7.1. Climate change: definition, causes and effects

Learning activity 7.1

Study carefully the below photographs and answer the questions that follow:



1) What does climate change mean?
2) Explain how industries contribute to the climate change?
3) Describe the effects of climate change

7.1.1. Definition of climate change

Climate change refers to the long-term changes in average conditions and characteristics of earth's lower surface atmosphere resulting either from natural variability or human activities that change atmospheric conditions of a region or location. It is also defined as a long term change of climatic elements such as temperature, rainfall, wind speed and direction, sunshine, atmospheric humidity, atmospheric pressure, cloud cover over a given region of earth's lower surface atmosphere or globally.

7.1.2. Causes of climate change

The causes of climate change are classified into natural causes and man - made causes

i) Natural causes of climate change

Natural causes of climate change include:

Variations in the earth's orbital characteristics

The more elliptical orbit makes the earth to be once year in closest position to the sun (Perihelion: 147 500 000 km) or in farthest position to the sun (Aphelion: 152 500 000 km). At the Aphelion, the earth receives the least solar energy while the maximum is received at the Perihelion.

Volcanic eruptions

Volcanic activity affects the climate. World temperatures are lowered after a series of volcanic eruptions. This is due to the increase in dust particles in the lower atmosphere which will absorb and scatter more of the incoming radiation. Sulphur dioxide gas is given off during some of the eruptions. This gas remains in the atmosphere for as long as three years and it reacts with water vapor and forms a bright layer in atmosphere. This layer reduces the amount of solar radiation reaching the earth surface by reflecting some back to universe.

Variations in solar output

Sunspot activity which occurs in cycles, may significantly affect our climate. Times of high annual temperatures on earth appear to correspond to periods of maximum sunspot activity. The results found from satellites measurements showed a decrease of 0.1% of the total solar energy coming to the earth in the early 1980s. This value was obtained over a period of 18 months. It is predicted that the increase in solar output of 1% per century will contribute to the increase of the global average temperatures by between 0.5^{0}C and 1^{0}C.

Variation of aerosols in atmosphere

Aerosols like solid particles of varying sizes and liquid droplets which include: ploughed soil cover, deserts, rocks, salt particles from seas and oceans; meteoric particles, organic matter, such as bacteria, seeds, spores and pollen. These particles help in selective scattering of shortwave electro-magnetic solar radiation which adds varied color of red and orange at sunrise and sunset. Some of the aerosols, mainly water droplets, absorb certain amount of solar radiation while some amount of radiant solar energy is reflected back to the space. The high concentrations of aerosols in atmosphere decrease the temperatures to reach the earth surface.

Sunspots

Sunspots, defined as dark areas within photosphere of the sun and surrounded by chromosphere, are created in the solar surface (photosphere) due to periodic disturbances and explosions. These dark areas are cool areas because they are characterized by 1, 500^{0}C less temperature than remain part of photosphere. The increase or decrease in number of sunspot is completed in a cycle of 11 years. It is believed that the energy radiated from the sun increases when the number of sunspots increases and consequently the amount of insolation received at the earth's surface also increases.

ii) Human causes of climate change

Human activities have been the mostly responsible for atmospheric alterations. Human activities participate highly in atmospheric pollution leading to the change in composition of atmosphere.
The atmosphere is polluted by human activities in the following ways:

Variations of carbon dioxide in atmosphere

Carbon dioxide (CO_2) is an important heat-trapping (greenhouse) gas. It is released through human activities such as burning fossil fuels and gases released from industries, as well as natural processes such as respiration and volcanic eruptions. There is a positive relationship between the concentration of carbon dioxide in atmosphere and the global temperatures: high concentrations of carbon dioxide result to the rise of temperature on the earth surface while low concentrations of carbon dioxide result to the lower temperatures.

Forest and grassland fire

It increases the concentration of carbon dioxide in atmosphere resulting from the burn of trees and grassland which are cut and put under fire for different purposes.

Deforestation and land use changes

When people clear large areas of forests and grasslands for cooking or construction, they reduce the main disposal system for carbon dioxide from atmosphere by photosynthesis, which leading to the increase of carbon dioxide, and eventually to the increase of temperature on the earth surface.

Industrial developments

Gases like methane, nitrous oxide, chlorine, bromine and fluorine are added into the atmosphere through industrial activities.

Industrial waste and landfills

Industries which are involved in cement production, fertilizers, coal mining activities, oil extraction produce harmful greenhouse gases. Also, landfills filled with garbage produce carbon dioxide and methane gas contributing significantly to greenhouse effect.

Urbanization

The buildings of cities increase the reflection and decrease the absorption of solar radiation which would change the temperatures on the earth surfaces. The urban activities participate also in increasing the concentrations of greenhouse gases in atmosphere leading to the rise in temperature.

Increase in Population

It is obvious that this last two decades the people have been huge increase in the population. Now, this has resulted in increased demand for food, cloth and shelter. New manufacturing hubs have come up cities and towns that release some harmful gases into the atmosphere which increases the greenhouse effect. So, more people means more usage of fossil fuels which in turn has aggravated the problem.

Farming

Nitrous oxide is one the greenhouse gas that is used in fertilizer and contributes to greenhouse effect which in turn leads to global warming.

7.1.3. Effects of climate change in the world (global, Africa, Rwanda)

i) Effects of climate change in the world

The following are the effects of climate change in different parts of the world:

Increase in the amount of rainfall: A rise in global temperatures could lead to an increase of evapotranspiration. This could eventually lead to the rise in amount of rainfall.

Melting of glaciers: A rise of temperature leads to the melting of glaciers in polar and mountainous regions resulting into flooding. This would cause the levels of the sea to rise by 20 cm by the year 2030.

Rise in the sea and ocean levels: The increase in the amount of rainfall and melting of glaciers leads to the increase of the sea and ocean levels destroying both human and physical features at the coast.

Increases in intensity of extreme weather: Climate change increases events such as heat waves, tornadoes and hurricanes.

The prolonged severe droughts: Some regions may experience prolonged droughts caused by reduction in rainfall, which may result in aridity.

Depletion of ozone layer: High amount of harmful ultraviolet radiation increases the cases of animal and human diseases such as cancers, blindness and other eye diseases.

Occurrence of acid rain: Acid rain is harmful to animal and human being.

Lower crop and timber yields: Since ultraviolet radiation slows down many aspects of plant growth such as photosynthesis and germination in many plants leading to low production.

Reduction of plankton growth: As temperature goes beyond coral reefs living standard, fish breeding and feeding patterns are disrupted.

Decrease of agricultural production: In some regions, the rainfall may decrease, or agriculture seasons be disrupted because of climate change. Some regions became drier and make soil infertile for crop production.

City environments becoming warmer: The increase of carbon dioxide makes the temperatures to increase most in urban areas.

Water use and long-term planning: A wetter or drier climate can affect water resources planning. Water reservoirs, dams, and hydroelectric projects might become useless in coming years.

Spread of vector-borne diseases: Because of high temperature there can be an increased range of insects.

Acidification of oceans: This can create a reduction in plankton, coral reefs and a drop-in fishing yield.

ii) Effects of climate change in Africa

The following are some of the facts showing the climate change and variability in Africa:

- Melting of glaciers on the top of the highest African mountains such as Kilimanjaro, Rwenzori, Kenya and Karisimbi;
- Warming in African tropical forests has been evaluated at 0.29 °C for the past 10 years and 0.1 °C to 0.3 °C in South Africa, while it ranged between 0.2 °C and 0.3 °C in the Nile Basin countries;

- Decreasing trends in temperatures; in eastern Africa, the situation has been complex because they have been observed over the regions close to the coast or major inland lakes and increasing in the rest of the region;
- The gradual heating, between 1961 and 2000, over the continent meant more warm spells (days) and fewer cold days across Africa. An increase in temperature in Sahara desert has led to the decline in volume of water in Lake Chad;
- Fluctuations of precipitation; the extent of variability is complicated and exhibits more spatial and temporal fluctuations across the continent;
- The decrease in rainfall has been registered in West Africa (between 4 ° and 20 °North; 20 °West and 40 °East), by up to 20% to 40% for the periods 1931-1960 and 1968-1990 respectively. A similar decline in mean annual rainfall has also been observed in the tropical rain-forest zone. A reduction of around 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960-1998.;
- Increases in rainfall have been registered in different parts of southern Africa (e.g., Angola, Namibia, Mozambique, Malawi, and Zambia);
- Increase in the desertification in south of the Sahara desert;
- Links have also been identified between the warm Mediterranean Sea and abundant rain fall over the surrounding regions.

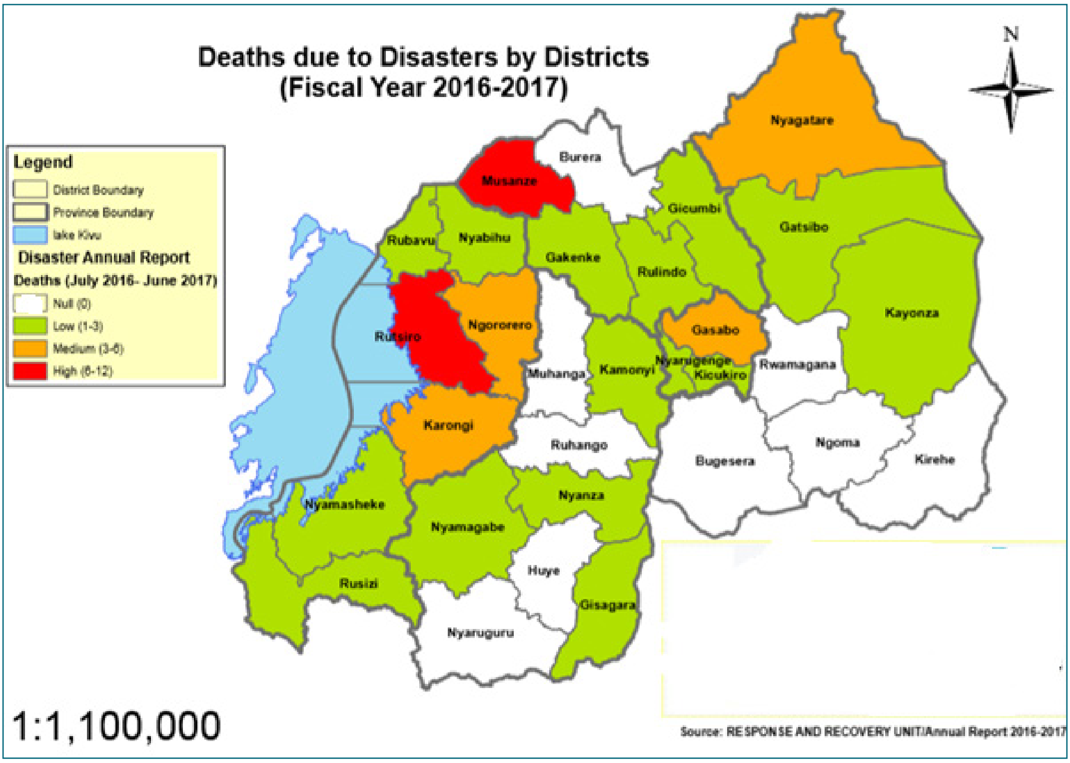
iii) Effects of climate change in Rwanda

Rwanda experiences some rainfall events that cause unexpected flooding and catastrophic events such as landslides etc. These extreme events are attributed to climate change. The figure below represents some effects of extreme rainfall events of climate change in Rwanda.

The following are effects of climate change in Rwanda:

- Significant increase in precipitations at a rate of between 2 and 6.5 mm per year over the Congo-Nile crest and the northern highlands for the period of 1935–1992.
- Floods that occurred in May 2002 caused the death of 108 persons in North western regions while the one occurred in 2007 have resulted to displacement of more than 456 families and destruction of hundreds of hectares of crops in Bigogwe sector in Nyabihu District;
- During September 2008 heavy rainfall accompanied by winds affected 8 of the 12 sectors of Rubavu district and provoked the displacement of more than 500 families, caused the destruction of about 2,000 hectares of crops and many other infrastructures;

– Floods reported in September 2012 in Nyabihu, Rubavu, Bugesera and Kirehe districts whereby more than 1000 families were displaced and their crops submerged completely;
– The landslides and floods caused by heavy rainfall are regulary observed mainly in north- western parts of Rwanda (Rulindo, Gakenke, Musanze, Nyabihu and Rubavu districts). For instance, the floods which occurred on 2nd and 3rd April, 2016 caused the death of 12 people, with 19 injured and destruction of 196 houses across the country. The floods which took place in Musanze district on 20th April 2016 caused the destruction of 64 houses and many hectares of crops and cattle;
– The significant increase in mean annual temperatures of between 0.036 and 0.066 °C per year for the period of 1961-1991;
– Since 1902, a number of famines following prolonged droughts episodes have been registered in Rwanda notably in eastern and south-eastern regions;
– More occurrences of lightning combined with the thunderstorms in 2013 caused 12 deaths in Karongi, 12 in Rubavu, 4 in Rusizi and 5 death in Rutsiro districts, respectively. The same districts suffered from the same extreme weather events which were reported to cause 15 deaths in 2015 (January-October) with 30 people injured.



Death due to disasters by districts (2016-2017)

Source: Ministry of disaster management and refugees

Application activity 7.1

1) Identify the areas of Africa that are susceptible to face the climate change challenges?
2) Describe the effects of climate change in Eastern and Western provinces of Rwanda.

7.2. Global warming and the green house phenomena (definition, causes and the effects)

Learning activity 7.2

1) Use different resources to find the meaning of the following:
   i) Global warming
   ii) Green house phenomena
2) Explain the reasons of practicing greenhouse farming.

7.2.1. Definitions of global warming and greenhouse phenomena

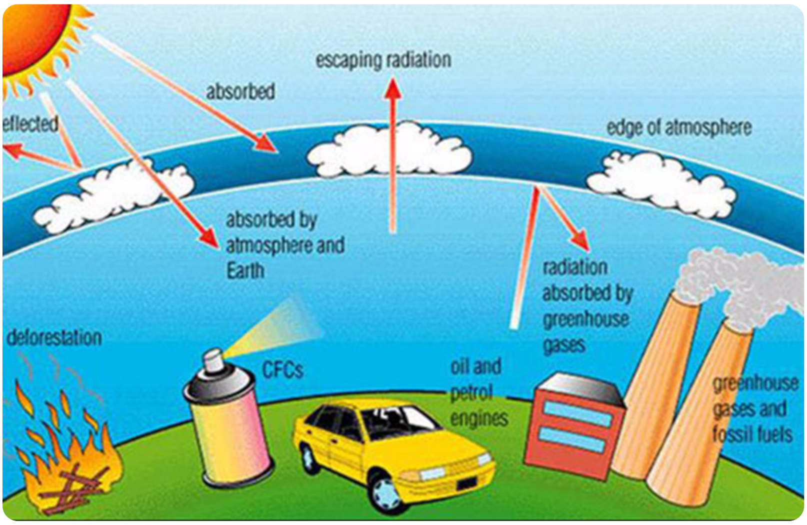
These two phenomena of global warming and greenhouse are related but are different.

i) Global warming

Global warming refers to the gradual rise in world temperatures. This is a gradual increase in the average temperature of the earth›s atmosphere and oceans due to increase in the amount of carbon dioxide. The increase in the amount of carbon dioxide leads to greenhouse effect. It is a change that is believed to be permanently changing the earth›s climate. An increase in greenhouse gases increases the greenhouse effect which in turn increases the global warming. In the last 100 years, the mean surface temperature on earth has increased by 0.5 °C.

i) Greenhouse effect

The greenhouse effect is a phenomenon in which the atmosphere of a planet traps radiation emitted by sun. It is caused by gases such as carbon dioxide, water vapor, and methane that allow incoming solar radiation to pass through but retain heat radiated back from the planet's surface.



Greenhouse phenomena

7.2.2. Causes of global warming and green house phenomena

The following are the causes of global warming and green house phenomena:

1) Human factors

Human activities produce various gases ejected in the atmosphere that are responsible for the global warming. These activities are destroying earth at fast rate: the emission of carbon dioxide from industries and vehicles, the burning of fossil fuels, cutting of trees and forests to build some new buildings and new malls, dumping of trash everywhere and not even recycling it, excessive use of the plastics and smoke from factories. All the activities performed by human beings are the major factors for gases that pollute the air and warm up the earth. These may contribute to the destruction of the ecological balance of the nature leading to the global warming.

Burning of fossil fuels

Fossil fuels are burnt on day-to-day basis. This activity produces large percentage of gases such as carbon, petroleum, coal and many other different gases which are emitted in earth's atmosphere. Carbon dioxide being one of gases with greenhouse effect is provided in excess in our atmosphere in far greater quantity in comparison with other gases produced by human activities.

Use of chemical fertilizers

The use of the artificial chemicals for crops has become one reason for the global warming. These chemicals are dangerous to the earth as well as to the human beings. These fertilizers are rich in the nitrogen oxide which is more dangerous than the carbon dioxide. Those oxides of nitrogen destroy ozone layer even faster than other greenhouse gas and hence let harmful ultraviolet rays enter atmosphere thus making earth warm and leading to the global warming.

Industrial advancement

More and more different industries and factories are set up in modern world to meet needs of the human beings. These factories need large amount of fuels like some coal, petroleum for power generation and electricity required by machines to work. Burning of these fuels also releases large amount of the carbon dioxide which absorbs harmful radiations from sun making it warm, hence increasing global warming.

Deforestation

The mass removal of trees, called deforestation, also affects the amount of carbon dioxide in our atmosphere. Forests around the world are being cleared for cultivation, mining, building, roads building, grazing cattle, etc. As they grow, trees take in carbon dioxide. When trees are removed, the carbon dioxide that they could have removed from the atmosphere is left. Cut-down trees are often burned. Burning produces more carbon dioxide. If the trees are cut, plants will not be able to produce oxygen and concentration of the carbon dioxide will increase. Increase of the carbon dioxide in air is very harmful for the human beings and also disturbs water cycle and hence total imbalance of our ecosystem. So being one of greenhouse gases it will lead to the global warming.

Air pollution

The harmful gases emitted from vehicles and the factories and greenhouse gases cause some pollution in the air and these gases get captured in atmosphere. The smoke gather up in atmosphere forming some clouds full of harmful gases which later fall as the acid rain which destroys plants. Plants provide us with oxygen and if they die level of carbon dioxide will increase in atmosphere which is known as a harmful gas. These gases emit heat which increases temperature of earth, hence causing global warming.

2) Physical factors

Volcanic eruptions

Volcanic eruptions are also among the causes of global warming. These eruptions contain the dust particles and gases like the sulfur dioxide which stays in the atmosphere for years and blocks the sunlight from reaching surface of earth making it somewhat cool. These dust particles affect balance of atmosphere and become contributing factor of the global warming.

Depletion of ozone layer

Depletion of ozone layers is an important factor that causes global warming. The ozone layer is known as the layer outside the atmosphere which protects surface of the earth from harmful ultra-violet and the infrared radiations causing some dangerous diseases like the skin cancer. Ozone layer depletion is one of causes of the global warming; entering of the harmful gases which helps in heating up the earth but other greenhouse gases like the carbon dioxide and methane that helps in heating up and tears up ozone layer making a hole called "**Ozone hole**". So, ozone layer depletes due to these gases which allow ultra violet radiations to enter the earth's atmosphere making it more warm than normal and also affects temperature leading to the global warming.

7.2.3. Impact of greenhouse process on global warming

Greenhouse effect is a process in which the atmosphere of the earth traps some of the heat coming from the sun and fails to radiate, making earth warming. This is due to the burning fuels, cutting of trees, concentration of the heat on earth is increased to some abnormal levels making the greenhouse effect as one of the major causes of the global warming. Carbon dioxide, nitrous oxide and methane are the greenhouse gases which help to keep earth warm. It is natural phenomenon that takes place with adequate concentrations of some greenhouse gases. When concentration of these gases rises then they disturb climatic conditions, thus making earth warmer. These gases are not able to escape and that causes the worldwide increase in temperatures. So balance of the carbon dioxide and some other gases should be maintained so that it does not become major reason for the global warming.

Application activity 7.2

1) Explain why causes of climate change and green house differ in rural and urban areas.
2) Among the effects of climate mentioned above, which ones do you observe in your local environment?
3) Referring to the greenhouse phenomenon, describe the advantages and disadvantages of the farming practiced in greenhouse.

7.3. Adaptation measures and mitigation for the climate change

Learning activity 7.3

In your local environment, identify any evidence of climate change and propose sustainable strategies to deal with it.

7.3.1. Adaptation measures for climate change

Adaptation for climate change refers to measures and strategies taken to cope with climate change and variability. These measures vary from one domain to the other like agriculture, livestock keeping, tourism, public health and water management; from one climatic region to the other as dry, wet, hilly, flat, depression, mountains, floodplains; from season to season as in dry and wet seasons; and across diverse actors as private, public, national, international, NGOs, local communities. Hence, adaptation measures are many and are not homogeneous. Some of them are briefly described below:

Maintaining current ecosystems wherever possible: This implies strengthening, extending and in some cases refining global protected area networks to focus on maintaining large blocks of intact habitat with a particular emphasis on climate change.

Agro-forestry: This is a land-use system that incorporates trees in food crop fields. In other words, it is a combination of agriculture and forestry for more diverse, profitable, productive and sustainable land use.

Progressive and radical terracing: This is used to reduce runoff, soil erosion and landslides. At the same time, terracing helps to improve soil quality and moisture retention, especially in steep areas.

Soil fertility conservation: Practices like the use of manure, mulching, planting of leguminous crops help to improve soil fertility by increasing the micro-organism composition in the soil.

Seed and grain storage: This involves collecting seeds and grains from farmers at post-harvesting season and releasing them within the timely agreed periods.

The use of pesticides: It is a wide range use of compounds such as insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others to control pests, insects, fungi, weeds, bacteria, rodents, all of which are harmful to crops.

Ecological pest management: This is the use of natural enemy dynamics or environmental positioning (e.g. crop shading) to eliminate or reduce the presence of pests.

The use of improved seeds and species: This is vital to improve crop productivity.

Crop varieties and diversification: This measure consists of integration of different varieties of crops and hybrids of a particular crop. Multiple cropping aids in replenishing the soil and maintaining its fertility by ensuring that there is a constant balance of nutrients by decreasing dependence and saturation of any one product.

Land use consolidation programmes: This encourage farmers with adjacent lands to grow the same crop. This facilitates the provision of inputs (e.g. seeds and fertilizers), post-harvest activities (e.g. driers, seed and grain storage facilities) and safer and faster transport of agricultural products.

Rain water harvesting: It is the practice of collecting and storing rainwater from rooftops, land surfaces or rock catchment areas for different use.

Irrigation like **drip irrigation** is a practice based on the constant application of specific and controlled quantity of water to the crops. The system uses pipes, valves and small drippers or emitters that transport water from the sources (i.e. wells, tanks and reservoirs) to the root area and applying it in controlled quantities and pressure specifications while **Sprinkler irrigation** involves spraying the crops with water using sprinklers in a manner that resembles rainfall.

Wastewater use: It forms a reliable source for crop irrigation and a positive way to dispose of sewage water. Whereas wastewater contains a lot of nutrients on the one hand, it carries pollutants like micro and macro organic and inorganic matters that potentially pose hazards to human health, the environment, crops and soils, on the other.

Biotechnology of crops: It involves the practical application of biological organisms, or their sub-cellular components in agriculture and livestock. The techniques currently in use include tissue culture, conventional breeding, molecular marker-assisted breeding and genetic engineering.

Barrier crops: These are crops that are used as a cultural control strategy for reducing the spread of pests and diseases to the most vulnerable crops. These crops provide benefits over "hard infrastructure" in a number of ways: first, they offer a natural form of protection; second, they contribute to the biodiversity and often soil improvement; third, they can provide an added source of food provisions or income and, finally; they can play a determinant role in soil erosion reduction.

Integration of meteorological information in agriculture: It is used to develop early warning systems, crop monitoring and disaster management.

Training farmers: By offering short courses, seminars and group discussions on the impacts of climate changes and on various ways of adaptation.

Facilitating the farmers: this consists of facilitating farmers to access capital that they need to purchase seeds, installation of tube wells, drilling of pumping sets, chemical fertilizers, plant protection chemicals, tractors, harvesters, threshers and other accessories.

Development of infrastructure: This concerns the improvement of transport networks, electricity and marketing facilities which use to be affected by climate change phenomena to promote a sustainable livelihood of population.

Development of agricultural institutions: The institutions such as universities provide experts and researchers who offer critical services like assessment, promotion of agricultural and livestock innovations and dissemination of research findings to agronomists and farmers at all levels.

7.3.2. Measures for mitigating the climate change

Mitigation measures for climate change consist of actions to limit the magnitude and the rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases. Anthropogenic greenhouse gases include carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O) and a group of gases referred to as halocarbons.

The following are mitigation measures for climate change:

Storing and reducing carbon dioxide: Carbon dioxide can be captured and stored, but also it can be reduced. Carbon dioxide Capture and Storage (CCS) is a process consisting of the separation of CO_2 from industrial and energy related sources, transport to a storage location and long-term isolation from the atmosphere. Conserving electricity is one strategy to reduce CO_2. When we conserve electricity, we reduce the amount of fossil fuel that must be burnt. One way to save fuel is to change daily activities that rely on energy from burning fuel.

Use of energy that reduces the atmospheric pollution: The use of renewable energy supply technologies, particularly solar, wind, geothermal and biomass are recommended to reduce the atmospheric pollution. Renewable energy systems such as hydro-electricity can contribute as well to the security of energy supply and protection of the environment.

Reduction of the energy use in buildings: Cooling energy use in buildings can be reduced by different measures, for example reducing the cooling load by building shape and orientation.

Land-use management: Forest land, cropland, grassland, wetlands, settlements have to be well managed by fighting against any threaten to them. Changes in land use may result in net changes in carbon stocks and in different impacts on water resources.

Crop land management: The use of agricultural practices which promote the conservation of water, and its quality. There is a need for improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands.

Afforestation and reforestation: The increase of number of trees helps to capture the CO_2 and decreases the flow of water from catchments.

Solid waste management and waste water treatment: Controlled landfill (with or without gas recovery and utilization) controls and reduces greenhouse gas (GHG) emissions but may have negative impacts on water quality in the case of improperly managed sites.

Application activity 7.3

1) If you were the Director General of REMA, demonstrate the adaption measures to climate change in Rwanda.
2) Suppose that you are a manager of a big industrial complex, describe the strategies to mitigate climate change.
3) Explain the process by which the use of refrigerator contributes to climate change.

7.4. Desertification (definition, causes, effects)

Learning activity 7.4

Study the photograph below and answer the questions that follow:

1. Explain what happen in the area shown in the photograph.
2. Explain how climate change contributes to desertification.
3. Referring to the figure below, describe the challenges that face people living in desert areas.

Drought threat in the Horn of Africa 2012

7.4.1. Definition of desertification

Generally, desertification is described as the turning of the land into desert. It is the process by which the land undergoes degradation from which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife. Desertification is caused by a variety of physical factors, mainly the climate change and human activities.

7.4.2. Causes of desertification

Desertification **is caused by a combination of factors that change over time and vary** with location. These include the following:

Less rainfall (total amount) and **increased drought** (frequency and intensity) lead to drought of rivers and water bodies and decrease in protective vegetation cover.

Global warming: It causes higher temperatures and increased evapotranspiration. This reduces condensation and leads to shortage of rainfall.

Population growth: The effect of this is the over-cultivation which reduces soil fertility and leaves the soil exposed to erosion.

Deforestation: An increased demand for cultivation land, wood for cooking, heating, building, increases the risk of soil erosion.

Poor crop cultivation practices: Some farmers do not know how to use the land efficiently. Farmers may essentially strip the land of everything that it has before moving on to another plot of land. By stripping the soil of its nutrients, desertification becomes more and more of a reality for the area that is being used for farming.

Urbanization and other types of land development: Development can cause people to go through and kill the plant life. It can also cause issues with the soil due to chemicals and other things that may harm the ground. As areas become more urbanized, there are less places for plants to grow. This can contribute to the process of desertification.

Soil erosion: The losses of the top soils and vegetation leads to the desertification.

Climate Change: Climate change plays an important role in desertification. As the days get warmer and periods of drought become more frequent, desertification becomes more and more eminent. Unless climate change is slowed down, huge areas of land will become desert; some of those areas may even become uninhabitable as time goes on.

Over exploitation of the land of resources: If an area of land has natural resources like, oil, or minerals, people will come in and mine it or take it out. The removal of resources is usually associated with the striping of the soil and depletion of nutrients. Consequently, plants are died and from there starts the process toward becoming a desert biome as time goes on.

Natural disasters: There are some cases where the land gets damaged because of natural disasters, such as natural fires, drought, floods, and earthquakes.

Rise of salinity: In the soil which causes the vegetation to be stunted.

Overgrazing: If there are too many animals that are overgrazing in certain spots, it is difficult for the plants to grow back. Biomes are affected and lose their original vegetation.

7.4.3. Effects of desertification

The following are the major effects of desertification:

Farming becomes unproductive: If an area becomes a desert, it's almost impossible to grow substantial crops there without special technologies. This can cost a lot of money to try and do so as many farmers will have to sell their land and leave the desert areas.

Hunger (famine): Without farms in these areas, the food that those farms produce will become much scarcer. The people who live in those local areas will be a lot more likely to try and deal with hunger problems. Animals will also go hungry due to food shortage.

Flooding: Without the plant life in an area, flooding is much more eminent. Some huge rivers cross deserts which experience a lot of flooding because there is nothing to stop the water from gathering and going all over the place.

Poor water quality: If an area becomes a desert, the water quality is going to become a lot worse than it would have been otherwise. This is because the plant life plays a significant role in keeping the water clean and clear.

Overpopulation of the new areas: When areas start to become desert, animals and people will go to other areas where they can actually thrive. This causes overcrowding and overpopulation, which will, in the long run, end up continuing the cycle of desertification that started this whole thing anyway.

Poverty: All of the issues that are described above (related to the problems of desertification) can lead to poverty if it is not kept in control. Without food and water, it becomes harder for people to thrive, and they take a lot of time to try and get the things that they need for their subsistence.

Acceleration of desertification: The increased frequency and severity of droughts resulting from projected climate change is likely to further accelerate desertification.

Involuntary migration: Rural population affected by the effects of climate change, especially the drought or aridity migrate towards different areas. This may also lead to rural exodus.

Shortage of drinking water and water to use for other purposes: This is where overpopulation causes pressure to exploit dry lands for farming. These marginally productive regions are overgrazed, the land is exhausted, and groundwater is over drafted.

Application activity 7.4

Observe carefully the picture below and answer the questions that follow:

i) Referring to the factors of desertification discussed above, describe the causes of the above phenomenon.

ii) Explain the effects of drought to the people living in such area.

iii) Considering the physical conditions of Rwanda, suggest the districts in which the above phenomenon is likely to happen and the strategies to limit this problem.

Skills Lab

Provide specific examples and analyze how human activities affect climate change.

End unit assessment

1. Compare the factors that can cause the climate change in China and Rwanda.
2. Explain the causes of climate change in developed and developing countries.
3. The World needs to develop at high rate with its industrialization processes which is among the most causes of greenhouse effects. Suggest the mitigation measures for climate change in this regard.
4. The world is facing the problem of climate change and this is substantially leading to the problem of desertification.
   a. Indicate the most affected areas by that problem?
   b. Suggest the sustainable strategies to address the problem of desertification.

UNIT 8

GLOBAL DRAINAGE SYSTEMS

Key Unit competence

The student-teachers should be able to investigate the economic importance of the global drainage systems and the reasons for their conservation

Introductory activity

1. Do research using the internet and other geographical resources to explain the following drainage terms: Drainage system, river discharge, river velocity, catchment area, river divide and river basin
2. Explain the processes of river erosion, river transportation and river deposition.
3. Explain the importance of drainage systems
4. Discuss why there is need to conserve drainage systems

8.1. River system

Learning activity 8.1

1. Do research and explain the types of rivers and the river profiles.
2. What do you understand by the concept of a river profile?

8.1.1. Definition of a river and the associated terms

A **river** is a large natural stream of fresh water flowing along a definite course, usually into the sea, being fed by tributary streams. The water originates from a known source and empties into a sea, lake or another river. The river flows along a channel, whose water volumes increases as the river goes downstream.

The following terms are used in describing a river channel

Discharge: is the amount of water originating from precipitation which reaches the channel by surface runoff, through flow and base flow. Discharge is, therefore, the water not stored in the drainage basin by interception, as surface storage, surface moisture storage or groundwater storage or lost through the evapotranspiration.

River Velocity: Is the speed at which the water flows through the channel. It is less at the sides and bed than at the center of a river. The velocity also depends on the river's gradient.

A river Basin: Is an area of land drained by a river and its tributaries. Its boundary is marked by a ridge of high land beyond which any precipitation will drain into adjacent basins. This boundary is called a **watershed**.

A river divide: This is the crest of the upland or mountain from which the streams flow down the slopes on both sides to their journey.

River width: This is the distance across the surface of a river from one bank to another bank.

River depth: Is the vertical distance from the river surface down to its bed.

River slope, also called ***river gradient*** is the angle between the horizon and the river surface.

Catchment area is an area from which a river derives its water. This can be an upland or mountain.

8.1.2. Types of rivers

There are different types of rivers. The following are the main ones:

- **Perennial River:** This is a river with water flowing permanently in its channel throughout the year.
- **Intermittent River**: This is a semi-permanent river which stops flowing at some point in space and time. It stops to flow every year or at least twice every five years.
- **Ephemeral River:** This is a seasonal river that flows only when there is heavy rain or when snow has melted.

8.1.3. The river system: The work of a river

As a river moves from its source to its mouth, it performs the triple function (three phases) of erosion, transportation and deposition. The following is the work of a river:

A. River erosion

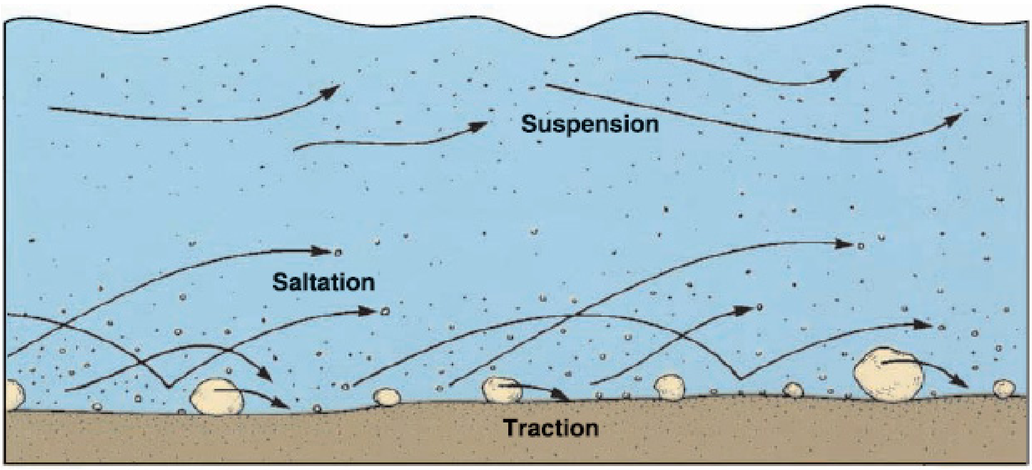
This involves the removal of different soils and rock particles of varying sizes from the river's bed and banks. Erosional work of rivers depends on the channel gradient, the volume of water, the river's velocity, water discharge and the sediment load (amount of eroded material). The river erosion is at its peak when the river passes through a steep gradient where the speed of flow is great. The river erodes its bed and channel in the following ways:

- **Hydraulic action**: This is the process by which fast flowing water enter into the cracks on the river bed and channel sides. The repeated friction and pressure of water force cracks to widen and finally erode weaker rocks.
- **Solution or corrosion**: This is the removal of rocks like salt, limestone etc. that are soluble in water. Such rocks dissolve in water and are carried in solution form.
- **Abrasion or corrasion**: This is the erosion of the river's bed and channel sides by the rolling action of materials or river load against rocks. The heavier rocks transported in water rub and slid against the bed and channel rocks eroding them as they are transported downstream.
- **Attrition:** This is the erosion of the river's load by the load itself. As rock fragments moving as load are transported downstream, boulders collide with other material and they are fragmented and gradually reduced in size, and their shape changes from angular to rounded.

B. River transportation and types of steam loads

Rivers ***transport*** refers to the carrying away of eroded material downstream. As represented on figure below, rivers transport their load in the following ways:

- **Solution:** This is the downstream movements of soluble material like salt, carbonates dissolved in water.
- **Suspension:** This is where the light particles of plants, soil and rocks are carried away while floating or maintained within the turbulence flow of water.
- **Saltation:** This occurs when the load carried by the river is transported in a series of short jumps or hops. It involves the transportation of particles which are not too heavy but cannot remain suspended in water. Materials such as pebbles, sand and gravel are temporarily lifted up by the river currents and then dropped back along the bed in a hopping motion. Such movements are known as hydraulic lift.
- **Traction:** This is where large and heavy materials are rolled, pushed and dragged downstream by the force of moving water. Such materials include rocks, pebbles and boulders.



Transport of solid load in a stream: Clay and silt particles are carried in **suspension**. Sand typically travels by **suspension** and **saltation**. The largest (heaviest) particles move by **traction**.

There are **three main types of stream load**.

1. Mineral and chemical elements of rock material held in solution constitute the **dissolved** or **solution load.**
2. **Suspended load** consists of the small clastic particles being moved in suspension.
3. **Bed load** is constituted of larger particles that move in traction along the streambed**.**

C. River deposition

This refers to the situation where a river fails to transport its load. The river, then drops its load due to the reduction in its energy. The heavy load is selectively deposited first, while the fine and lighter particles are deposited last. The material deposited by a river is referred to as alluvium.

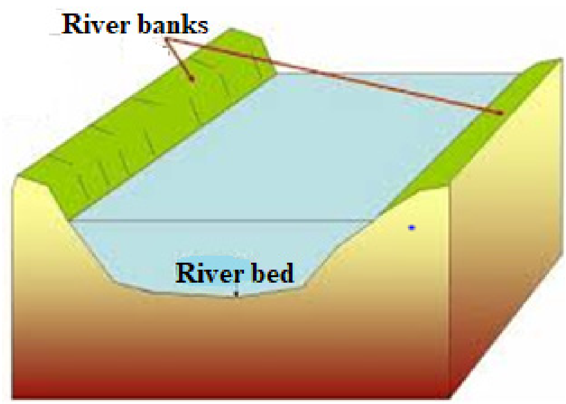
8.1.4. The river profile and its characteristics

A river profile is a section through the river channel from its source to its mouth or from one bank to another. There are two types of river profile: cross profile and long profile.

– **Cross profile**

This is also known as the transverse section of a river. It is the shape a river assumes from one river bank to the other. It develops as a result of down-cutting and lateral cutting of the riverbed and banks by water currents. This undercutting makes a section of a river valley, have different shapes and forms. For example, in the upper valley, vertical erosion produces a steep "V"-shaped valley. However, this depends on the rate of erosion and weathering taking place on the valley sides.

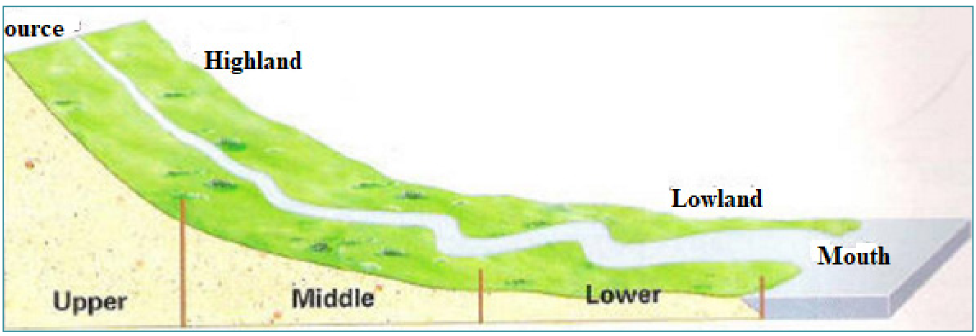
In the middle and lower stages, the river valley begins to become shallow and wide due to increased lateral erosion. The valley assumes a "U" shape.



A cross profile of a river

– **Longitudinal profile**

This is the longitudinal section of a river. It contains a variety of erosional and depositional features. Based on its distinctive characteristics, the long profile of a river is divided into three stages (upper/youthful, middle/mature and lower/old stages) known also as normal cycle of erosion

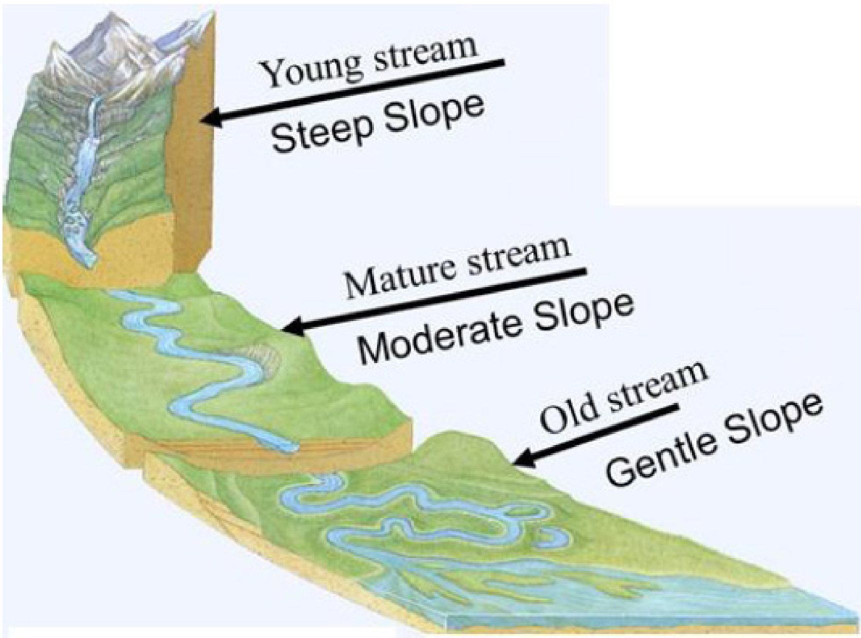


Longitudinal profile of a river

The Course of a river presents three successive **stages**. They are represented on figure bellow and described as follows:

- The **youthful stage**, referred to as upper stage of a river is found in the mountains and hills where the river rises from its source. It has the following characteristics:
  - The topography at this stage is steep and the river is usually fast flowing in the upper course.

- The main river gradually deepens its valleys.
- Often waterfalls and rapids are also found in this course;
- The main type of erosion is vertical. The valleys are narrow and deep.
- The features found in this stage include gorges, rapids and waterfalls.
- There are lots of stones and boulders for the water to flow over. The river starts as a *stream* in the upper course and flows through *V-Shaped valleys.*



Course of a river and its successive stages

- **Mature stage** is known as ***valley stage***. This ***middle course*** corresponds to the ***mature stream*** and presents the following characteristics:
  - This is the stage between the upper and lower courses of the river;
  - The slope of the riverbed is reduced, and the speed of the water is also reduced;
  - The main type of erosion is lateral and the river begins to widen its channel. There is also some deposition of sediments;
  - More tributaries join the river, leading to a large volume of water;
  - The river begins to meander or follow a winding course;
  - The features found in this stage include cliffs, slip-off slopes and bluffs.

- **Old stage**, also known as the ***old stream,*** is the ***lower course*** where the river becomes its widest and deepest. It has the following characteristics:
  - The slope of the river is very gentle; therefore, the river flows slowly.
  - The valley is shallow, wide and flat.
  - Seasonal floods occur.
  - There is a lot of deposition of sediment on its bed.
  - The features found in this stage include ox-bow lakes, deltas, floodplains etc.

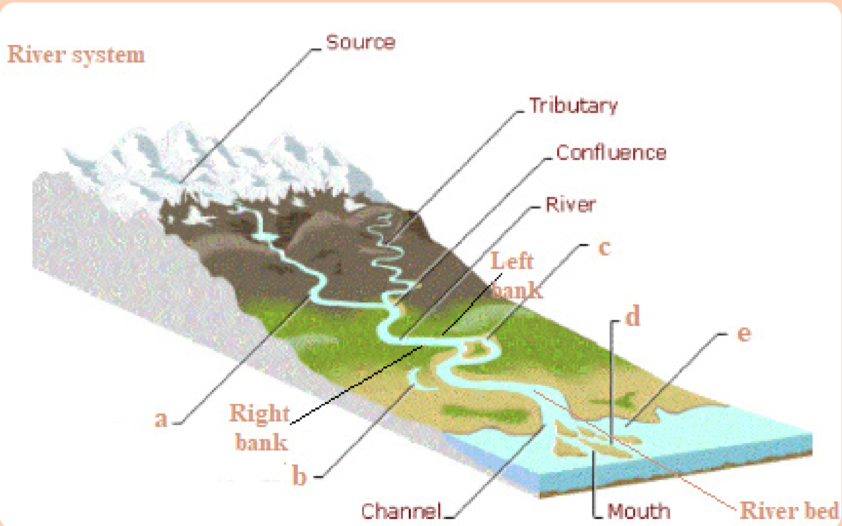
Application activity 8.1

1. Explain the major work of a river.
2. Describe the characteristics of a river that you observe in your local environment and how that river affects the environment around.

8.2. Formation of the major landforms associated with a river profile

Learning activity 8.2

Observe the diagram below and answer the following questions.



1) Name the landforms labeled a, b, c, d and e;
2) Apart from the features named above, what are other landforms created by a river?

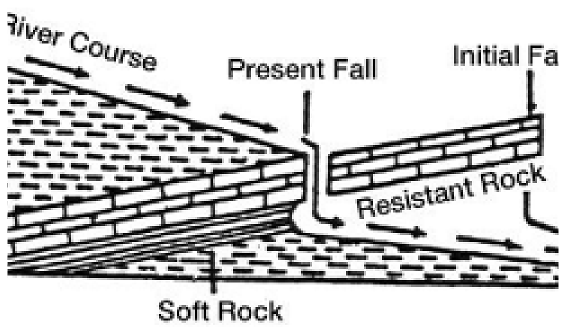
8.2.1. Formation of landforms in youthful stage

Youthful stage is the first stage of a river near its source. This stage is characterized by a steep gradient, fast flowing water, vertical erosion etc. There are several landforms that are created in this stage especially due to vertical erosion and the nature of the gradient. The landforms like waterfalls and rapids, potholes and plunge pools are the main landforms:

i) Waterfalls and rapids

Waterfall refers to movements of water or simply sudden descents of water due to abrupt breaks in the longitudinal course of the river. Waterfalls are mostly caused by variations in the relative resistance of rocks and topographic reliefs. A waterfall, therefore, is a vertical drop of a big volume of water from a great height along the profile of a river.

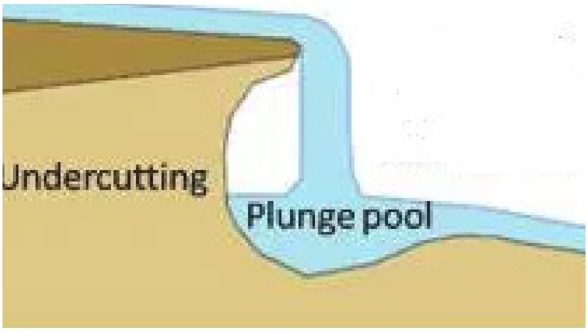
Rapids are alternate breaks along the river's profile. Rapids are smaller than waterfalls. Generally, they are found upstream from the main falls, and are also found independently.



Waterfall, Deep plunge pool and Rapid

ii) Potholes and Plunge pools

These are kettle-like and cylinder-shaped depressions in the rocky beds of the river valley. They are circular depressions cut at the bed of the river by fast flowing water. They are formed due to saltation and traction movement of large pebbles and boulders on resistant rocks. Plunge pools are formed when pot holes are further widened and deepened by circular and fast movements of water.

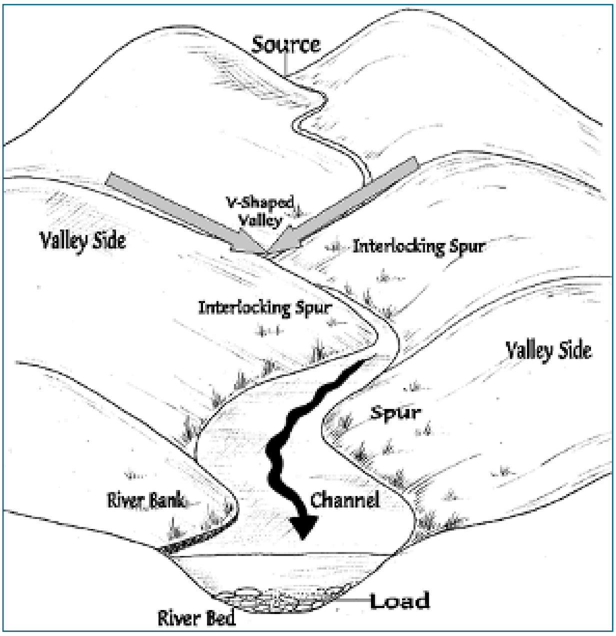


Plunge pool

Pot holes

iii) Interlocking spurs

These are alternate bands of resistant rocks or hill sides formed when the river attempts to avoid hard and resistant rocks on a steep gradient. The hard rocks are not eroded hence, the river meanders between interlocking headlands.



Interlocking spurs

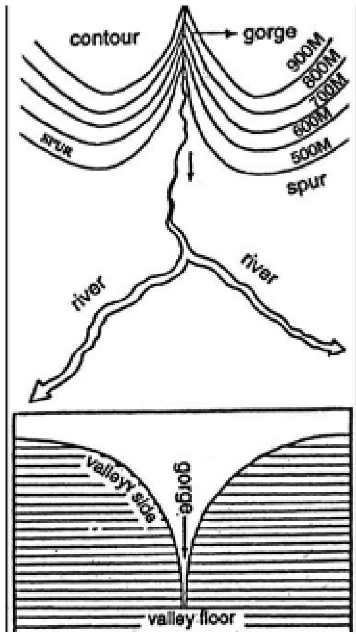
8.2.2. Formation of landforms in mature stage

A mature stage of the river is the middle stage of a river's course where the gradient is lower and where the river begins to flow slowly as it widens its channel.

The following are the major landforms:

i) **River valleys:** The valleys carved out by the rivers are significant erosional landforms. The shape and dimension of fluvial originated valleys change with the advancement of the stages of fluvial cycle of erosion.

ii) **Gorges and Canyons**: Are very deep and narrow valleys with steep sides/slopes that are wall-like. They are formed when water falling over the hard rock, undercuts the rock leaving it hanging. The hanging rocks may cause water to retreat upstream leaving behind a narrow and deep sided valley



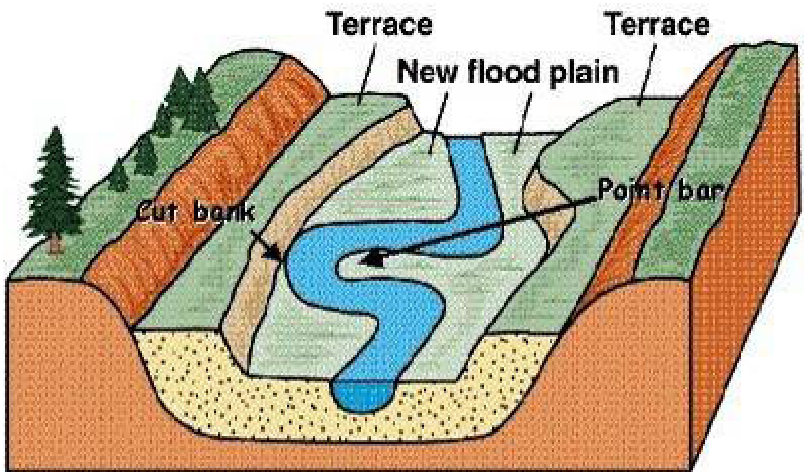
A river valley with gorges and Canyons

iii) **Alluvial fans:** These are fan-shaped deposits of coarse alluvium. They are formed when a fast flowing river loses its velocity when it enters the gentle slope. The river immediately deposits its load composed of course materials especially rocks, boulders and bigger pebbles. The deposits are laid in form of a fan, hence the name, "alluvial fan".

Alluvial fans

iv) **River Benches:** These are step-like flat surfaces on either side of the lowest valley. The benches or terraces formed due to differential erosion of alternate bands of hard and soft rock beds are called structural benches or terraces because of lithological control in the rate of erosion and consequent development of benches.

v) **River terraces:** The narrow flat surfaces on either side of the valley floor are called river terraces which represent the level of former valley floors and the remnants of former (older) flood plains.



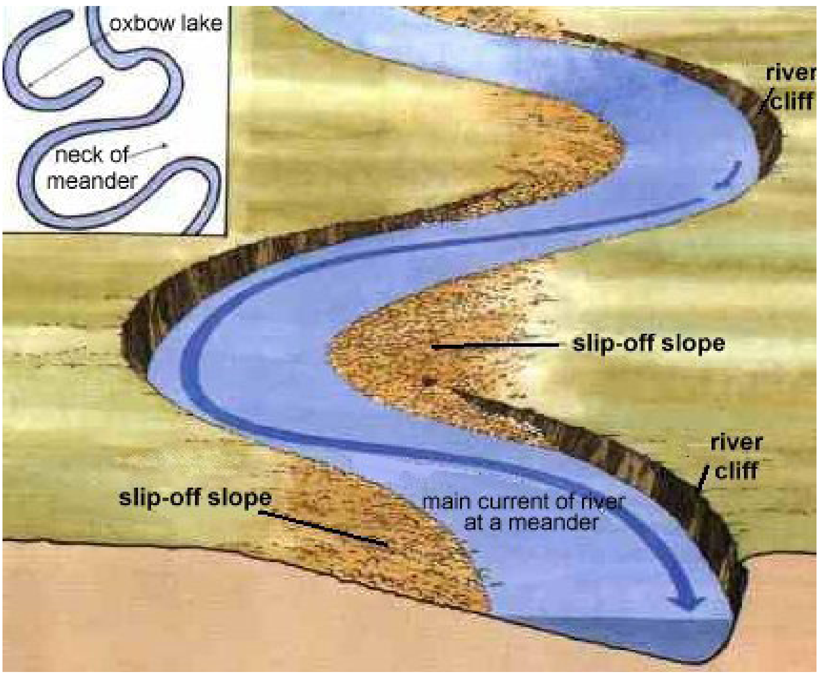
A river benches and terraces

8.2.3. Formation of landforms in old stage

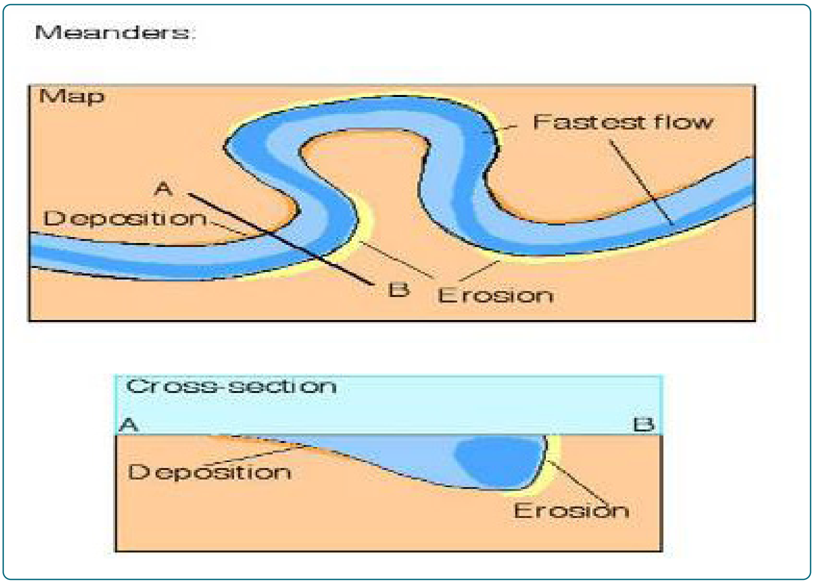
The lower or ***old stage*** of river is the last stage where a river nears its destination. This stage is characterized by large deposits along the river's bed and channel. The large deposition is a result of increased lateral erosion, very slow movement of water and very wide river channel. In this stage the river drops its load due to the reduction in its energy. The material deposited by a river is called alluvium. River deposition results into the formation of the following features:

i) River meanders

River meanders are the bends of the rivers. The bends of sinuous rivers have been named meanders on the basis of Meander River of Asia Minor (Turkey) because it flows through numerous bends. Each bend of the meander belt has two types of slopes of valley sides. One side is characterized by concave slope while the other side of the meander belt is characterized by convex slope. The convex or slip off slope receives deposition mostly of sands and gravels and alluvium at other times. Therefore, the bank of maximum deposition is also called a slip-off slope. The concave slope is a bank of maximum erosion or undercutting. It is steeper than the slip-off slope.



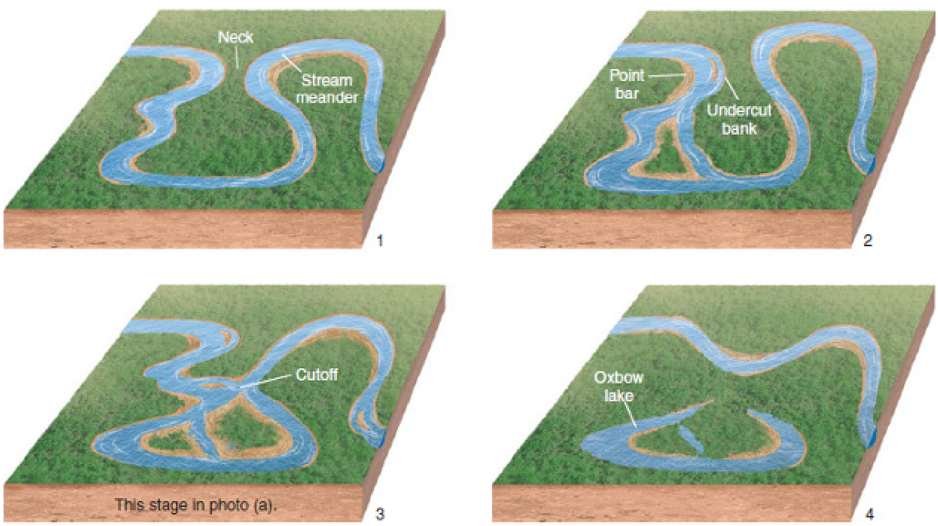
River meanders and its features



A river meander

ii) An Ox-bow lake

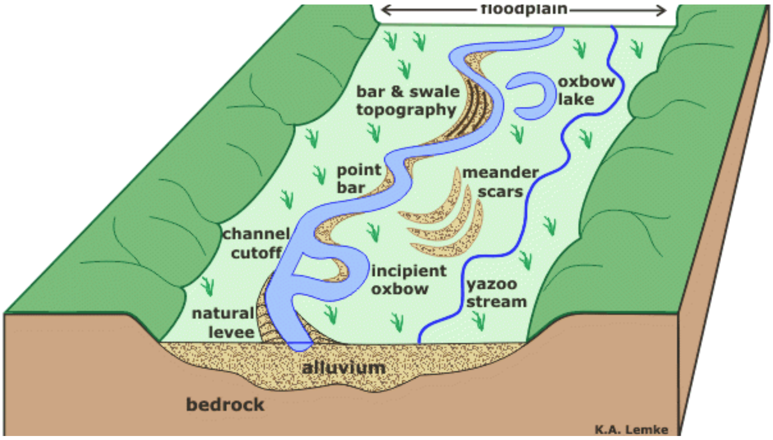
This is a horse-shoe lake formed due to stagnation of water in the abandoned meander loop. Ox-bow lakes are formed when a river develops very pronounced meanders in the flood plains. As erosion and deposition continues on the river's banks, the neck of the meander is cut off and the water flow straight by-passing the old meander. The abandoned or cut off meander therefore becomes an ox-bow lake.



Development of a river meander and an oxbow lake simplified in four stages

iii) Flood plain

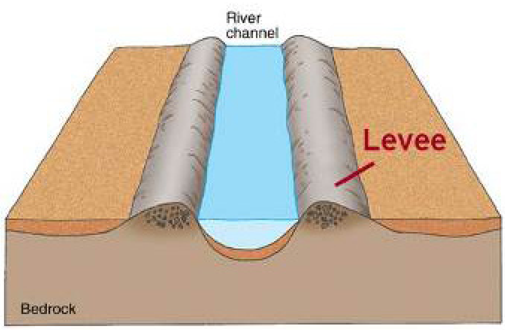
This is a very gentle low-lying plain of alluvial deposits on a floor of a river valley. It is formed where a river flows in a meandering way. As a river swings back and forth across the valley, it widens its valley floor. The valley becomes so broad that the meanders swing freely without touching the valley sides. When the level of water rises during the flood time, all the plain along the river valley becomes flooded. The river then deposits its alluvium in the plain.



Flood plains

iv) Levees

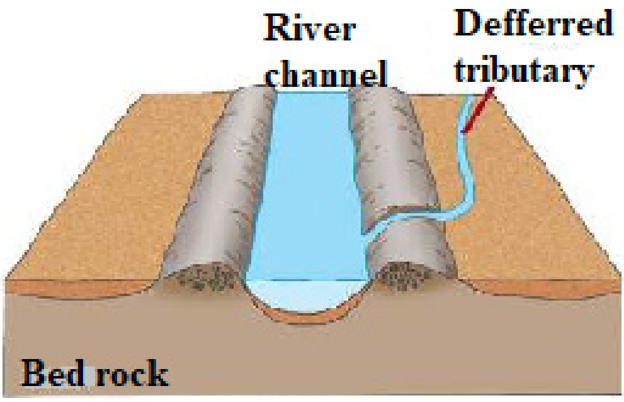
These are raised river banks made up of alluvial deposits. Levees are formed when a river deposits its load along its banks during flooding. Slightly coarse materials are deposited on the banks, while finer alluvium is transported further onto the flood plains. With time, accumulation of coarse material raises the banks of the river to form levees. During the dry seasons when the river retreats into its channel, deposition are left both on the river's bank and on its bed. This leads to the formation of raised river beds and banks.



Levees

v) Deferred tributaries

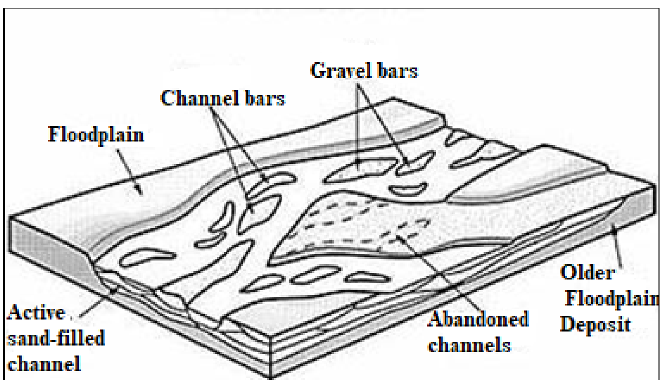
These are small tributary rivers that flow alongside the main river. They are formed when raised levees stop tributaries from joining the main stream. As a result, such tributaries, flow parallel to the main river until they encounter a break in the river bank where they now can join the main stream. They are thus referred to as deferred tributaries or Yazoo streams. The point at which they join the main stream is referred to as a deferred confluence. The tributary flows to the main channel and finally break through levees and join the main channel.



Deferred tributaries

vi) Braided channel

This is a wide and shallow channel where a river breaks into a series of interconnecting distributaries separated by sandbanks and islands of alluvium. It is formed in the middle or old stage of a river where the valley is wide and gently sloping. The river carrying a large load flows at a low velocity, fails to transport its load and finally deposits its load on the bed. Gradually, the river bed is raised and the deposits divide the flow of water into small tributaries and distributaries.



Braided channel

vii) Delta

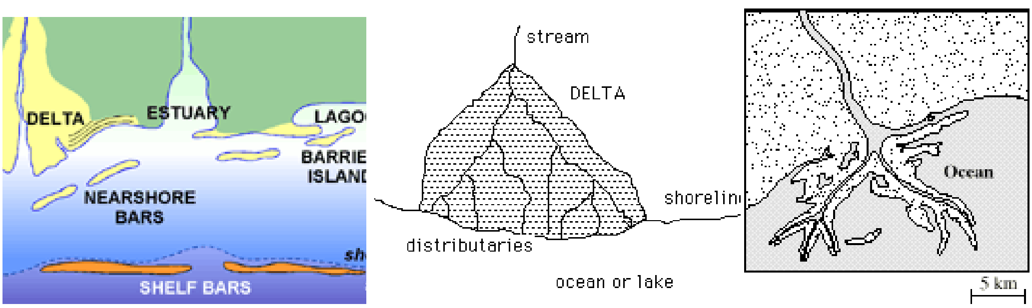
A **delta** is a low-lying swampy plain of alluvium at the mouth of a river. A delta forms when a river fails to carry its entire load into the sea or mouth but deposits these into its mouth. The deposits divide the river's mouth into tributaries and sub tributaries. The deposits gradually become colonized by various types of plants and form a triangular shaped mouth of a river. This is called delta. The river splits up into several separate channels in much the same way as river braids. Deltas are classified into three categories depending on the shape and growth where there are growing deltas and blocked deltas. They include the following:

- Estuarine deltas,
- Arcuate deltas,
- Bird's foot deltas.

– **Estuarine delta:** This is a submerged mouth of a river. It is a delta formed from materials deposited in the submerged mouth of a river. This takes the shape of the estuary. Examples are the Zambezi Estuary in Mozambique, and Volta Delta in Ghana.

– **Arcuate delta:** this is a triangular and convex shaped delta. It is formed by a river with many distributaries transporting materials. It occurs where off-shore currents are strong enough to round the seaward edge of the delta. Examples are Sondu Delta in Kenya, Nile Delta in Egypt and Amazon Delta in Brazil.

– **Bird's foot delta:** This is a delta that looks like the claws of a bird's foot. It is also known as **digitate delta**. It is formed when a river transporting large load of mainly fine material enters into water that has low energy wave. The distributaries extend from the shore into the open water. Examples are Omo River Delta on Lake Turkana and Mississippi Delta in the USA.



Estuarine deltas (left), Arcuate deltas (center), Bird-foot deltas (right).

Application activity 8.2

1. Visit the nearest rivers and do the following:
   i) Identify the landforms formed along a river.
   ii) Explain the importance of the above landforms to the local people.
2. Describe the relationship between landforms in the lower stage of a river and human activities

8.3. River capture, river rejuvenation, superimposed and antecedent drainage and impact of rivers

Learning activity 8.3

1. Make a research and establish the effects of the river capture and river rejuvenation.
2. Identify how superimposed and antecedent drainage are formed.
3. Discuss the importance of rivers.

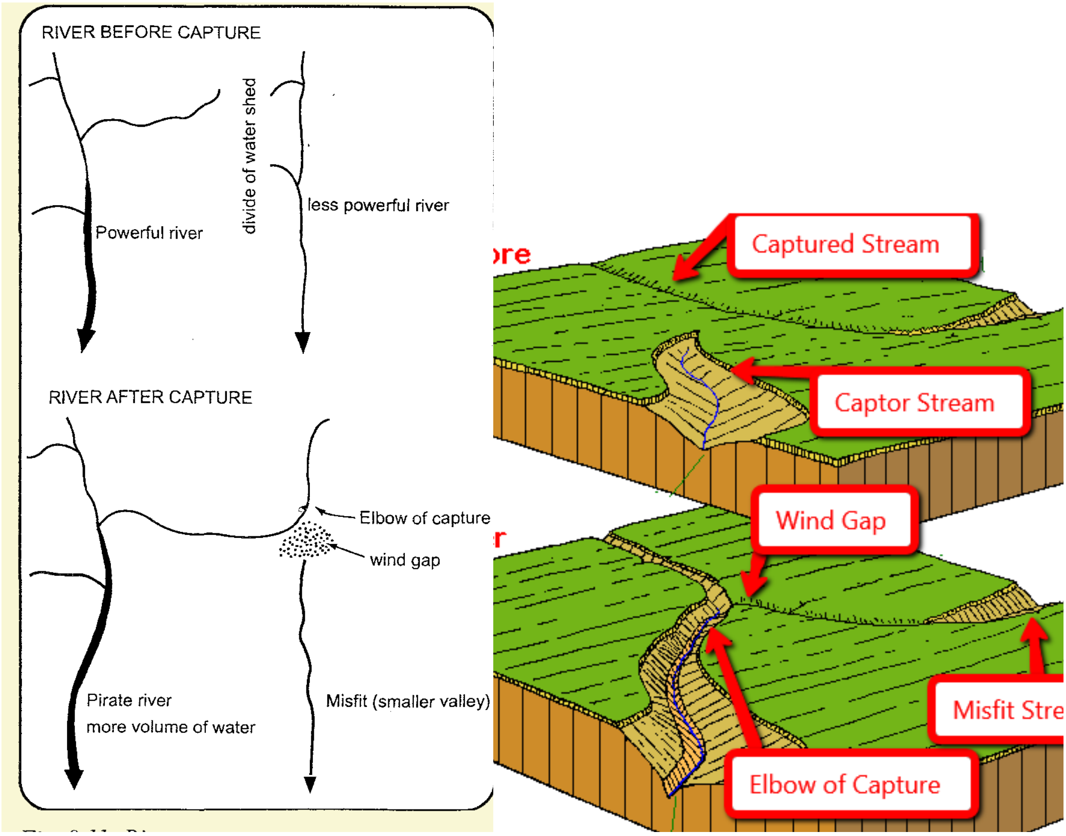
8.3.1. River capture

A) Definition of river capture

River capture refers to the diversion of headwaters of a weaker river system into a system of the stronger neighboring river. It is also referred to as river piracy. The point of capture is known as "elbow of capture". This point is usually found near the dry valley or misfit stream. A misfit stream is the river whose water has been beheaded or diverted into another stream. It contains very little or no water at all and is not therefore fit to be in that river. This is why it is called misfit stream. Beyond the misfit stream is a valley that no longer contains water. It is only covered by old alluvial deposit. This is called a dry valley.

B) Features of river capture

There are four major features of river capture: elbow of capture, cols or wind gaps, misfit or under fit streams and dry valleys.



River capture process

C) Causes of river capture

A river capture can be caused by headward erosion, lateral erosion, or coalescence of meanders. The following are the causes of river capture:

- The presence of a river with a larger volume of water compared to its neighbour (the weaker river). The stronger river erodes its valley faster by vertical erosion compared to its neighbour.
- The presence of soft and easily eroded rocks in the valley of a stronger river
- Earth movements like faulting, folding, warping and volcanicity on the valley of a stronger river can also cause river capture
- Change in base level as a result of river rejuvenation. A fall or rise in a river's base level can cause river capture

For river capture to take place, the following conditions are necessary:

- There must be a powerful river or pirate stream and a misfit stream flowing adjacent or parallel to each other.
- The pirate river must be flowing over a much steeper valley than the misfit or beheaded stream

- The pirate river must be having more active head ward erosion compared to its neighbouring river
- The pirate river must be flowing over easily eroded rocks compared to those of its neighbour

D) Effects of river capture

The following are the effects of river capture (after the occurrence of river capture):

- The volume of water in the pirate stream increases;
- The capturing/beheading river becomes bigger and more stronger than it was before capture;
- The beheaded stream having lost its waters contains very little water and almost dries off (a misfit river);
- The pirate river develops an elbow of capture. This denotes a sharp change in the direction of a river course (at the point of capture);
- The valley of the beheaded stream below the point of capture becomes dry and hence the name, “wind gap”;
- Incision of the pirate river near point of capture. This valley becomes wider due to increased vertical erosion (head ward erosion).

8.3.2. River rejuvenation

A) Definition of river rejuvenation

River rejuvenation is the renewed erosive activity of a river. It is an acceleration of erosive power of the fluvial process of rivers. Rejuvenation length is the period of the cycle of erosion. For example, if the cycle of erosion is passing through senile stage (old stage) characterized by gentle channel gradient, sluggish river flow and broad and shallow alluvial valleys, after rejuvenation (caused either due to substantial fall in sea level or due to uplift of landmass) the cycle is interrupted and is driven back to juvenile (youth) stage characterized by steep channel gradient and accelerated valley incision.

There are three types of rejuvenation as follows:

i) **Dynamic rejuvenation**: It is mainly caused by uplifting in the landmass, tilting of land area and lowering of the outlet.

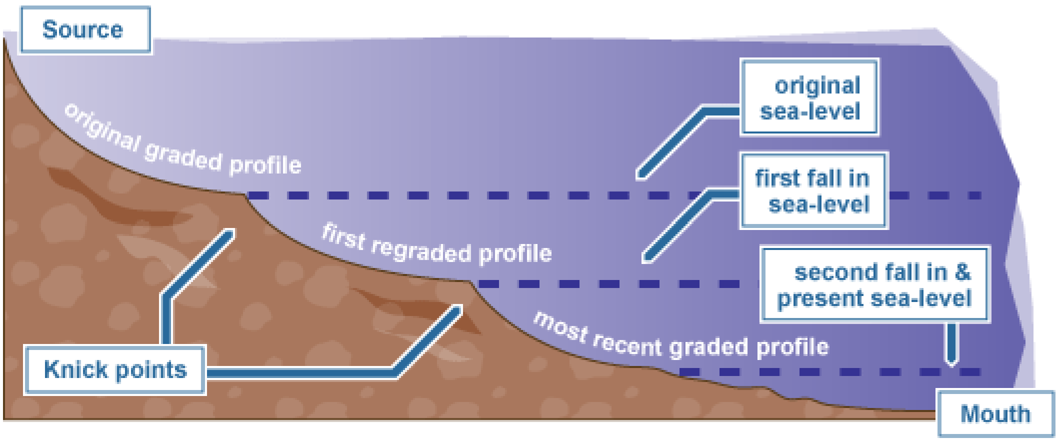
ii) **Eustatic rejuvenation:** This occurs because of changes in sea level due to diastrophic events (subsidence of sea floor or rise of coastal land) and glaciations causing fall in sea level.

iii) **Static rejuvenation**: Its main causes are decrease in the river load, increase in the volume of water and consequent stream discharge due to increased rainfall, increase in water volume of the main river due to river capture.

B) Causes of river rejuvenation

River rejuvenation is caused by the following:

- A fall in base level or fall in the level of the sea.
- Earth movements involving uplift, down faulting
- River capture which may cause an increase in the volume of water (river discharge)
- Change in rock resistance



Rejuvenation of a river (http://slideplayer.com/slide)

C) Effects of river rejuvenation on the landscape

River rejuvenation produces several features as follows:

- **Knick point**: This is a break of slope in the long profile of a river valley. It indicates the point where rejuvenation started. Knick points are associated with rapids and water falls.
- **Paired terraces**: These are steps or bench-like river valleys on both sides of a rejuvenated valley. They are marked by old alluvial deposits laid down before river capture occurred. It is therefore a part of the former flood plain valley that is above the present river level.
- **Incised meanders**: An incised meander is a curved bend of a river that has been incised or cut into the land surface so that a river now winds between steep valley walls. Incised meanders develop from an already meandering river.

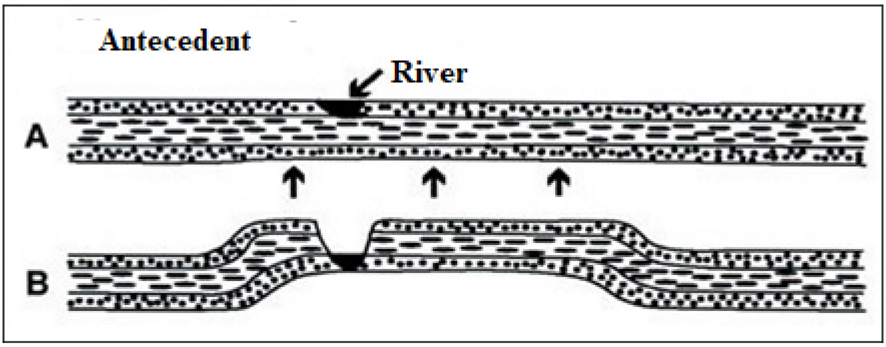
- **Ingrown meanders**: These are incised meanders with asymmetrical steep valley sides. They develop on resistant rocks and where the base level falls gradually and the meander shifts gradually and laterally

- **Valley within a valley**: This is also referred to as a rejuvenation gorge. These are steps at the opposite sides of a rejuvenated valley. They form where rejuvenation was very rapid with a large fall in base level. The river flows in a deep channel within paired terraces that were once the remains of the flood plain.

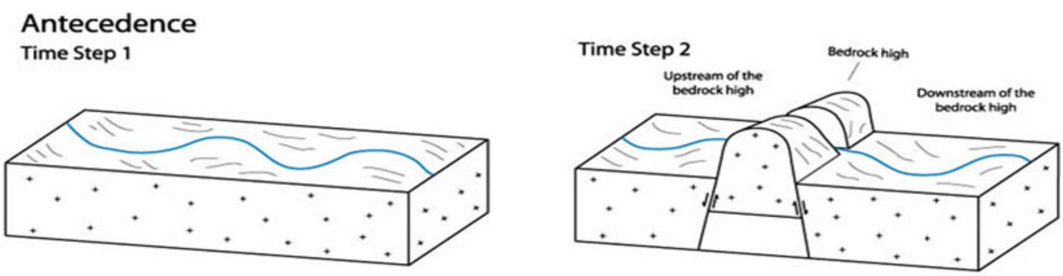
8.3.3. Superimposed and antecedent drainage

A) An antecedent drainage

This is a drainage made of streams that maintain their original course and pattern despite the changes in underlying rock topography. Antecedence is when the drainage pattern developed before such structural movements as the uplift or folding of the land, and where vertical erosion by the river was able to keep pace with the later uplift. A stream with a dendritic drainage pattern for instance, can be subject to slow tectonic uplift. However, as the uplift occurs, the stream erodes through the rising ridge to form a steep-walled gorge. The stream thus keeps its dendritic pattern even though it flows over a landscape that will normally produce a trellised drainage pattern.



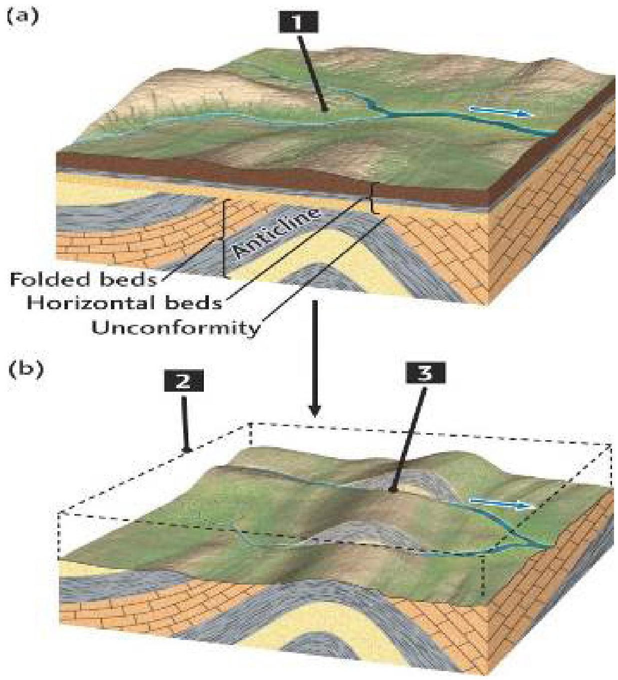
An antecedent drainage in folded structure



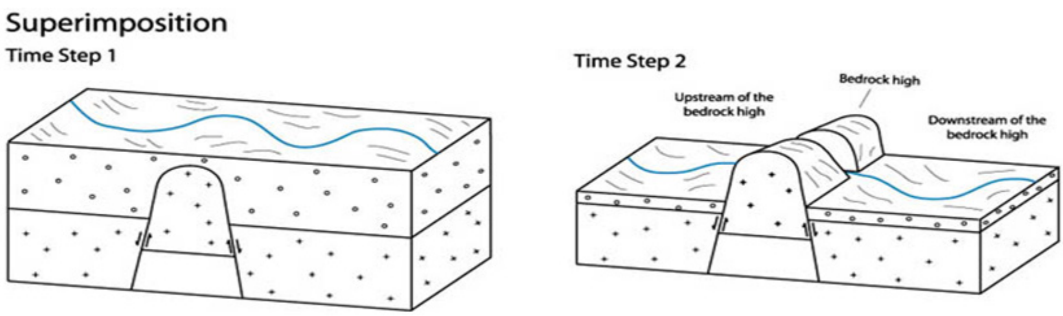
An antecedent drainage in faulted structure

B) A superimposed drainage

This kind of drainage pattern seems to have no relationship to the present-day surface rocks. Superimposed pattern is a drainage that formed over horizontal beds that overly folded and faulted rock with varying resistance. The stream erodes through the underlying horizontal beds, and retains its course and pattern despite changes in the underlying rock. The stream erodes a gorge in the resistant bed and continues its flow as before.



A superimposed drainage in folded structure



A superimposed drainage in faulted structure

8.3.4. Impact of rivers

Rivers play an important role both to human beings and the surrounding environments. Rivers can also negatively affect people and the surrounding environments.

A) Positive impacts of rivers

The rivers and riverine landforms present the following advantages for humans:

- Rivers provide water for various uses such as domestic, industrial uses, drinking by animals;
- Navigable rivers provide natural route-ways used for transportation;
- Rivers provide water for irrigation especially in areas of low rainfall. This promotes agriculture, hence increasing food production;
- Waterfalls provide natural sites for the production of hydroelectric power. Examples are: waterfall between lakes Burera and Ruhondo, River Rusizi in Rwanda, River Tana in Kenya, River Volta in Ghana, water falls along River Nile, etc;
- River Ria, estuaries and deltas are deep and sheltered, hence they promote the development of ports like Alexandria on the Nile delta;
- Building materials such as sand, gravel and pebbles are obtained from river beds and valleys;
- Some rivers have spectacular features such as waterfalls, gorges and canyons which attract the tourists. For example, Rusumo falls on river Akagera in Rwanda;
- Alluvial deposits in some river valleys are a source of valuable minerals such as alluvial gold for example in Miyove valleys in Northern Province of Rwanda;
- Building materials such as sand, gravel and pebbles are obtained from riverbeds and valleys;
- Flood plains and deltas contain fertile alluvial soils which have been exploited for agriculture. Example is the Nyabarongo river valley, Nile valley in Egypt etc;
- The livestock activities are mostly developed near water bodies where drinking and green vegetation water is available throughout the year.

B) Negative effects

The following are some of disadvantages of rivers and riverine landforms that influence negatively humans:

- Some large rivers form barriers to communication between communities of the same culture;

- During flooding some rivers cause destruction of property and loss of human life;
- Some river water may act as a medium for the spread of water borne diseases, for example, Malaria, Bilharzia;
- Some rivers host dangerous animals such as crocodiles and hippopotamuses. These at times attack human beings and destroy crops.

Application activity 8.3

1. Using your knowledge and skills acquired in this unit, explain the factors that favour river capture.
2. Examine the difference between river capture and river rejuvenation.
3. Analyze the impact of rivers to the development of the country.

8.4. Lakes, Seas and Oceans

Learning activity 8.4

1. Identify any 5 lakes found in Rwanda.
2. Use internet and other geographical resources to research on types of lakes and their mode of formation.

8.4.1. Types of Lakes

A lake is a large mass of water that occupies a basin or depression on the surface of the earth. Lakes receive water from streams, overland flow, and ground water, and so they form part of drainage systems. Lakes may be permanent or seasonal. This depends on the volume of water that gets in, and the amount of water that is lost. The loss of water is through evaporation and river outlets.

Lakes are categorized according to their mode of formation. They are grouped in various ways as follows:

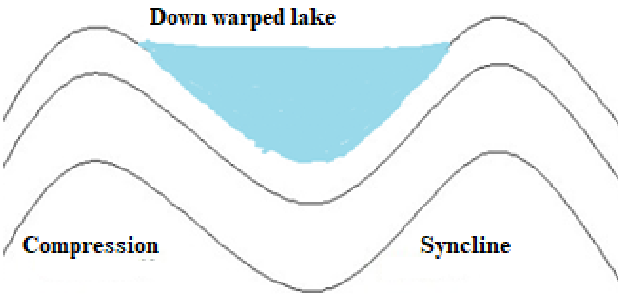
- Through earth movements (tectonic lakes)
- Volcanic action (lava dammed and crater lakes)
- Erosion (erosional lakes)
- Deposition (depositional lakes)
- Human activities (man-made lakes)

8.4.2. Mode of formation of Lakes

The lakes are differentiated on the basis of their mode of formation. The following are the major modes of lakes' formation.

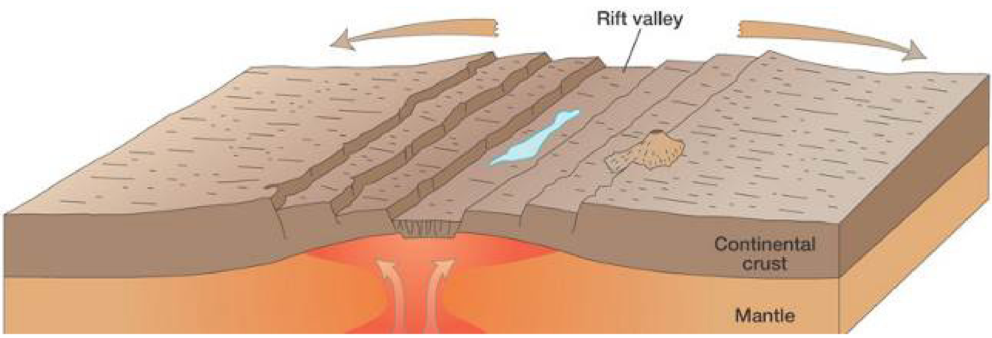
A) Lakes formed by earth movements

Lakes caused by crustal warping: These are lakes that occupy a basin-like depression. They were formed when water occupied down warped basins immediately after crustal warping. These lakes are also called subsidence Lakes. Examples are Lake Chad and Lake Victoria in Africa. In Rwanda, Lakes like Muhazi, Mugesera, Cyohoha were also formed as a result of subsidence.



A section through a folded landscape showing a down warped lake

Rift Valley Lakes: These are Lakes that occupy depressions within rift valleys. They are usually deep, elongated, and have steep sides. They are located on the floor of a rift valley. Examples are Lakes Kivu in Rwanda, Turkana in Kenya, Tanganyika and Malawi in Tanzania.



A rift valley lake

B) Lakes produced by glacial erosion and glacial deposition

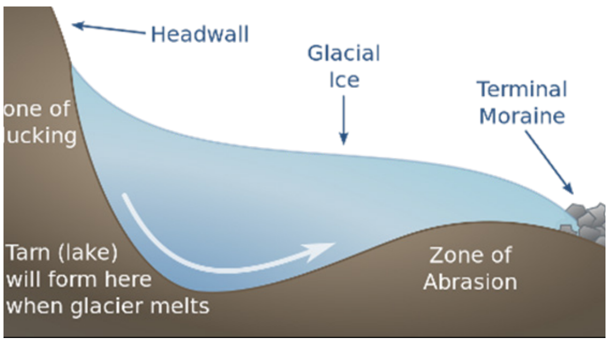
Cirque lake, also call a ***Tarn Lake*** is a Lake that forms in a glaciated highland. Such lake occupies an armchair-like depression, called a cirque. During thawing (melting of snow), water collects in circular depressions that were left behind where large avalanches or boulders were uprooted by melt glaciers.

A cirque lake sometimes feeds a mountain river. Tarns occur on the sides of Mount Kenya like Teleki Tarn and on Mt Rwenzori for example Stanley Lake.

A cross section through a cirque lake

Trough Lake: This occupies an elongated hollow excavated by ice on the floor of U-shaped valley. It is sometimes called a ribbon lake. Lake Michaelson, in the Gorges Valley, near to Mount Kenya, is a trough lake.

Trough Lake



A section through a glaciated trough during frozen season

- **Kettle Lakes:** These are small lakes that are formed in depressions in glaciated lowlands. They are formed when melt water occupy depressions called kettle holes.
- **Moraine dammed lakes:** These are lakes that form in glaciated lowlands when a moraine dams the flow of melt waters in glaciated lowlands.

C) Lakes produced by wind erosion

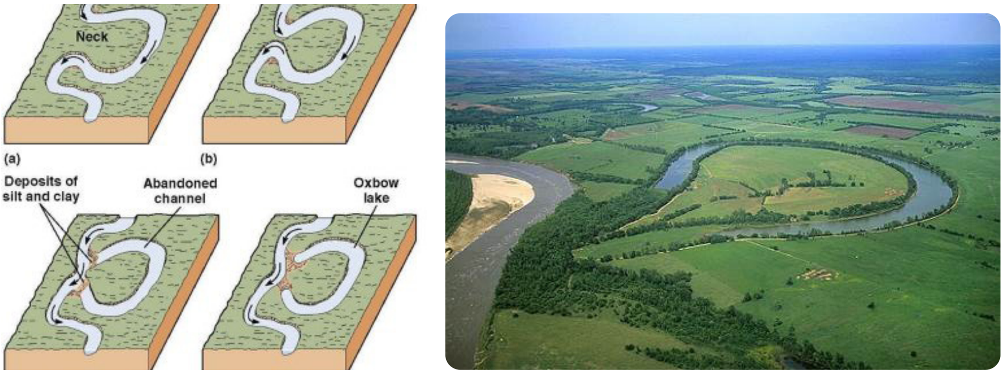
These are lakes that form in desert depressions left behind where large masses of sand dunes and pebbles have been removed. Wind deflation sometimes produces extensive depressions which reach down to the water-table in arid deserts. The lakes of these depressions are not always true lakes-they may be nothing more than muddy swamps. The Quattara depression, in Egypt, is a good example.

Wind Erosion Lake

More permanent desert lakes develop when an aquifer becomes exposed. These lakes are called oases. Some desert lakes dry up because of excessive evaporation and all that remains is a lake bed of salt. This is called a playa or a Salt Lake.

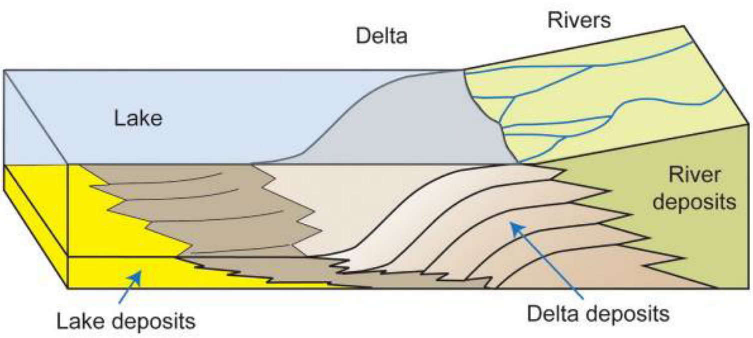
D) Lakes produced by river deposition

Ox-bow Lake: It is formed when a meander loop of a river on a flood plain is cut off from the main river. The river Galma, in Nigeria, has several ox-bow lakes.



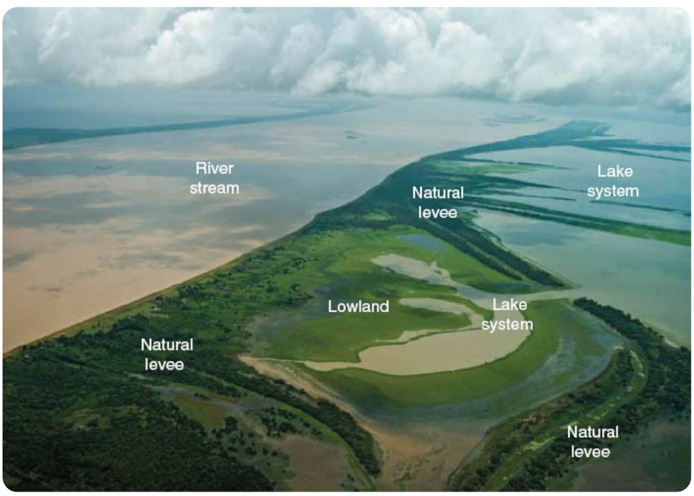
An Ox-Bow Lake

Delta Lake: This Lake is formed by the deposition of alluvium by rivers turning either a part of the sea into a lagoon, or part of a distributary into a lake. The Etang de Vaccares is a delta lake. Delta lakes occur in the Nile Delta, in Egypt.



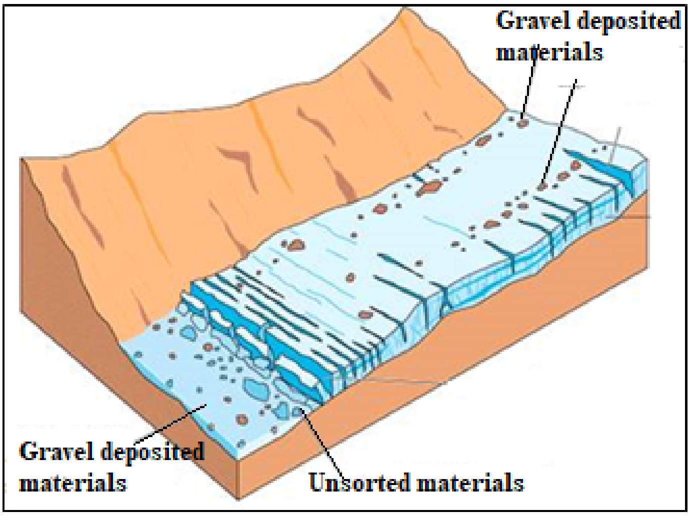
Delta Lake

Flood plain Lake: A levée sometimes prevent water from returning to the river, thus causing a lake to form. There are several lakes of this type on the River Congo.



Flood plain Lake

Boulder Clay Lake: Some boulder clay deposits contain depressions which become the sites for lakes. There are lakes of this type in Northern Ireland.



Boulder Clay Lake

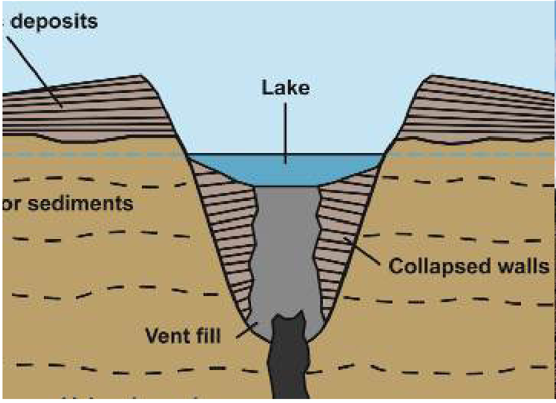
A. Lakes produced by marine deposition

Lagoon: This is a lake formed by a sand bar or sand spit extending along a coast and cutting off a coastal indentation hence forming a lagoon. Sometimes a barrier beach extends across the mouth of a river, producing a lagoon.

Lagoon lakes

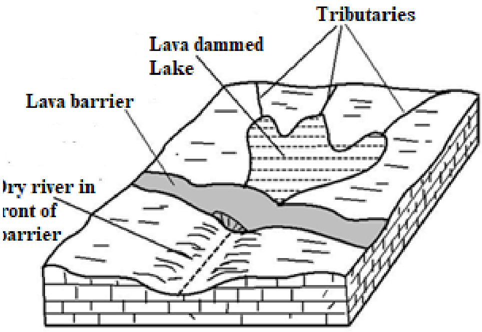
B. Lakes produced by volcanicity:

1. **Crater lakes** or caldera lakes are formed in volcanic craters and calderas, which fill up with precipitation more rapidly than they empty via evaporation, groundwater discharge or combination of both. **Crater** (small volcanic depression) and **Caldera** (large volcanic basin) There are several caldera lakes in Africa: Lake Shala, in Ethiopia, Lake Ngorongoro in Tanzania, Lake Toba, in Sumatra (Indonesia) is also a caldera lake. In Rwanda, the Crater Lakes are also found on Mountains Bushokoro, Muhabura and others.



A crater lake

2. **Lava-dammed lake:** A flow of lava may sometimes block the flow of a river valley which causes a lake to form. The Sea of Galilee, in the Jordan valley, was formed by lava damming the flow of river Matiandrano. The lava dammed lakes in Rwanda are Lakes Burera and Ruhondo in Burera district of Northern Province.



A Lava dammed lake

C. Other types of lakes

- **Solution Lake:** This sometimes develops in a limestone area when rainwater has dissolved the rocks to form a cave, and when the floor of this cave is near to the base of the limestone. Lake Scutari, in Yugoslavia, is a solution.
- **Temporary Barrier Lake:** Such a lake forms when an avalanche, or scree fall, or landslide blocks a river valley. A lake of this type is only temporary.
- **Man-made lake:** This is often called a reservoir. It is deliberately formed by building a dam across a narrow, steep-sided section of a river valley, usually a gorge, or constructing a wider depression or water dam to trap rain water in a valley for the purpose of storing water for irrigation, wet rice cultivation or for developing hydroelectricity or both. Such lakes in Rwanda are Cyabayaga in Nyagatare District and Rugeramigozi in Muhanga District.
- **Lakes produced due to mass movement:** Movement of debris down slope due to the influence of gravity may block a river valley. They may be landslides, mudflows, avalanches or rock slides.
- **Lakes produced by alluvial deposits:** These are lakes formed because of back ponding by rivers. Such lakes form in depressions within river valleys. Examples of such lakes are; Rweru, Ihema, Hago Rwanyakizinga etc. along the valley of river Akagera.

8.4.3. Impact of lakes

The usefulness of lakes to human society are briefly described below.

- **Source of fish**: Lakes are habitats for different varieties of fish. This has favoured the development of fishing and related industries.
- **Source of minerals and natural gases**: lakes such as Magadi in Kenya, Natron in Tanzania and Katwe in Uganda are source of salt, Lake Kivu in Rwanda contains natural gas.
- **Tourism:** Lakes provide beautiful sceneries and other activities which attract tourists. This earns a country foreign exchange.
- **Cheap transport:** Lakes form cheap natural waterways for goods and passengers.
- **Source of power:** Some lakes have been harnessed for the generation of hydroelectric power. For example, Lakes Burera and Ruhondo generate power on Ntaruka hydroelectric power plant.
- **Source of useful water**: Lakes are sources of water for domestic and industrial uses.
- Source of drinking water for animals like cattle, sheep, goats, etc.

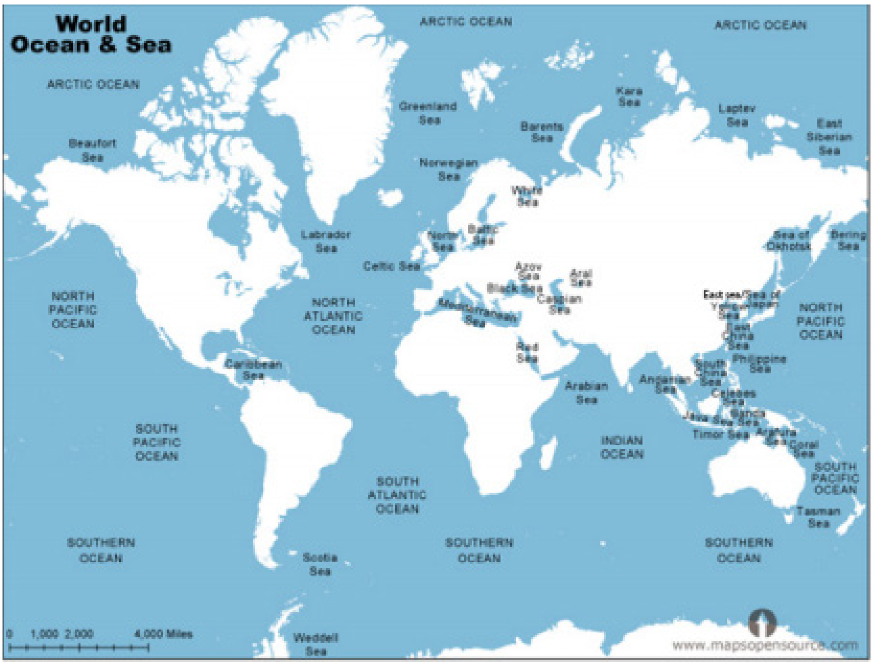
- **Source of building materials**: Some lakes are source of building and construction materials such as sand, pebbles, small rocks, water used in construction, etc.
- **Regulating river flow**: Some lakes help in controlling floods by regulating the flow of rivers.
- **Modification of climate:** Lakes are important factors controlling the climate of the surrounding areas because they provide the moisture. The lakes also modify the climate of the adjacent areas.
- **Source of rivers:** Some lakes are sources of rivers. They act as reservoirs and stores of water to rivers. For example, Lake Kivu is a source of river Rusizi, Lake Muhazi is source of Nyabugogo River, etc.

8.4.4. Distribution of seas and Oceans

A) Distribution of Seas

A sea is a very large mass of saline water that occupies a very huge depression. Seas occupy large basins on the continental margins. Lakes are smaller than seas but seas are also smaller than oceans. Seas are of two types namely:

- Inland seas. These are shallow seas over part of a continent. They are connected to oceans by straits
- Marginal Sea. This is a sea partially enclosed by islands, archipelagos, or peninsulas, adjacent to or widely open to the open ocean at the surface, and/or bounded by submarine ridges on the sea floor.



A map showing Seas and Oceans of the world

B) Distribution of oceans

An ocean is a large mass of saline water. Oceans occupy basins between continents. There are five oceans in the world. These are as follows:

- **Southern (Antarctic) Ocean**: with an area of 20 million kilometers square
- **Arctic Ocean**: with an area of 14 million kilometers square
- **Indian Ocean**: with an area of 68.5 million kilometers square
- **Atlantic Ocean**: with an area of 76 million kilometers square
- **Pacific Ocean:** with an area of 155 million kilometers square

Application activity 8.4

1. Draw a sketch map of Rwanda and on it indicate the types of Lakes.
2. Explain their mode of formation.

Skills Lab

Water pollution is a result of human activities. Give advice on how to prevent it.

End unit assessment

1. Some ocean currents originate from warm regions and others from cold regions. Describe the relationship between ocean currents and the atmospheric circulation.
2. Conduct your own research to describe the major ocean management projects in the world.
3. Discuss the economic advantages of drainage in Rwanda, and in the world.
4. Explain the strategies to mitigate natural hazards associated with drainage system.

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GLOSSARY

Active continental margins: Continental margins that coincide with tectonically active plate. **Asthenosphere**: The plastic like, soft layer below the lithosphere in earth's mantle, beneath the rigid lithosphere.

Adaptation measures for climate change: Measures and strategies taken to adapt to climate change and its variability.

Aerosols: Suspended Particulate Matter (SPM) in the atmosphere including solid particles of varying sizes and liquid droplets are collectively called **aerosols** which include: ploughed soil cover, deserts, rocks, salt particles from seas and oceans; meteoric particles, organic matter: bacteria, seeds, spores and pollen.

Andesite: Extrusive igneous rock of diorite composition, dominated by plagioclase feldspar; the extrusive equivalent of diorite.

Antecedent drainage: A part of a river slope and the surrounding area uplifts but the river maintains its original slope.

Basalt: Extrusive igneous rock of gabbro composition; occurs as lava.

Bleach coral reefs: These are white coral reefs after expelling the algae (zooxanthellae)

Clay minerals: class of minerals produced by alteration of silicate minerals, having plastic properties when moist.

Clay: sediment particles smaller than 0.004 mm in diameter.

Climate change mitigation: Involves reductions in human (anthropogenic) emissions of greenhouse gases.

Climate variability: It is variations of atmospheric conditions at a specific location or globally in short term.

Coal: Rock consisting of hydrocarbon compounds, formed of compacted, lithified, and altered accumulations of plant remains (peat).

Collision: Process where two continental crust collide and, as neither can sink, are forced up into fold mountains.

Compression (tectonic): Squeezing together, as horizontal compression of crustal layers by tectonic processes.

Conglomerate: A sedimentary rock composed of pebbles in a matrix of finer rock particles.

Continental crust: Crust of the continents, of felsic composition in the upper part; thicker and less dense than oceanic crust.

Continental drift: Hypothesis proposed by Alfred Wegener, which states that continents have moved horizontally around the globe, over time, to reach their current location.

Continental lithosphere: Lithosphere bearing continental crust of felsic igneous rock.

Continental margins tectonic: Marginal belt of continental crust and lithosphere that is in contact with oceanic crust and lithosphere, with or without an active plate boundary being present at the contact.

Continental margins: A zone which combines both the continental shelf and the continental slope and is distinct from the deep-sea floor.

Control Gate: A facility used to control over the water travelling in penstock.

Convection current: The driving forces of plate tectonics in which hot, plastic-like material from the mantle rises to the lithosphere, moves horizontally, cools, and sinks back to the mantle.

Convergent boundary: In plate tectonics, the boundary between two plates that are converging, or moving toward each other.

Coral reef: Skeletons of very small sea creatures.

Coral: A marine polyp capable of secreting calcium carbonate to build an external skeleton.

Coriolis force: Deflecting motion caused by the rotation of the earth which makes a body or current moving across its surface to be deflected to the right in the north hemisphere, and to the left in the south hemisphere.

Crane*:* A type of machine, generally equipped with a hoist rope, wire ropes or chains, and sheaves that is used both to lift and lower the gates which regulate intake gates or water flow from reservoir through the tunnel of a dam.

Crust: Outermost solid layer of the earth, composed largely of silicate materials

Dam: a barrier constructed across a river to hold back water and raise its level, forming a reservoir used to generate electricity or for domestic, irrigation or industrial water supply. Some dams are built also to preventing the flow of water or loose solid materials (such as soil or snow).

Deposition: The laying down of material that has accumulated after having been eroded and transported.

Desertification: Land degradation in which a relatively dry land region becomes increasingly arid, typically losing its water bodies as well as vegetation and wildlife.

Development: The process in which some economic sectors or activities (e.g. agriculture, industry, technology, etc.) grow or change and become more advanced

Diorite: Intrusive igneous rock consisting dominantly of plagioclase feldspar and pyroxene; a felsic igneous rock.

Divergent boundary: In plate tectonics, the boundary between two plates that are diverging, or moving away from each other.

Dolomite: Carbonate mineral or sedimentary rock having the composition calcium magnesium carbonate.

Drainage pattern: A plan made by a river and its tributaries along the landform

Dredging: Clear the bed of a harbour, river, or other area of water by scooping out mud, weeds, and rubbish with a dredge"the dredging and deepening of the canal".

Dry farming: This is also called Dry land Farming. It is the cultivation of crops without irrigation in regions of limited moisture, typically less than 20 inches (50 centimetres) of precipitation annually.

Earthquake: A trembling or shaking of the ground produced by the passage of seismic waves.

Ecosystem: Total living things in an area including ways they interact each other in the environment

Effluents: Liquid waste or sewage discharged into a river or the sea from industries.

Eustasy: any uniformly global change of sea level that may reflect a change in the quantity of water in the ocean, or a change in the shape and capacity of the ocean basins

Extinction: the state or process of being or becoming extinct /disappearance, vanishing.

Extrusive igneous rock: Rock produced by the solidification of lava or ejected fragments of igneous rock (tephra).

Feldspar: Group of silicate minerals consisting of silicate of aluminum and one or more of the metals potassium sodium, or calcium (See also *plagioclase feldspar, potash feldspar*)

Felsic igneous rock: Igneous rock dominantly composed of felsic minerals.

Felsic minerals (**felsic mineral group**): Quartz and feldspars treated as a mineral group of light color and relatively low density. (See also *mafic minerals*.)

Flood control: Methods are used to reduce or prevent the detrimental effects of flood waters.

Gem: Also called Game stone is a valuable mineral highly prized because it is rare and beautiful.

Gentle slopes: These are areas located in rolling countryside where slope is between 5 and 15% and the pattern of rainfall distribution regularly results in erosion events. They are very common in Mediterranean countries

Glacier: It is a large mass of ice in motion.

Gondwanaland: A supercontinent of the Permian period including much of the regions that are now South America, Africa, Antarctica, Australia, New Zealand, Madagascar, and peninsular India.

Granite: Intrusive igneous rock consisting largely of quartz, potash feldspar and plagioclase feldspar with minor amounts of biotite and hornblende; a felsic igneous rock

Gravity: The force by which objects are attracted to one another because of their mass on the earth surface.

Greenhouse effect: Is process in which atmosphere of earth trap some of heat coming from sun, making Earth warm than usual.

Holomorphic soils: These are intrazonal soils which have developed in areas where salts have accumulated at or near the surface.

Hurricane: A type of tropical cyclone with sustained winds that exceed 74 mph and accompanied by rain, thunder and lightning

Hydromorphic soils: These are intrazonal soils developed in presence of excess water.

Ice cap: An area of permanent ice.

Intrusive igneous rock: Igneous rock body produced by solidification of magma beneath the surface, surrounded by preexisting rock.

Laurasia: A supercontinent of the Permian period, including much of the region that is now North America and western Eurasia.

Lava: Magma emerging on the Earth's solid surface, exposed to air or water.

Levee: Also called embankment or flood bank or stop bank is an elongated naturally occurring ridge. It is usually earthen and often parallel to the course of a river in its floodplain or along low-lying coastlines.

Lithosphere: The rigid, outermost rock layer of the earth, about 100 km thick, composed of the crust and part of the mantle, lying above the asthenosphere.

Mafic igneous rock: Igneous rock dominantly composed of mafic minerals.

Mafic minerals (mafic mineral group): Minerals, largely silicate minerals, rich in magnesium and iron, dark in color, and of relatively greater density.

Magnetometer: A sensitive instrument that records magnetic data and is used to study earth's magnetic field.

Marble: Variety of metamorphic rock derived from limestone or dolomite by recrystallization under pressure.

Metamorphic rock: Rock altered in physical structure and/or chemical (mineral) composition by action of heat, pressure, shearing stress, or infusion of elements, all taking place at substantial depth beneath the surface.

Mid-oceanic ridge: One of three major divisions of the ocean basins, being the central belt of submarine mountain topography with a characteristic axial rift.

Mineral: Is a naturally occurring chemical compound, usually of crystalline form and abiogenic in origin (not produced by life processes). A *mineral* has one specific chemical composition, whereas a rock can be an aggregate of different *minerals* or mineraloids. The study of *minerals* is called mineralogy

Oasis: A moist fertile place in the desert usually surrounding a well or spring

Oceanic crust: Crust of basaltic composition beneath the ocean floors, capping oceanic lithosphere.

Oceanic lithosphere: Lithosphere bearing oceanic crust.

Oceanic trench: Narrow, deep depression in the seafloor representing the line of sub-duction of an oceanic lithospheric.

Ore: A mineral containing a useful substance, such as metal, that can be mined at a profit.

Ox-bow Lake: A horse shoe shaped lake form from a meander that is cut off and abandoned by the main river.

Pangaea (pan JEE uh): The name Alfred Wegener gave to the single large landmass, made up of all continents, that he believed existed before it broke apart to form the present continents.

Parent rock: It is the material (rock) from which soil is formed.

Passive continental margin: Continental margin lacking active plate boundaries at the contact of continental crust with oceanic crust.

Peridotite: Igneous rock consisting largely of olivine and pyroxene; an ultramafic igneous rock occurring as a pluton, also thought to compose much of the upper mantle.

Petrology is the branch of geology that studies rocks and the conditions under which they form. Petrology has three subdivisions: igneous, metamorphic, and sedimentary petrology

Plate tectonics: Theory that earth's crust and upper mantle (lithosphere) are broken into sections, called plates that slowly move around on the mantle.

Prevailing wind: The direction of wind most frequently observed during a given period.

Pyroclastic materials: The fragmental rock products ejected by a volcanic explosion having been broken by fire.

Quartzite: Metamorphic rock consisting largely of the mineral quartz.

Reservoir: Usually means an artificial lake, storage pond or impoundment created using a dam or lock to store water. Reservoirs can be created by controlling a stream that drains an existing body of water.

Rhyolite: Extrusive igneous rock of granite composition; it occurs as lava or tephra.

Ridge: An elongated area of relatively high altitude bordered by an increasingly low altitude side.

River capture: The diversion of waters of a weaker river into the system of a stronger river.

River profile: A section of a river from its source to its mouth.

River rejuvenation: The renewed erosive activity of a river.

River terraces: A portion of the former flood plain of a river now, abandoned and left at a higher level as the stream down cuts its sides

River: A mass of flowing water from a known source to a known destination

Rock or **stone** is a natural substance, a solid aggregate of one or more minerals or mineraloids.

Run off: The proportion of rain water that reaches streams either by flowing over ground.

Sandstone: Sedimentary rock consisting largely of mineral particles of sand size.

Schist: Foliated metamorphic rock in which mica flakes are typically found oriented parallel with foliation surfaces.

Sea: A body of salt water smaller than an ocean and generally in proximity to continent.

Seafloor spreading: The theory that magma from earth's mantle rises to the surface at mid-ocean ridges and cools to form new seafloor, which new magma pushes away from the ridge.

Sediment: Finely divided mineral matter and organic matter derived directly or indirectly from pre-existing rock and from life processes.)

Sedimentary rock: Rock formed from accumulation of sediment.

Shale: Fissile, sedimentary rock of mud or clay composition, showing lamination.

Siltation: It is the pollution of water suspended sediments dominated by clay and silt. Siltation is most often caused by soil erosion.

Slate: Compact, fine-grained variety of metamorphic rock, derived from shale, showing well-developed cleavage.

Slope: It is an inclined surface.

Snow: precipitation in form of white ice crystals

Soil: It is the thin layer of unconsolidated material covering the surface of the earth that is able to support plant life.

Spreading plate boundary: Lithospheric plate boundary along which two plates of oceanic lithosphere are undergoing separation, while at the same time, new lithosphere is being formed by accretion.

Steric effect: When some regions experienced sea level rise while others experienced a fall, often with rates that are several times to the global mean rate.

Subduction zone: In plate tectonics, the area where an ocean-floor plate collides with a continental plate and the denser ocean plate sinks under the less dense continental plate. It is a boundary between two crustal plates along which subduction is occurring and lithosphere is being consumed.

Subduction: Descent of the down bent edge of a lithospheric plate into the asthenosphere so as to pass beneath the edge of the adjoining plate.

Superimposed drainage: A drainage pattern which exhibits a discordant drainage: with the underlying rock structure because it is originally developed on a cover of rocks that have now disappeared owing to denudation.

Surface run off: The proportion of rain water that reaches streams either by flowing over ground or by seeping through the soil.

Syzygy: A term given to the situation when the earth, moon and sun are in conjunction or opposition. i.e. when they are all in a straight line.

Tectonic: Pertaining to the internal forces which deform the earth's crust thereby affecting the pattern of sedimentation or resultant landforms.

Terra Rosa: It is a reddish clay-loam soil developed under a warm seasonally dry climate on limestone.

Tethys Sea: inland sea from where the two blocks of landmasses separated

Tidal currents: A horizontal movement of sea water in response to the rise and fall of the sea or ocean.

Tide: The regular rise and fall of water level in the world's oceans, resulting from the gravitational attraction that is exerted upon the Earth by the sun and the moon.

***Tornado*:** A violently rotating column of air that extends from a thunderstorm to the ground and is often - although not always - visible as a funnel cloud.

Transform fault: In plate tectonics, a boundary between two plates that are sliding horizontally past one another.

Transform plate boundary: Lithospheric plate boundary along which two plates are in contact on a transform fault; the relative motion is that of a strike-slip fault.

Tsunami: Train of sea waves set off by an earthquake (or another seafloor disturbance).

Tuffaceous limestone: A sedimentary limestone that contains up to fifty percent volcanic tuff these are ash and cinders.

Ultramafic igneous rock: Igneous rock composed almost entirely of mafic minerals, usually olivine or pyroxene group.

Visibility: The longest distance that prominent object can be seen.

Volcanism: General term for volcano building and related forms of extrusive igneous activity.

Volcano: Conical, circular structure built by accumulation of lava flows and tephra.

Wave: Is a deformation of water surface in the form of oscillatory movement which manifests its self by an alternating rise and fall of that surface.

Windblown area: This is an area which experiences a lot of wind as an agent of erosion.