# Geography S6

## Student's Book

**Kigali, January 2019**

# FOREWORD

Dear Student,

Rwanda Education Board is honoured to present to you this Geography Book for Senior six which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of geography subject. The Rwandan educational philosophy is to ensure that you achieve full potential at every level of education which will prepare you to be well integrated in society and exploit employment opportunities.

The government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate your learning process. Many factors influence what you learn, how well you learn and the competences you acquire. Those factors include the instructional materials available among others. Special attention was paid special attention to the activities that facilitate the learning process in which you can develop your ideas and make new discoveries during concrete activities carried out individually or with peers.

In competence-based curriculum, learning is considered as a process of active building and developing knowledge and meanings by the learner where concepts are mainly introduced by an activity, a situation or a scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values. For effective use of this textbook, your role is to:

- Work on given activities which lead to the development of skills
- Share relevant information with other learners through presentations, discussions, group work and other active learning techniques such as role play, case studies, investigation and research in the library, from the internet or from your community;
- Participate and take responsibility for your own learning;
- Draw conclusions based on the findings from the learning activities.

I wish to sincerely extend my appreciation to the people who contributed towards the development of this book, particularly REB staff who organized the whole process from its inception. Special gratitude goes to the University of Rwanda which provided experts in design and layout services, illustrations and image anti-plagiarism, lecturers and teachers who diligently worked to successful completion of this book. Any comment or contribution would be welcome for the improvement of this textbook for the next edition.

**Dr. Irénée NDAYAMBAJE**

**Director General, REB**

# ACKNOWLEDGEMENT

I wish to express my appreciation to all the people who played a major role in development of this Geography textbook for Senior Six. It would not have been successful without active participation of different education stakeholders.

I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB in the in-house textbooks production project. I wish to extend my sincere gratitude to lecturers, teachers and all other individuals whose efforts in one way or the other contributed to the success of writing of this textbook.

Special acknowledgement goes to the University of Rwanda which provided content providers, quality assurers, validators as wellexperts in design and layout services, illustrations and image anti-plagiarism.

Finally, my word of gratitude goes to the Rwanda Education Board staff particularly those from the Curriculum, Teaching and Learning Resources Department (CTLR) who were involved in the whole process of in-house textbook writing.

**Joan MURUNGI,**

**Head of Curriculum, Teaching and Learning Resources Department (CTLR)**

# TABLE OF CONTENTS

# UNIT 1

## CROSS SECTIONS AND SKETCH MAPS

# UNIT 1: CROSS SECTIONS AND SKETCH MAPS

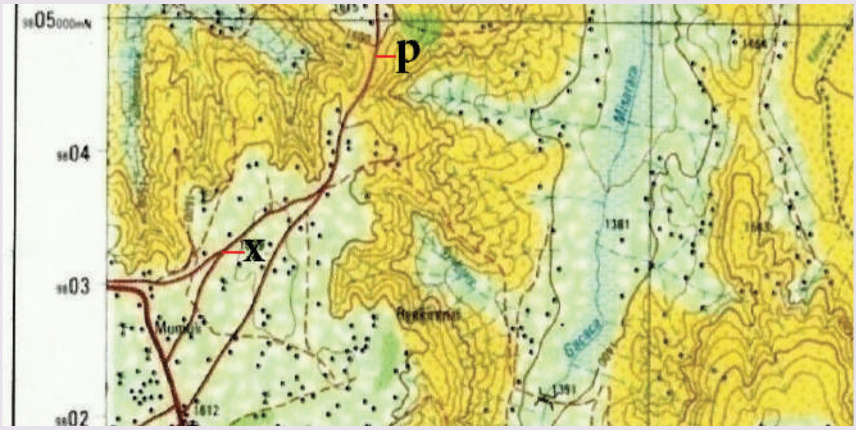
## Key unit competence:

By the end of this unit, I should be able to draw cross sections and sketch maps by reduction or enlargement.

### Introductory activity

Using the previous knowledge and skills acquired in S4 and S.5, study the extract of the topographic map of Rwanda provided below to answer the following questions:

Map of Rwinkwavu

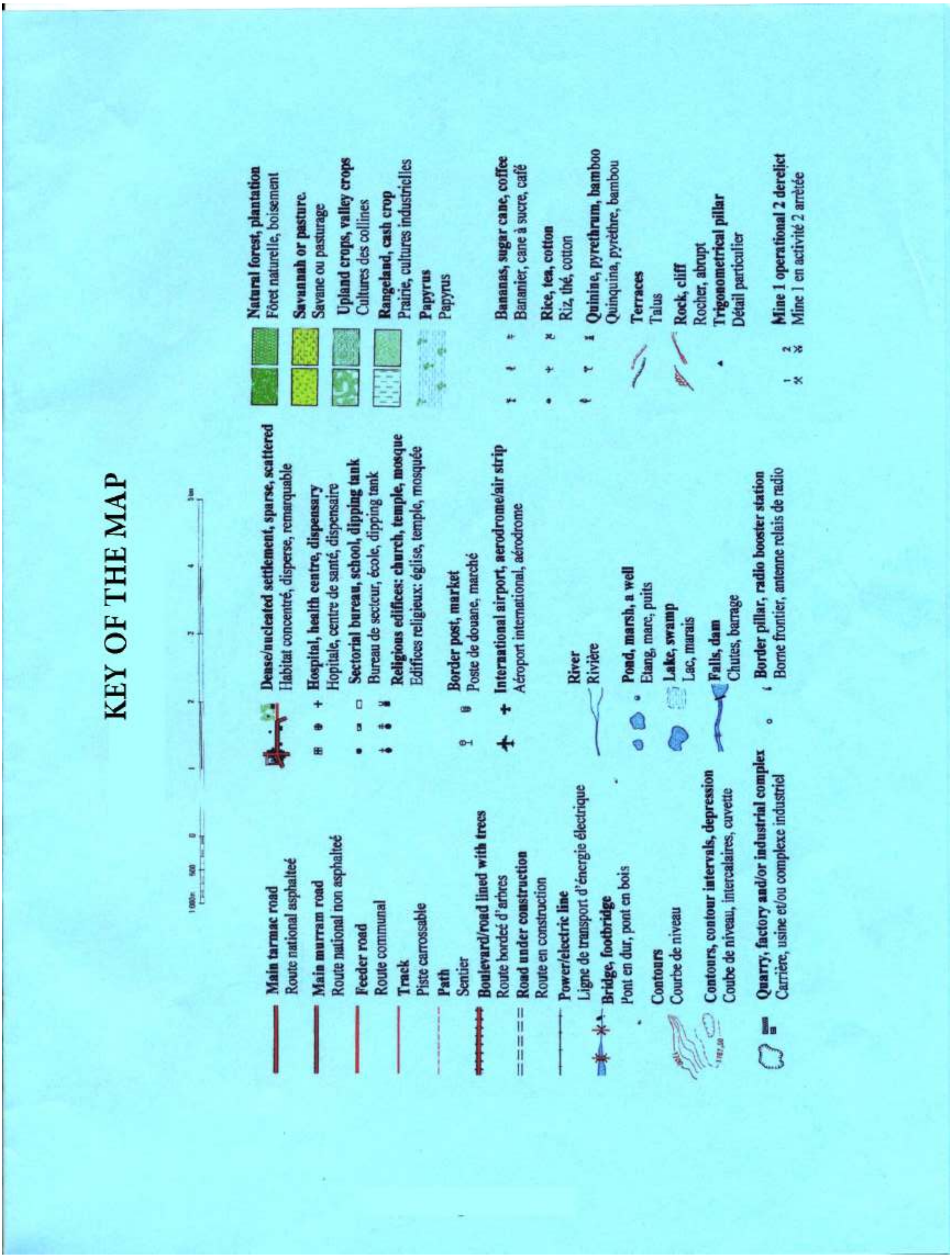



*Source: © Service de Cartographie du Rwanda 1989*

*Scale: 1:50,000*

1. Use the above map to measure the distance from X to P
2. Describe the relief on the map above

## 1.1. Contour, contour interval and importance of contours

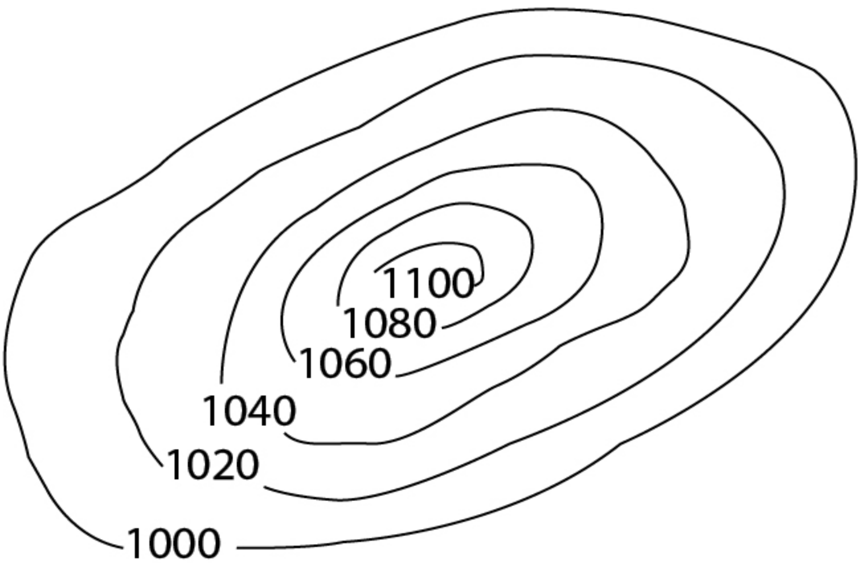


Learning activity 1.1

1. Explain the meaning of the term contour
2. Discuss the reasons why contours are important in map work

**A contour** is a line drawn on a map joining all the places with the same height above sea level.
Contours cannot cross each other because each has its own fixed height and they can be close to one another in case of steep slopes. Contours are drawn at constant intervals known as the contour interval (CI). This is also called Vertical Interval (VI).

C**ontour interval** is the difference in height between two adjacent contour lines. Contours are labeled from the lowest to the highest altitude as shown below.




*Contour Interval / Vertical Interval (VI)= 20 m*

*Figure 1.1 Contours*

In the study of geography, contours are important to analyze the landforms:

- They help to identify landforms like hills, plateaus, mountains and valleys on a topographic map by analyzing the contour patterns formed by contour lines.

- Hills/mountains on a topographic map are shown as concentric rings of contours with the highest values in the middle.

- In cases where contours are very close to each other, the relief of the area is steep.

When contours are separated by a wide space that shows a flat land.

## Application activity 1.1

Use the topographic map provided below to describe contours represented on the map and their interval.

**MAP OF KARONGI**

*Scale: 1:50,000*

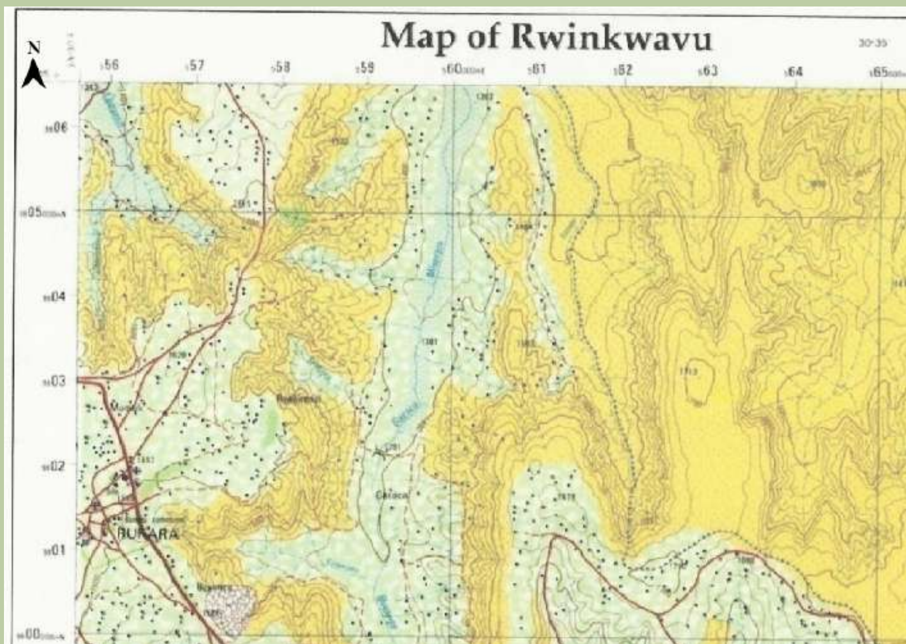

*Source: National Institute of Statistics of Rwanda*

## 1.2. A cross-section

### Learning activity 1.2

Use the topographic map provided below to identify flat slopes, gentle slopes and steep slopes.

*Scale: 1:50,000*




***Source:*** *© Service de Cartographie du Rwanda 1989*

A cross section is a topographical profile drawn between two points taken along a straight line. It normally shows changes in relief of the area indicated by two points on a topographic map.

When drawing a cross section, the following steps are followed:

- Determine the beginning and the end points of the section.
- Draw a straight line lightly in sharpened pencil from one point to another.
- Place a piece of paper with a straight edge along the pencil line.
- Mark the contour values and other important information like rivers, settlements, roads, on the paper.
- Transfer the information on the paper to your graph paper and mark the point

on the cross section.

- Construct a frame with two vertical lines whose baseline is equivalent to the length of the line between the two points marked on the map.
- Join all the points with a curved line following the dots on the paper to decide the bends of the line.

An example of drawing a cross section is given on the map below. The area of study is represented by the line between point A and point B.

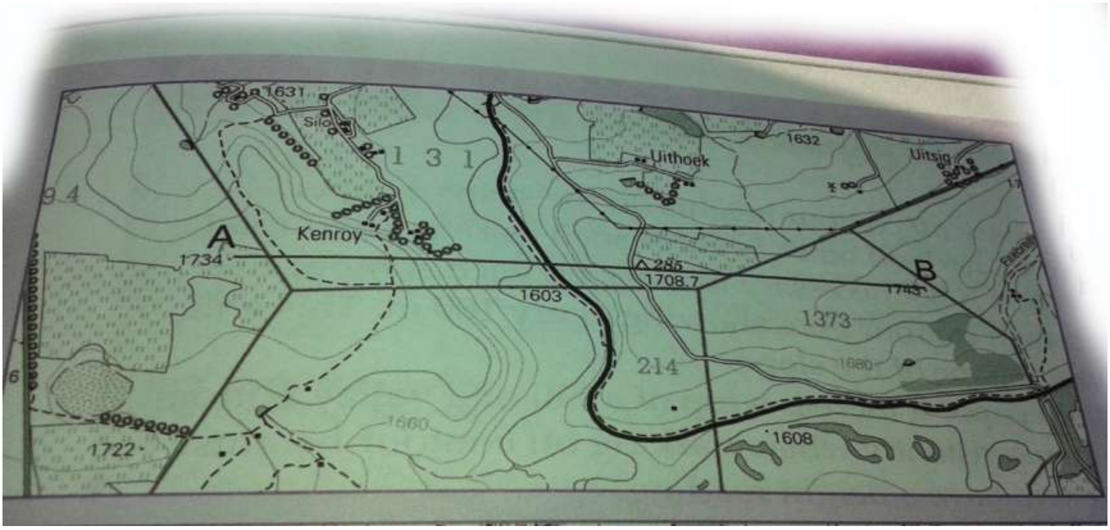



***Figure 1.2*** *Line cross cutting the area of study*

To do this exercise, consider the following steps:

- Place a piece of paper on a map above along the line marked A and B
- Mark all the contours heights on the paper as shown below

The map below indicates further steps followed in recording contours on paper. These contours indicate elevation and distances in two dimensions.

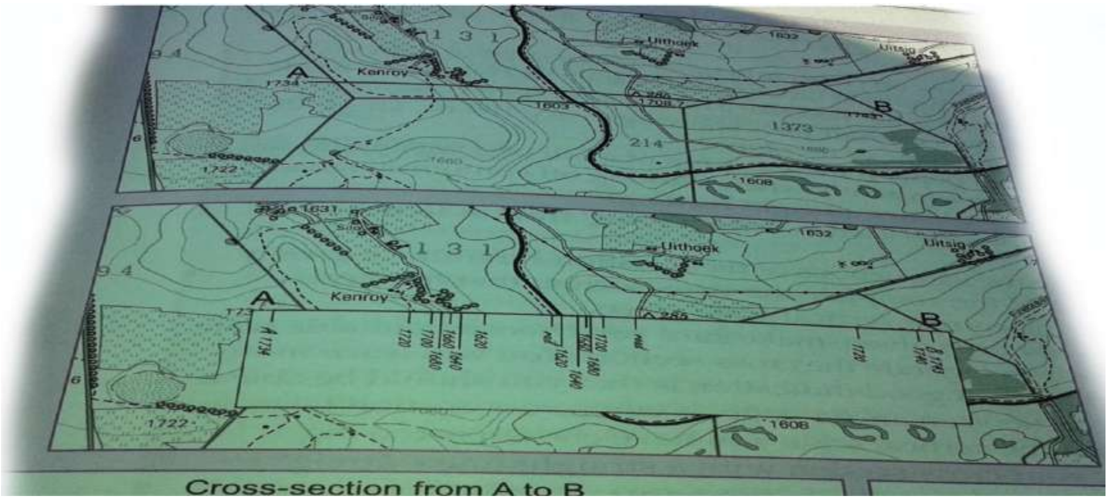



*Figure 1.3 Marked contour lines on the map*

- Draw two vertical lines at each end of the horizontal line, these will represent the Y -axes where the mark off the vertical scale will be made.
- Label point A and point B on the other end of the horizontal axis.
- Use the information on the paper to mark the highest and lowest heights marked along the line A and B.
- Label the horizontal axis by writing the horizontal scale
- Label the vertical axis by writing the vertical scale.
- Write a title of the cross-section: cross-section from point A to point B
- Join all the dots on the graph using a free-hand line.
- Make sure the cross-section line links to points A and B on the vertical axes.

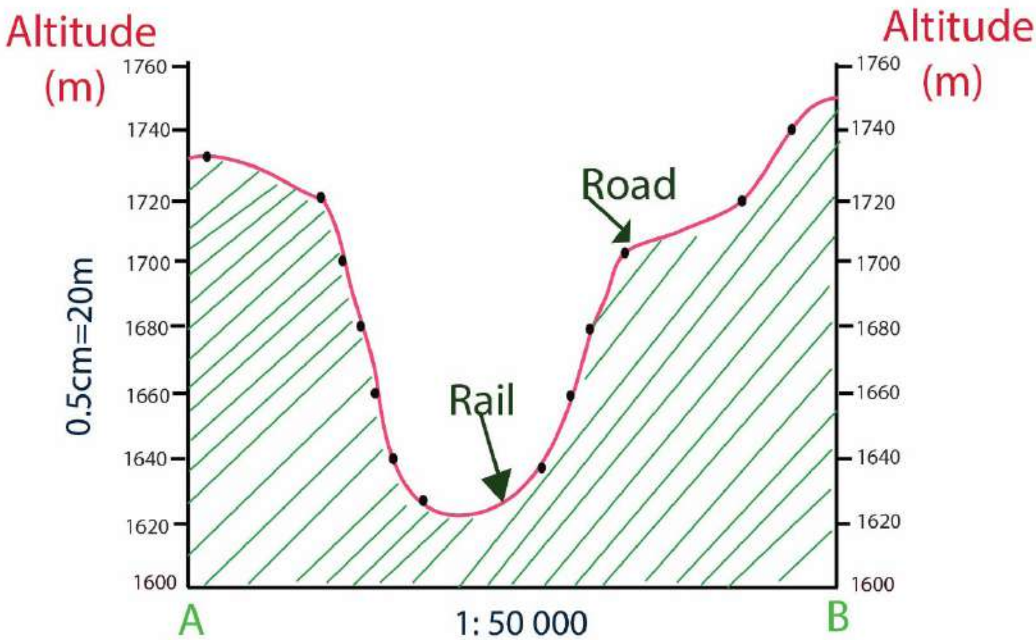
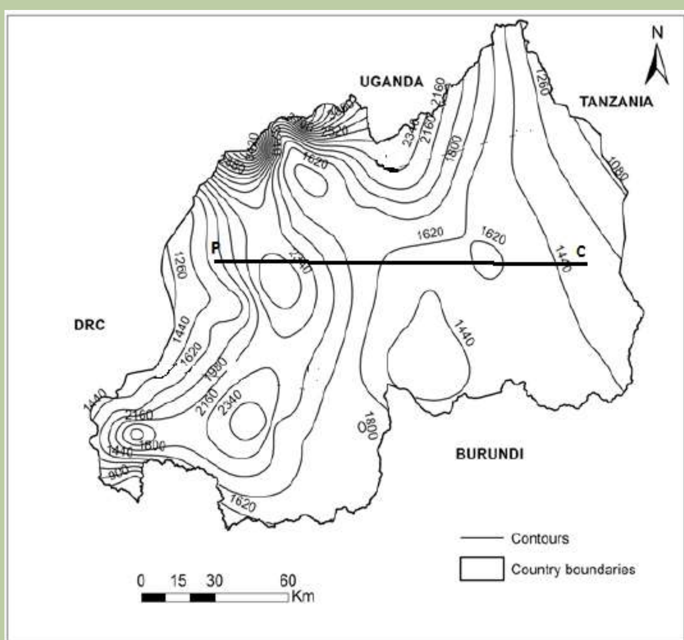


*Figure 1.4 A complete cross-section between points A and B*

## Application activity 1.2

Use a topographic map provided below to draw a cross section between point P and C.



## 1.3. Determining vertical exaggeration, the gradient, amplitude and inter-visibility

Learning activity 1.3

1. Using different types of maps identify and explain different types of scale.
2. Make research and explain the meaning of these terms: a) Vertical exaggeration *b) Gradient*

### 1.3.1. The vertical exaggeration

The vertical exaggeration is the relationship between the vertical scale and horizontal scale. It is calculated after drawing a cross section.

**Vertical Exaggeration (VE)** $=\frac{\textit{vertical scale}}{\textit{horizontal scale}}$ or VE= $\frac{vs}{Hs}$

Using the cross section drawn in figure showing a complete cross-section between points A and B presented above, vertical exaggeration is calculated as follows:

**VE (vertical exaggeration)=** $\frac{VS\ \textit{(vertical scale)}}{HS\ \textit{(horizontal scale)}}$

- To determine the vertical scale, refer to the scale given when asked to draw a cross-section, e.g. 0.5 cm represents 20 m. This scale needs to be converted into centimeter units to be used in the formula.

0.5 cm = 20 m

0.5cm = 2000cm

5cm = 20,000cm

1cm = 4000cm

Therefore, 1cm represents 4000 cm

- On topographic maps, the horizontal scale is most of time the same 1: 50,000, i.e. 1 cm represents 50 000cm.
- As all units have been converted into centimeters, insert these measurements into the formula.

$$VE = \frac{vs}{Hs} = \frac{\frac{1}{4000}}{\frac{1}{50000}} = \frac{1}{4000} \times \frac{50000}{1} = 12.5 \text{ times}$$

The vertical exaggeration (VE) = 12.5 times

### 1.3.2. The gradient

Gradient refers to the steepness of a slope between two places expressed as a proportion between the vertical intervals (VI) and horizontal equivalent (HE).

When two places are located at different heights (altitude), the difference in height between them is known as the vertical rise or the vertical interval (V.I).

The horizontal distance is the distance between the two places represented on a map which is corresponding with the real distance on the ground.

Gradient is calculated as follows:

- Plot the two points on the map which are needed to determine the gradient. Name them for instance as A and B or X and Y.
- Join those two points by a straight line.
- Use the scale to measure the distance between A and B (H.E). Let us consider the distance to be 8 cm.
- Calculate the actual ground distance using the map scale. If the scale of the map is 1:50,000 meaning that 1 cm on the map represents 50,000 cm on the ground. Therefore, the ground distance of the represented area would be 8 x 50,000 which 400,000 cm = 4000 m.
- Calculate the difference in height between points A and B, using the contours. For example, the difference in height between A and B is 200 m.
- The formula for calculating the gradient is:

$$\text{Gradient} = \frac{\text{vertical interval}}{\text{Horizontal equivalent}} \quad G = \frac{V.I.}{H.E.}$$

Therefore, in this example, the Gradient $= \frac{200m}{4,000m} = \frac{1}{20}$

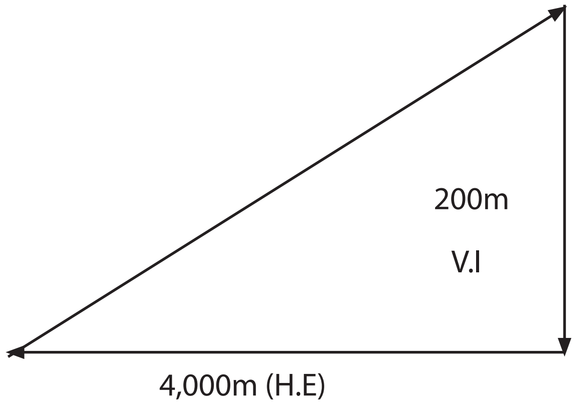



*Figure 1.5 Gradient between A and B*

### 1.3.3. Amplitude

Amplitude refers to the difference between the highest altitude and the lowest altitude along the cross section.

### 1.3.4. Intervisibility

Intervisibility refers to whether one point on a map can be seen from another point.

- A point is intervisible when it can be seen from another point, i.e. there is no higher land between the two points.
- A point is not intervisible when there is higher land or some obstruction that blocks being able to see one point represented on a map from another point.
- Intervisibility can be established by drawing an intervisibility line between two points on a cross- section.
- Intervisibility can also be established by looking at the contour heights on a topographic map between two points to see if there are any higher areas of land blocking the view between these two points.

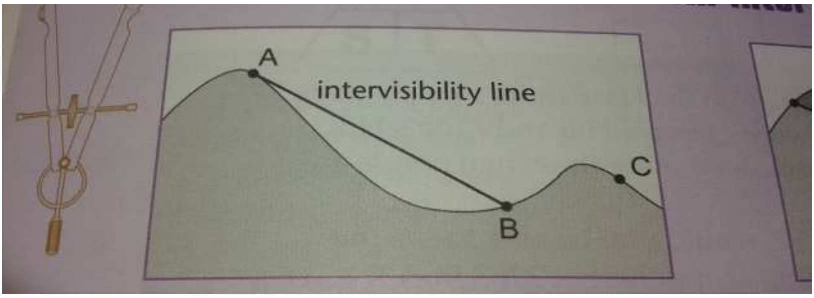



*Figure 1. 6 Cross-section from point A to point B. Point A is intervisible from point B*

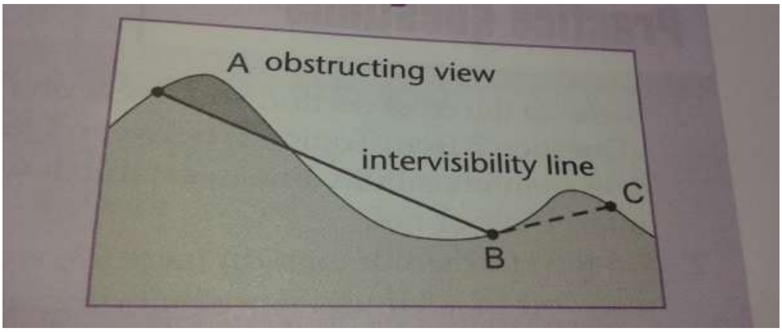


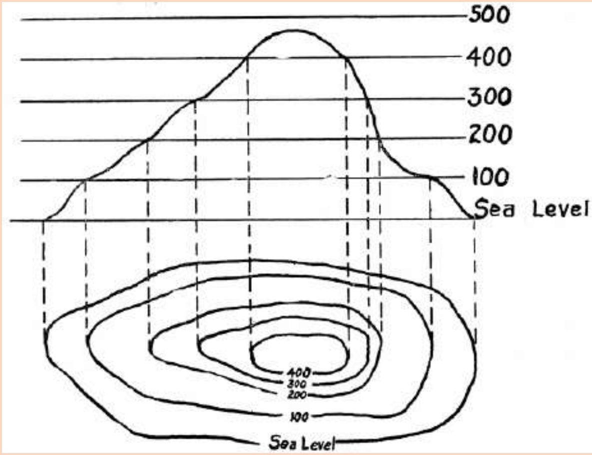

*Figure 1.7 Cross-section from point A to point B. Point A is not inter-visible from point B*

- On the cross-sections in Figure 1.6 and 1.7 draw a straight line (an intervisibility line) between the two points A and B on each sketch.
- In Figure 1.6, the intervisibility line is above the cross- section at all heights. This means that point A is inter-visible from point B.
- In Figure 1.7, the intervisibility line is below the cross-section in one section. This means that point A is not intervisible from point B.

When checking for intervisibility on a topographic map, join the two places with a straight light line using a pencil or place a ruler along a line between the two points. Check the heights all along this line to see if there is higher land blocking the view between the two points.

## Application activity: 1.3

Use the figure below to calculate the amplitude of the area indicated




## 1.4. Drawing sketch maps

## Learning activity 1.4

Move around your school and draw the site of the school compound in your note book and explain the steps followed in drawing that sketch map.

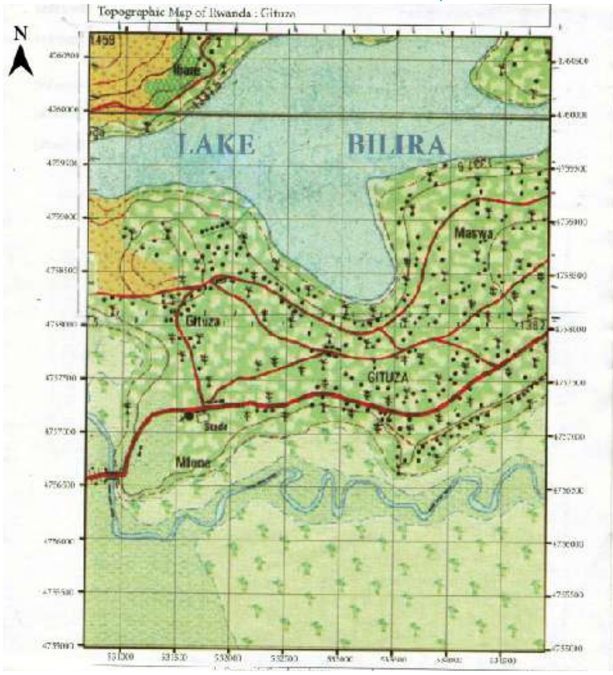
**A sketch map** is a simple representation of part or whole of a sheet map drawn on a piece of paper without using a given scale.

When drawing a sketch map, use the following procedures:

- Identify and critically observe the area to be sketched on the map given.
- Measure the edges of the map.
- Make a frame by either reducing or enlarging the map as instructed.
- Indicate both physical and human features as requested.
- Provide the key for the sketch map.

The following are examples of a map and a drawn sketch map of Gituza respectively:

Scale: 1:50,000




***Source:*** *© Service de Cartographie du Rwanda 1989*

*Figure 1. 8 Topographic map of Gituza*

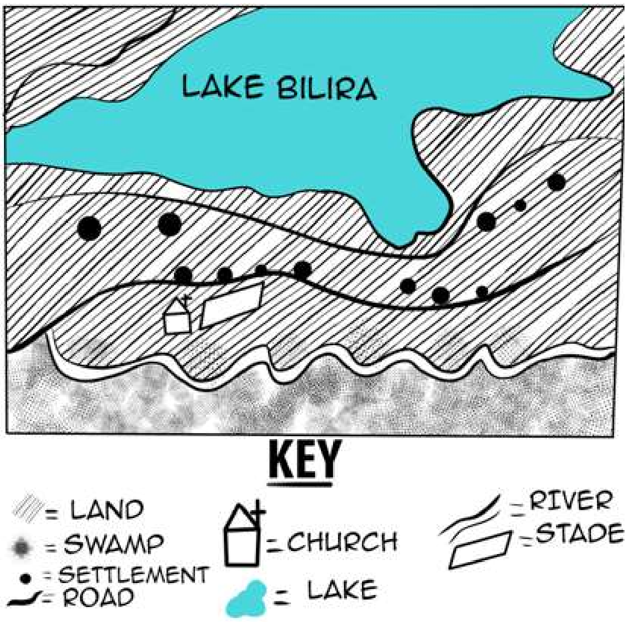



*Figure 1.9 Sketch map of Gituza*

Application activity 1.4

Make a field trip around your school and draw a sketch map of the nearby market place.

## 1.5. Enlargement and reduction of a map

Learning activity 1.5

1. Draw a sketch map of your school, identify, mark and name the features found there.
2. Use the same sketch map drawn in (a) above:
   i. To reduce it by 2 times
   ii. To enlarge it by 2 times

### 1.5.1. Map Enlargement

Map enlargement refers to the changing of the size of a given map to a bigger one. It becomes bigger depending on the number of times it is enlarged. For example, it may be decided that part of a map is enlarged, and its outline drawn.

The following steps should be followed:

- Identify an area of the original map or part of the map to be enlarged.
- Measure the length and width of the original map or identified part of the map.
- Multiply the length and width by the number of times the map is to be enlarged.
- Draw an outline that has new dimensions.
- Mark and label the features in their relative positions.
- The scale also changes (becomes bigger).


*Figure 1.10 Map of Africa*

The following map of Africa has been enlarged by 2 times from the above map.

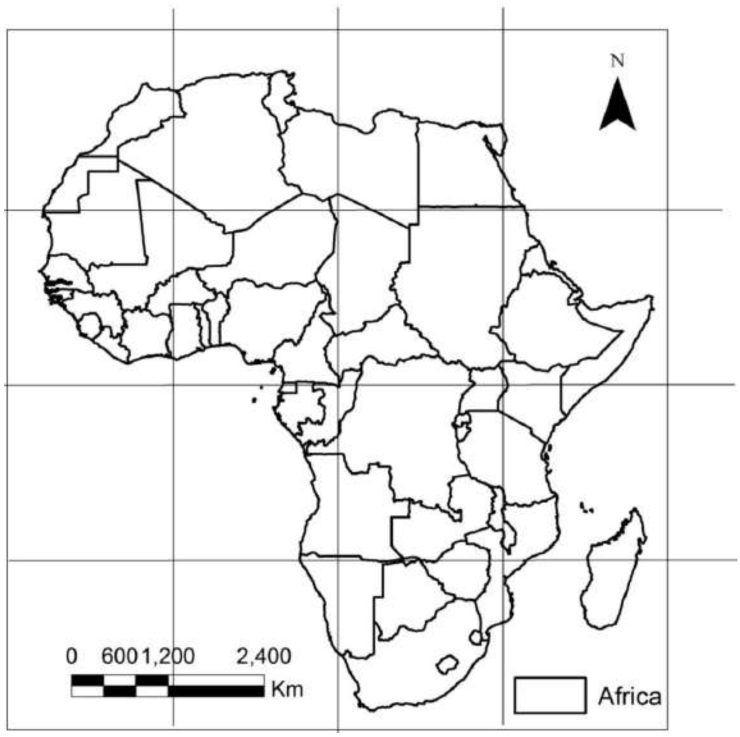



*Figure 1.11 Enlarged map of Africa*

### 1.5.2. Map reduction

Map reduction refers to the changing of the size of the map to a smaller one. Below are the steps to follow for map reduction:

- Measure the length (L) and width (W) of the given part or whole map. For example, L=11cm and W=10.8cm.
- Divide the length and width by the number of times the given map is to be reduced or as directed by the demands of the question. For example, by 2 times.

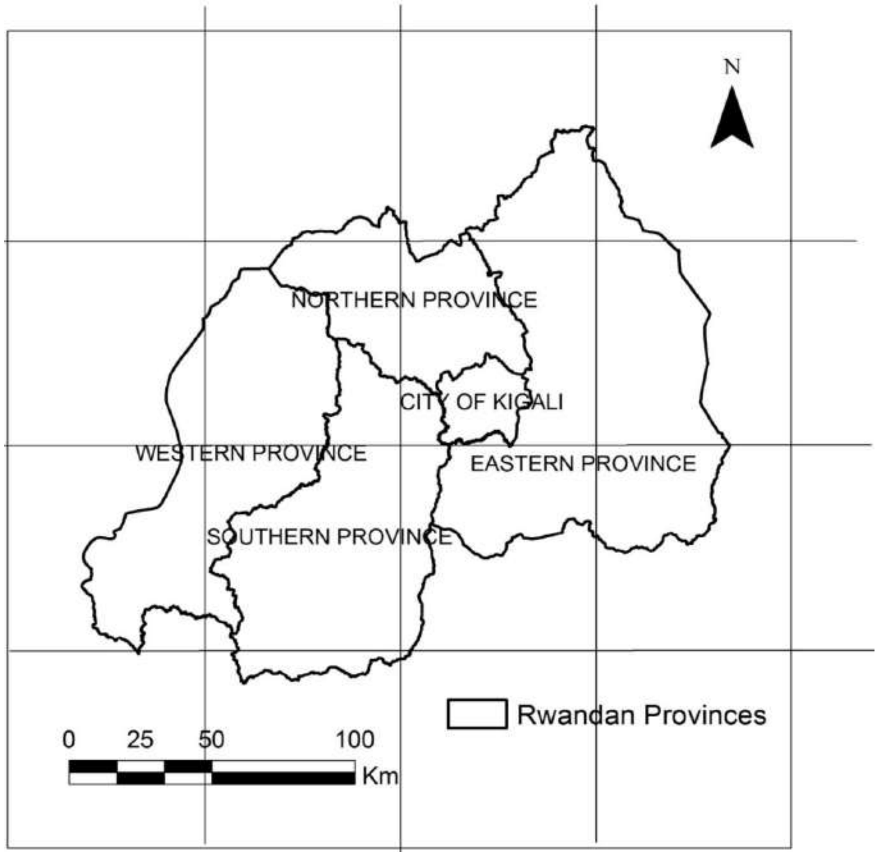



*Figure 1. 12 Map of Rwanda*

- Draw an outline that has the new length and width. For example, L=5.5cm, W=5.4cm.
- Mark and label the features in their relative positions.
- Use a key to label features in the map.
- The scale changes (becomes smaller).

An example of a reduced map can be seen below:


*Figure 1.13 Reduced map of Rwanda*

## Application activity 1.5

Reduce by two the administrative map of Rwanda provided below and draw its outline.

Scale: 1/40,000

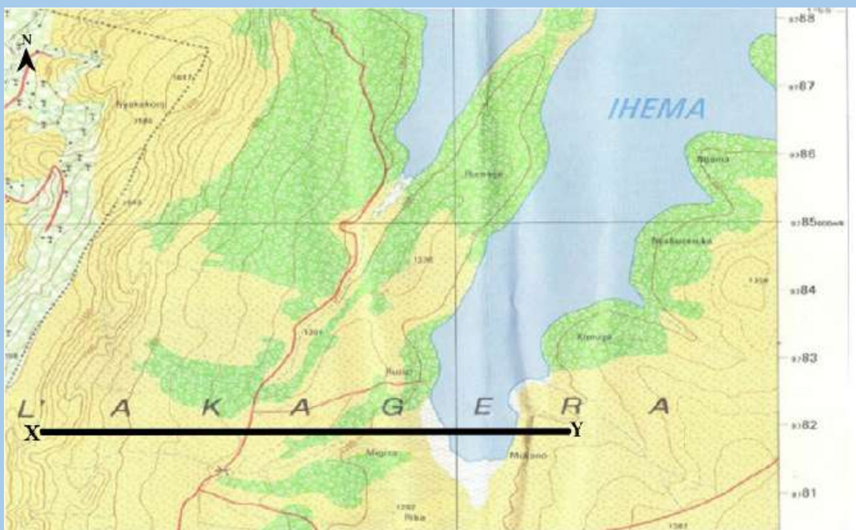

*Source : Macmillan (2006), Geography Atlas, Malaysia.*

## End unit assessment

1. Explain how contours help to describe the relief of an area.
2. Make a visit of the school compound; draw its sketch map indicating on it all observed physical and human features.
3. Use the topographic map provided below and answer the following questions:

MAP OF AKAGERA

Scale: 1:50,000




***Source**: © Service de Cartographie du Rwanda 1989*

i. Draw a cross section between point X and Y, make a class presentation.
ii. Enlarge two times the area on the map south of the northings 85 and draw its outline.

# UNIT 2

# INTERPRETATION OF PHOTOGRAPHS AND VIDEO IMAGES

# UNIT 2: INTERPRETATION OF PHOTOGRAPHS AND VIDEO IMAGES

## Key Unit Competence:

By the end of this unit, I should be able to interpret photographs, video images and draw sketches by reduction or enlargement of the photographs.

### Introductory activity

In the previous unit, it was shown that maps are very important tools to indicate and to describe physical and human features. Describe other ways used in geography to show physical and human features.

## 2.1. Definition and types of photographs

### Learning activity 2.1

Provide the difference existing between the two photographs provided below

### 2.1.1. 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 ways 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 be seen clearly. A hidden ground/area which cannot be seen by a camera when a photograph is taken is called a **dead ground**.

### 2.1.2. Major types of photographs

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

1. Ground Photographs

*Figure 2.14: Livestock farm ground photograph*

**Ground photographs:** These are photographs taken from the ground level. They record exactly what a person would see if he / 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 categories 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**.**

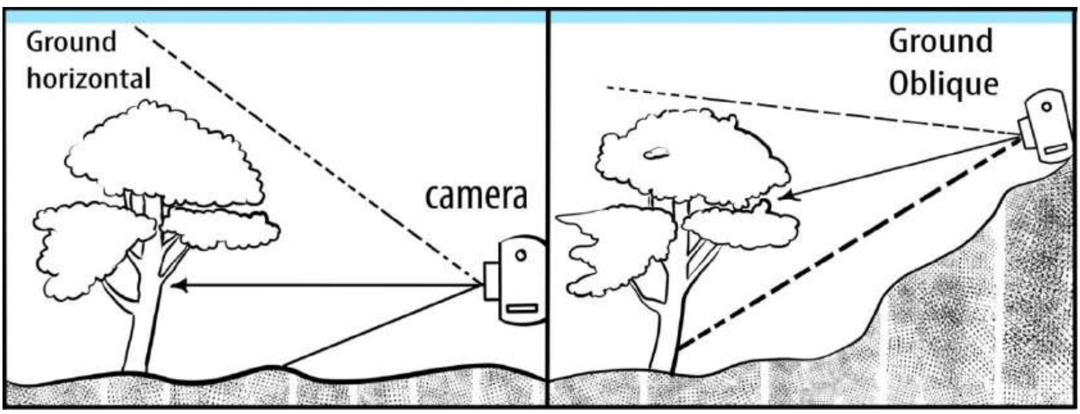



*Figure 1. 15 Ground photographs*

## 2. Aerial Photographs

*Source: httpswww.google.comsearchq=aerienen+of+photo+of+kigali+city*
***Figure 2.16*** *Aerial photograph of Kigali*

**Aerial photographs:** These are photographs taken from aerial station using aircrafts, satellites, and other flying objects**.** They cover a wide area, features are greatly reduced, show the top of the object, do not show the horizon. There are two categories of aerial photographs:

i. **Vertical aerial photographs**: These are photographs taken when the camera is directly above (overhead) the objects or when it is perpendicular to the ground.

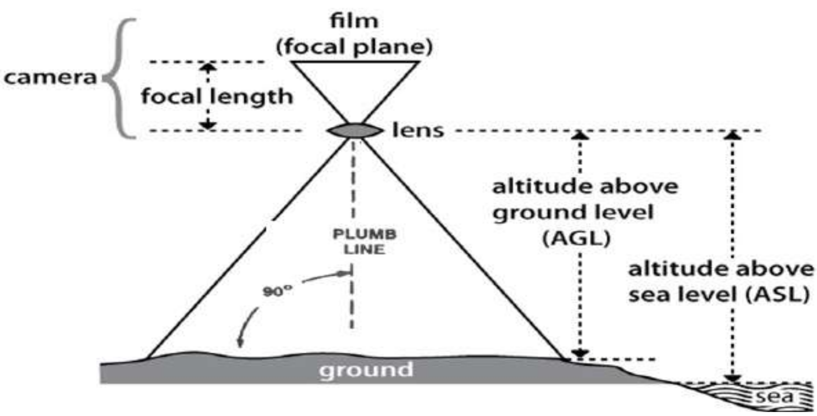



*Figure 2.17 Vertical aerial photograph*

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

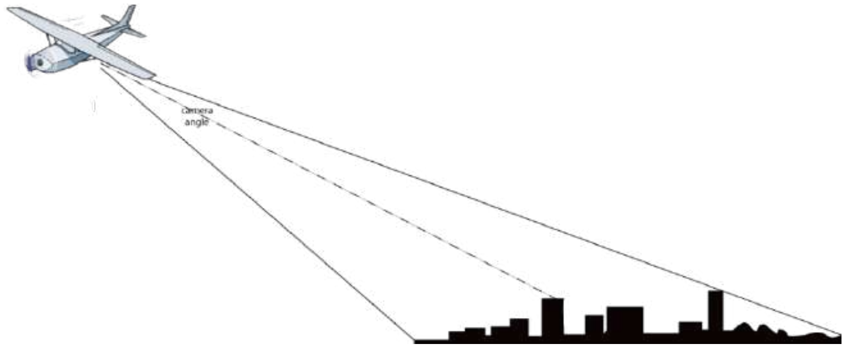


Figure 1.18 Oblique aerial Photograph

## Application activity: 2.1

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

A

B

## 2.2. Sections of a photograph and interpretation of physical and human aspects

### Learning activity 2.2

Observe the photograph below and answer the following questions:

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

### 2.2.1. Sections of a photograph

From a horizontal perspective, photographs fall under three categories as indicated 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 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 |

### 2.2.2. 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 features of the relief 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 2.2

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

## 2.3. Drawing sketches of photographs by reduction or enlargement

### Learning activity 2.3

Draw a sketch of the photograph provided below and explain the steps involved in drawing it.

A sketch of a photograph focuses on the identification, marking using symbols and labeling marked features in their relative positions. Sketching takes into account physical and man-made features and should reflect the proportional size of features.

To draw a sketch of a photograph by enlargement or reduction requires the following steps:

i. Draw a rectangle and a square of the size as requested on a piece of paper.
ii. Draw horizontal lines across the photograph by using a pencil to subdivide it into three equal sections. These will be the foreground, middle ground and background either reduced or enlarged as instructed.
iii. Draw vertical lines across the photograph by using a pencil. These will be left, centre and right.
iv. Place the framework of a photograph onto the prepared rectangle or square. The framework could be the guider in placing the various features in their respective positions.
v. Enlarge or reduce the size of features and the frame as requested.
vi. When filling in the main features, it is better to start with the background or right by drawing the skyline as it appears on the photograph.
vii. It is better to place and label all important features either physical or human as they appear on the photograph, reduce or enlarge them as required.
viii. Choose a suitable title, key, orientation of a sketch. It is possible to put on a sketch other elements of a sketch map which are useful in reading and interpreting it.

Therefore, a sketch of a photograph can be enlarged or reduced as shown below:

*Figure: 1.19 Linear Settlement and its surroundings*

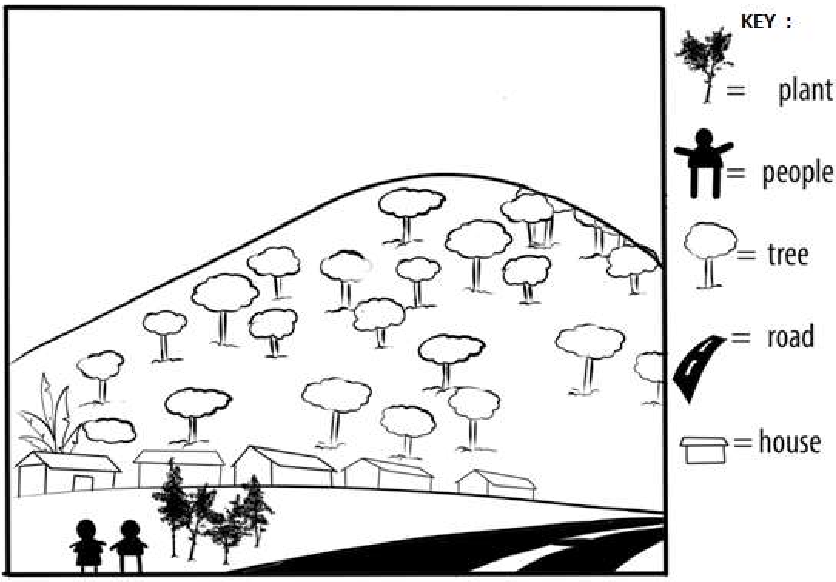



*Figure 1.20 A reduced sketch photograph of linear settlement and its surroundings*

*Figure 1.21 A house in rural area*

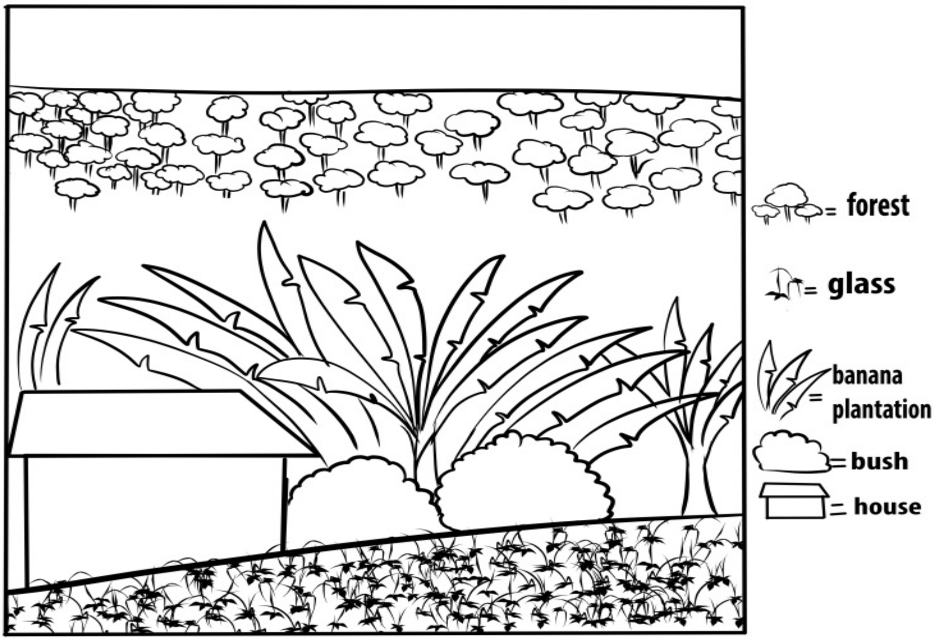



*Figure 1.22 An enlarged sketch photograph of rural settlement*

## Application activity 2.3

Draw a reduced sketch by 2 times of the photograph provided below and indicate all features represented on the photography.

## 2.4. Relationship between physical and human aspects on photographs and video images

### Learning activity 2.4

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

Some photographs and video images help in showing the relationship between human and physical aspects. The relationship between human and physical aspect is discussed basing on the photograph below:

***Figure:*** *1.23 Photograph showing human activities and physical features in Rwanda*

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: S**ettlement 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 2.4

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

## End unit assessment

1. Explain the key guidelines followed in drawing a sketch of a photograph.
2. Study the photograph provided below and answer the following questions:

   a. Identify the economic activities taking place and describe their importance to the people living in the area.

   b. Suggest ways of conserving the area in the background of the photograph for environmental sustainability.

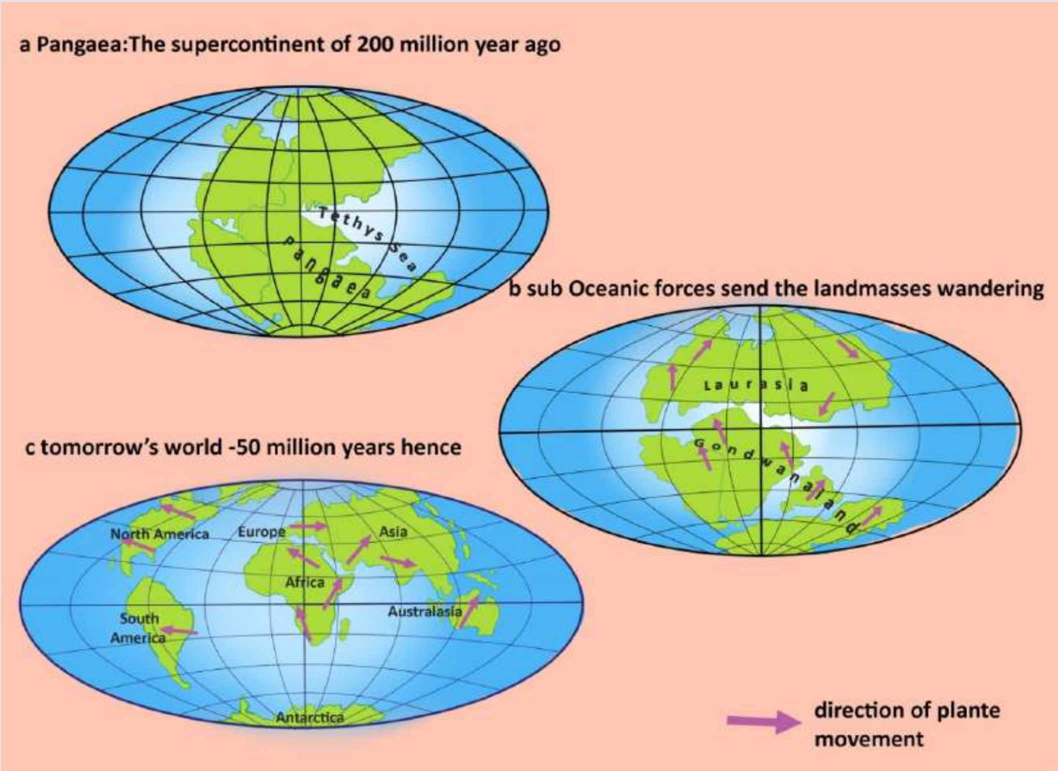
# UNIT 3

## THE ORIGIN AND DISTRIBUTION OF THE CONTINENTS

# UNIT 3: THE ORIGIN AND DISTRIBUTION OF THE CONTINENTS

## Introductory activity

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




*Source:* *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

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.

## 3.1. Concept and theories of continental drift

> **Learning activity 3.1**
>
> Make research using books and internet to explain briefly the theories related to the continental drift.

### 3.1.1. 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.

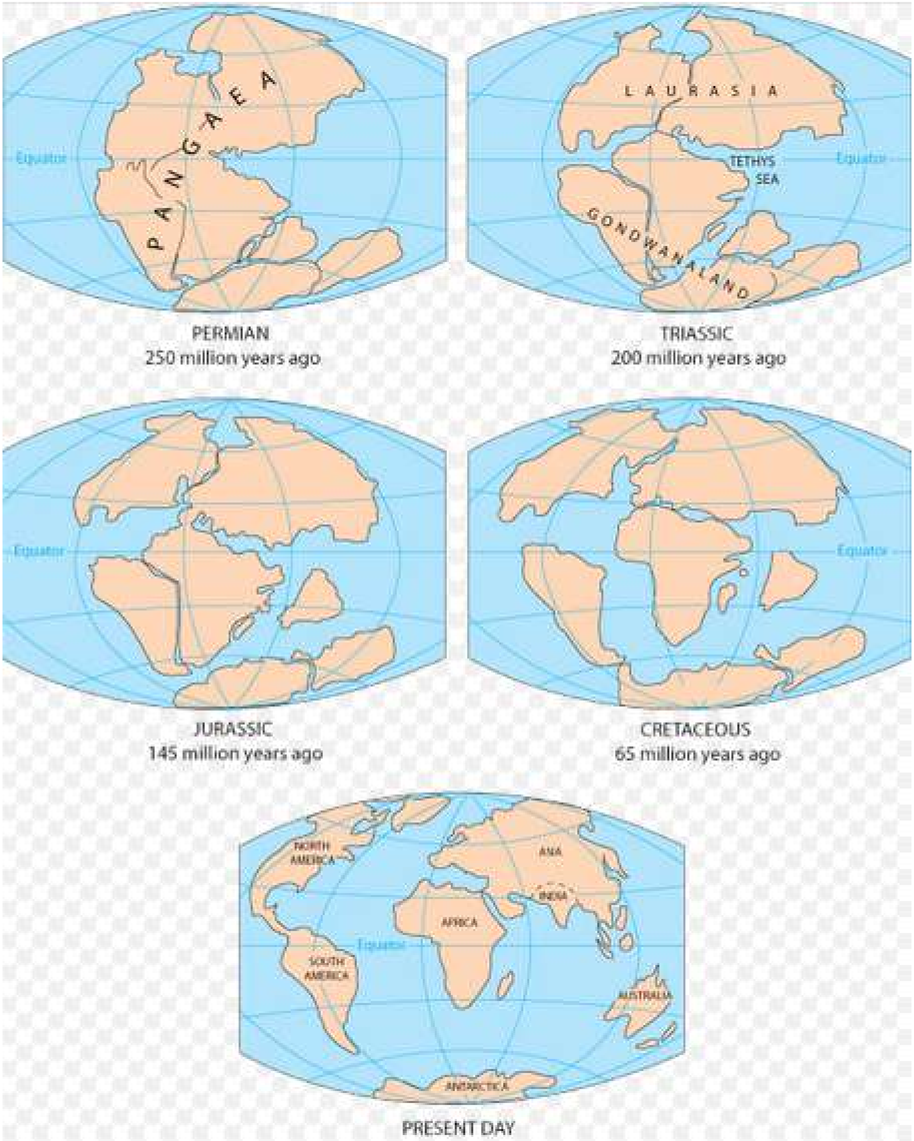
### 3.1. 2. Theories of the origin and distribution of the continents and ocean basins

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
- Frank Taylor's theory

#### a. Alfred Lothar Wegener's theory

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.




***Source**: Stephanie Pappas, 2012, Contributor*

***Figure 3. 24** 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 3.24). 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.

### f. Maurice Ewing's theory

Maurice Ewing confirmed the existence of Mid-Atlantic Ridge which is a mountain range extending the entire length of the ocean bed which is about 1000 km wide and rises 2500 m in height. Also, Ewing's studies argue that rocks of this range were volcanic and recent in origin. Similar ranges were later discovered on other oceans' floors.

### g. Harry Hammond Hess's Theory: Sea-Floor Spreading

The Seafloor spreading theory suggests 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.

The Sea-Floor Spreading theory was put forward by an American Geologist, Harry Hess. *Sea-floor spreading* occurs along mid-ocean-ridge; when the tectonic plates slowly moves away from each other, hot magma from the mantle comes up to the surface. As magma cools by the seawater the rock forms a new part of the crust.

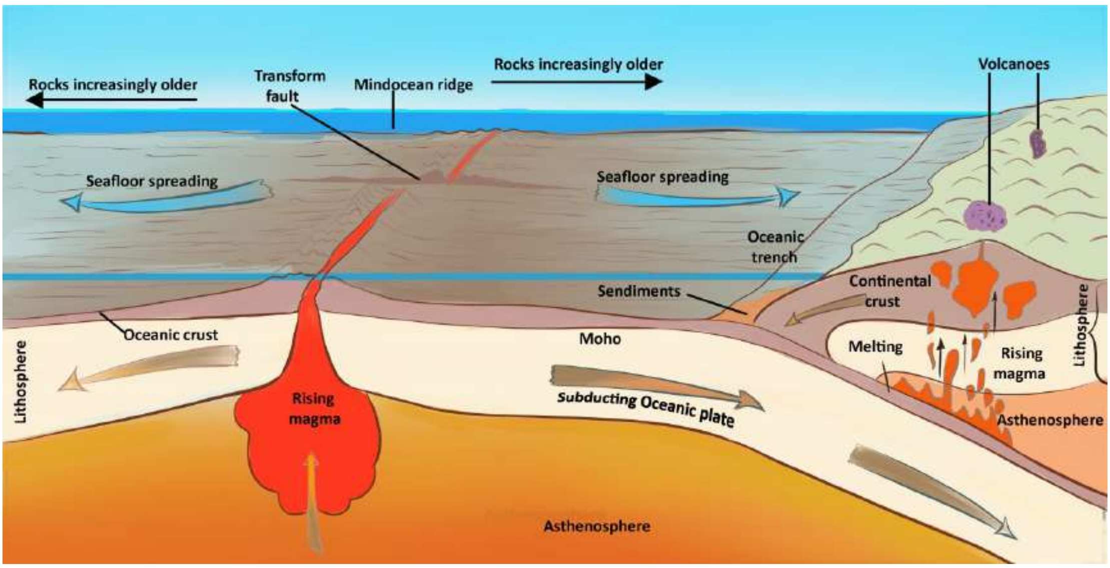
The interior of the Earth is in a molten (semi-fluid) state because of great heat resulting from radioactivity within the asthenosphere. This tremendous heat causes melting, or near-melting of rocks of the interior of the Earth. The molten rocks tend to rise from within the mantle in form of convection currents.

Material heated by radioactive elements in the earth's interior slowly rise in the crust. This magma reaches the surface along the Mid-oceanic ridges and flows away from them, cooling and hardening to form the rigid lithosphere.

New lava emerging from the ridges attaches itself to the near solidified older lava plates and forces them to move laterally.  Hess's studies demonstrated that after millions of years the lithospheric plates will have moved thousands of miles by constant additions of new lava at their rear.

The leading edges were eventually forced to sink down into the lithosphere under the continental crust block thus forming deep ocean trenches along the edge of continents. In this "recycling" process, later named "*seafloor spreading*", older sediments and fossils are carried off in the subduction zone, and continents are moved as new ocean crust spreads away from the ridges.

Hess explained how the once-joined continents had separated into the seven that exist today. The newest rocks were in the centre of the ocean, and were still being formed in Iceland, and that the oldest rocks were those nearest to the USA and the Caribbean. He also suggested that the Atlantic could be widening by up to 5 cm a year. This process produced by mantle convection currents was named the "*Sea floor spreading*".




***Source:*** *M., T. H. (2018, January 12).ENCYCLOPÆDIA BRITANNICA. Retrieved February 11,*

***Figure 3.25*** *Seafloor spreading*

### h. Taylor's theory

Frank Taylor's theory states that the original Laurasia was located near the current North Pole, whereas Gondwanaland was located near the South Pole. Both landmasses radially moved to the Equator. Their collision would have resulted in the formation of folded mountains, such as Atlas, Alps mountain ranges and others.

He suggested that Laurasia and Gondwanaland were forced to move from their former positions because of the ***moon's tidal attraction***. According to this theory, the moon came very close to the earth during the cretaceous period.

This closeness of the moon to the earth exerted powerful tidal attraction, which pulled the landmasses from their polar position towards the Equator. Where there was resistance to the outward spread of landmasses, the crust usually would fold, raising mountain ranges in front, while resulting in stretches (troughs and basins).

The present basins of Southern Atlantic and Indian Oceans were formed in this way.

Taylor's arguments about continental drift have however been criticized:

- The theory doesn't clearly demonstrate how the causes of the movement of continents from their polar positions ought to have been from within the earth and not outside it.
- The theory was rejected because researchers of his time doubted how the moon could ever exert enough force to pull the huge landmasses (continents) as they are known today.
- Finally, Taylor doesn't explain the formation of earlier fold mountains like the Caledonian system of Siluro-Devonian times while explaining the possible formation of the fold mountains Atlas and Alps.

### Application activity 3.1

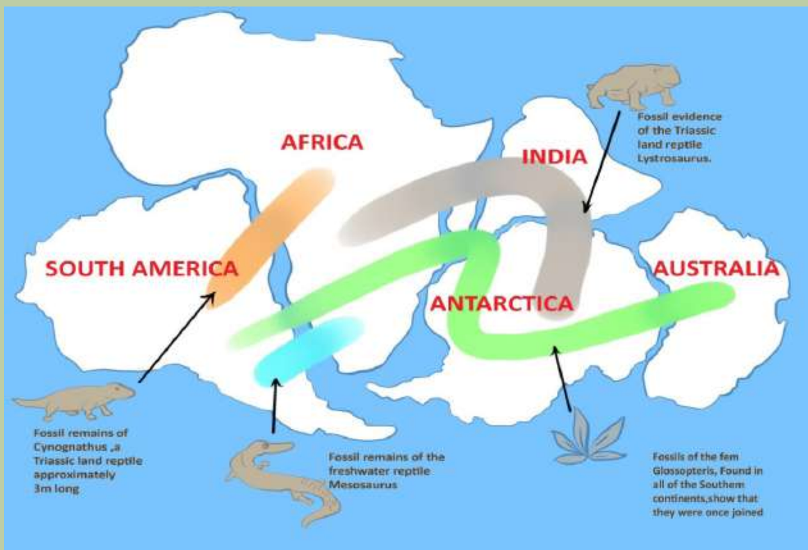
1. Discuss the contribution of each researcher's findings described in this section to the confirmation of continental drift.
2. Referring to the different theories of continental drift, explain why Taylor's theory about Moon's tidal attraction has been rejected.

## 3.2. Evidence of continental drift

### Learning activity 3.2

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?




***Source:*** *http://www.ricksci.com/ear/earr_images.htm*

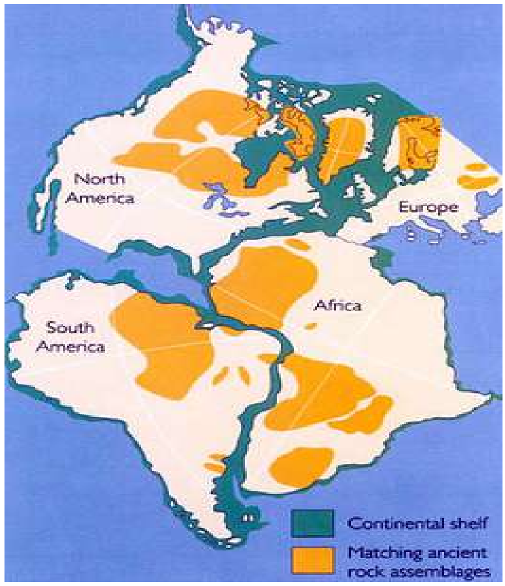
Many evidences of continental drift exist, but they can be summarized in four major categories:

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.

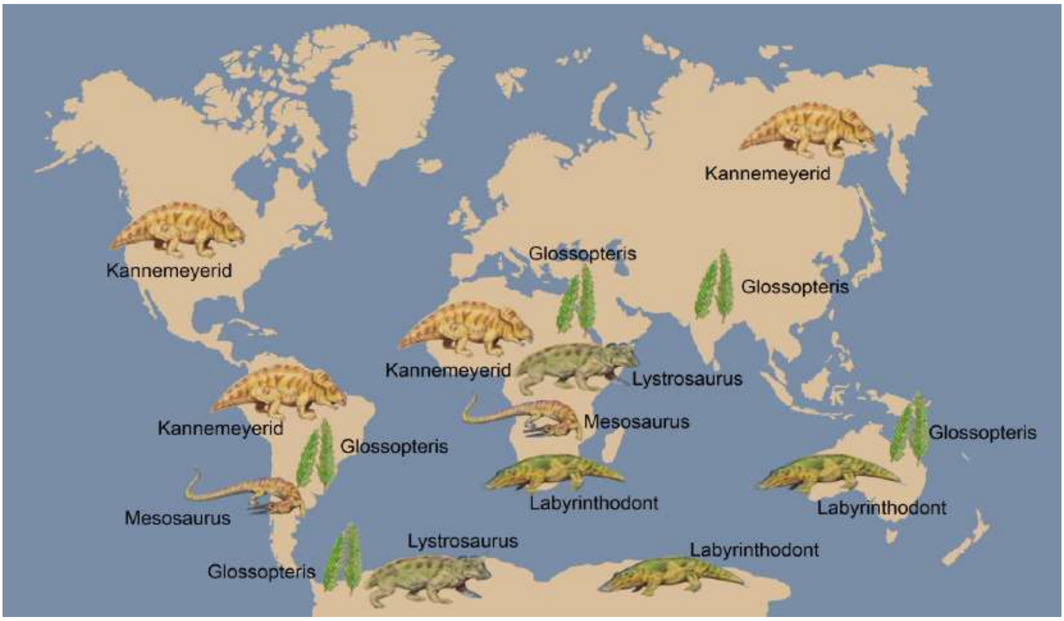

***Source:*** *http://www.ricksci.com/ear/earr_images.htm*

***Figure 3.26*** *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.



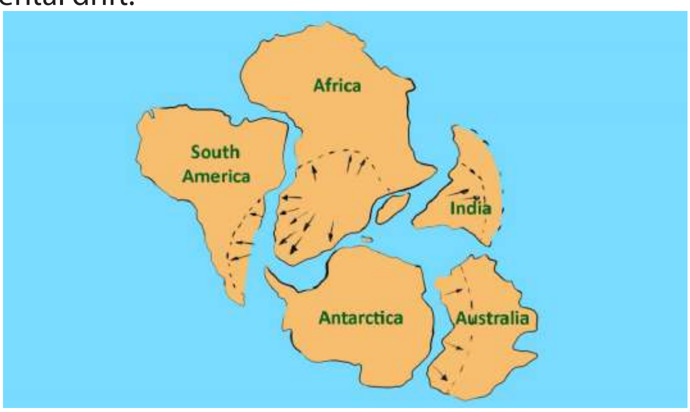

***Source:*** *Glencoe. (1999). Earth Science: Teacher Wraparound Edition. Westerville: McGraw-Hill.*

***Figure 3.27*** *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.




***Source:*** *http://www.ricksci.com/ear/earr_images.htmFigure 3.27Grooves curved by ancient Glaciers*

***Figure 3. 28*** *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 3.2

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.

## 3.3. Effects of continental drift on the evolution of physical features

### Learning activity 3.3

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 part 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;

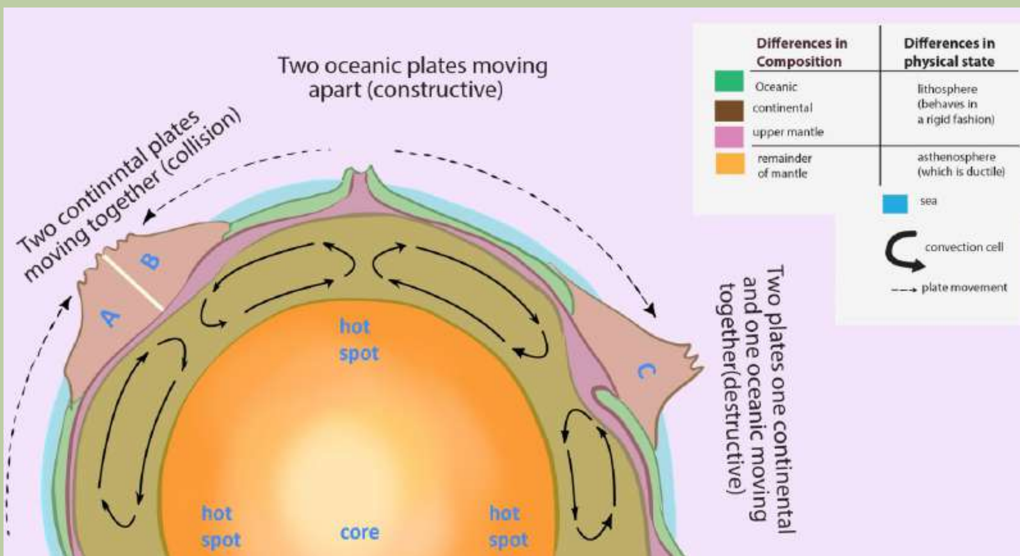
## Application activity 3.3

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

## 3.4. Plate Tectonics

### Learning activity 3.4

Observe the illustration below and answer the following questions:




***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

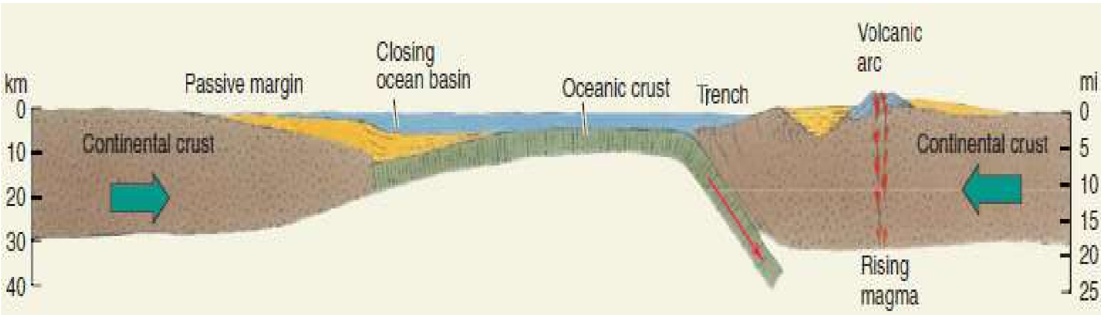
1. Identify the types of crust found on the map
2. Describe the difference between lithosphere and asthenosphere
3. Differentiate collision, constructive, and destructive processes
4. Determine the position of plate movements
5. Explain how convection cells cause the movement of plates

### 3.4.1. 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.

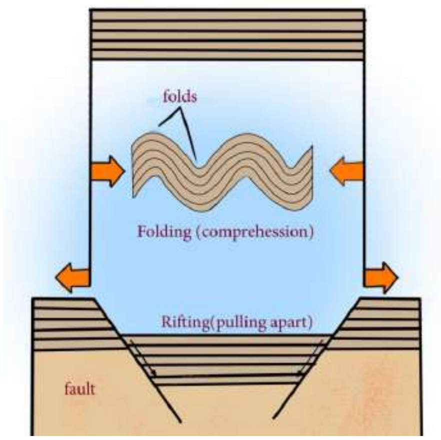
The plate size can vary greatly, from a few hundred to thousands of kilometers across. Plates are moved by the energy originating from the earth interior. This energy is a result of convection currents which form convection cells. Tectonic plates are irregularly shaped slabs of solid rocks, generally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




*Source: Strahler, A. (2011). Introducing Physical Geography, 5th Ed. Boston: John Willey and &Sons Inc.*

*Figure 3.29 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.




***Source:*** *Stahler, A. a. (2008). Visualizing Physical Geography. Hoboken: John Wiley & Sons.*

***Figure 3.30.*** *Two basic deformations resulting from tectonic activity*

### 3.4.2. 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

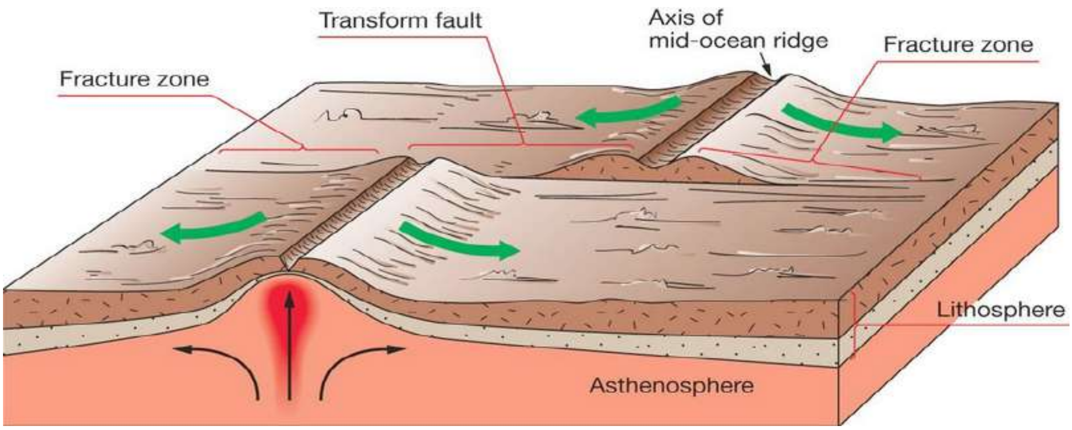
| Factor | Continental plate (SIAL) | Oceanic plate (SIMA) |
|---|---|---|
| Thickness of rock | 35-40 km on average, reaching 60-70 km under mountain chains | 6-10 km on average |
| Age of rocks | Very old, mainly over 1500 million years | Very young, mainly under 200 million years |
| Weight of rocks | 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 |

### 3.4.3. 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.

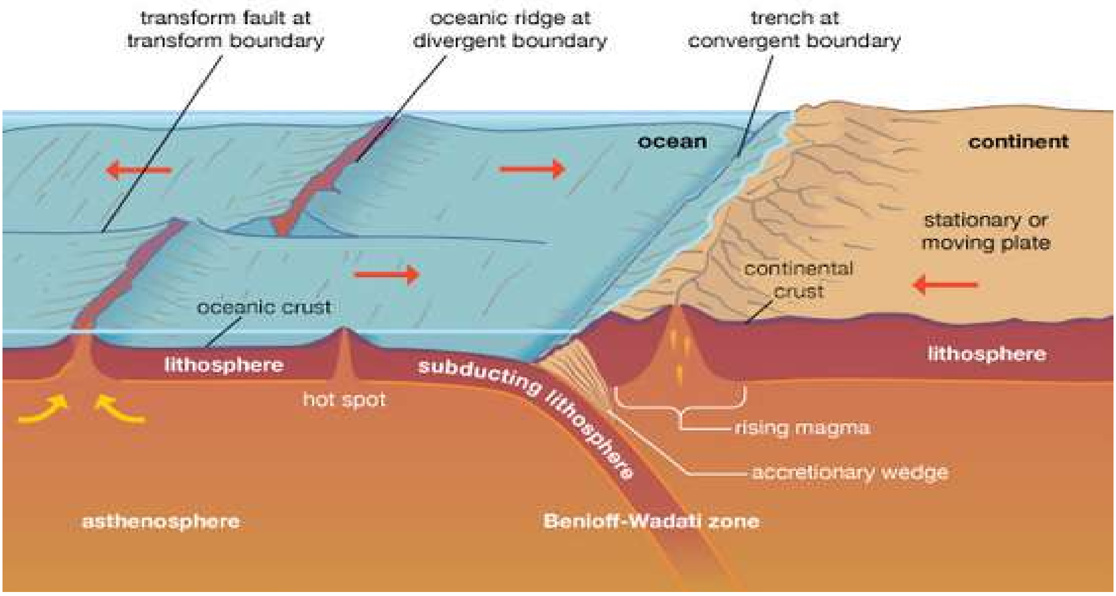
- **Divergent boundary (Mid-ocean ridge)**: It is an underwater mountain range which is formed when forces within earth spread the seafloor apart. It is created when convection currents rise in the mantle beneath where two tectonic plates meet at a divergent boundary, thus forming the oceanic ridge.
- **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).




***Source:** Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3.31** 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.



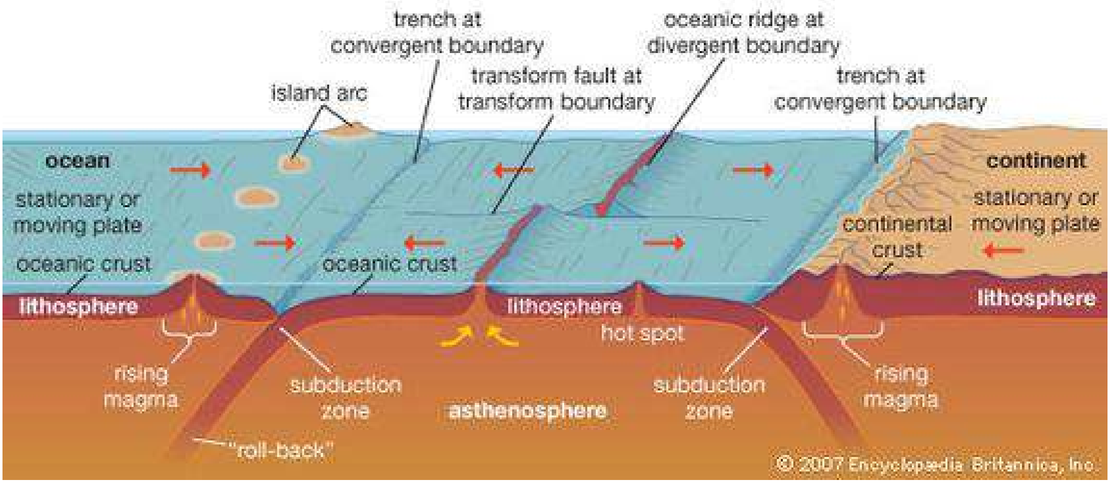

***Source:**Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson*

***Figure 3.32** Subduction zone corresponds to trench at the convergent boundary*

ii. 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.



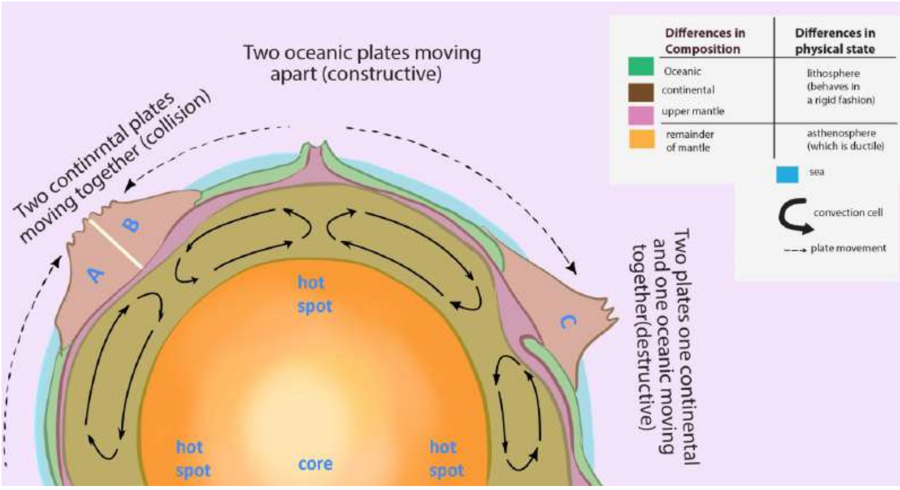

***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3.33.*** *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.




***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3.34.*** *Movement and resulting landforms at plate margins*

**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<br><br>**Rocky mountain chain** formed by Juan de Fuca, sinks under North Americas Plate, Island arcs of the West Indies and Aleutians<br><br>Examples of trenches: Mariana trench, Peru-Chile-trench (Pacific ocean), Puerto-Rico trernch 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,<br><br>**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 |

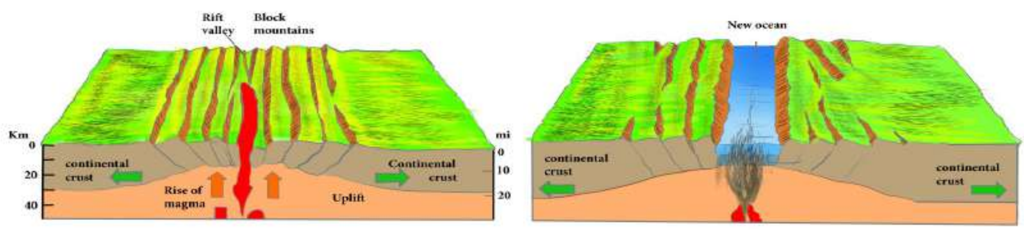
### 3.4.4 Characteristics of plate tectonics

Tectonic plates are characterized by the construction and destruction of landforms at margins of plates. However, at some boundaries, the construction or destruction may not occur. These are called passive margins or conservative boundaries.

#### i. Constructive landforms

Constructive landforms occur where two plates diverge, or move away from each other, and a new crust is created at the boundary. They are formed in the following ways:

- This occurs when a continent ruptures and the two new plates move apart and create a new ocean.
- The crust is uplifted and stretched apart, causing it to break into blocks that become tilted on faults. Eventually a long narrow *rift valley* appears.
- Magma rises up from the mantle to continually fill the widening crack at the center (**A**) as presented on figure below.
- The magma solidifies to form new crust in the rift valley floor.
- Crustal blocks on either side slip down along a succession of steep faults, creating mountains.
- A narrow ocean is formed, floored by new oceanic crust (**B**)as presented on figure below.

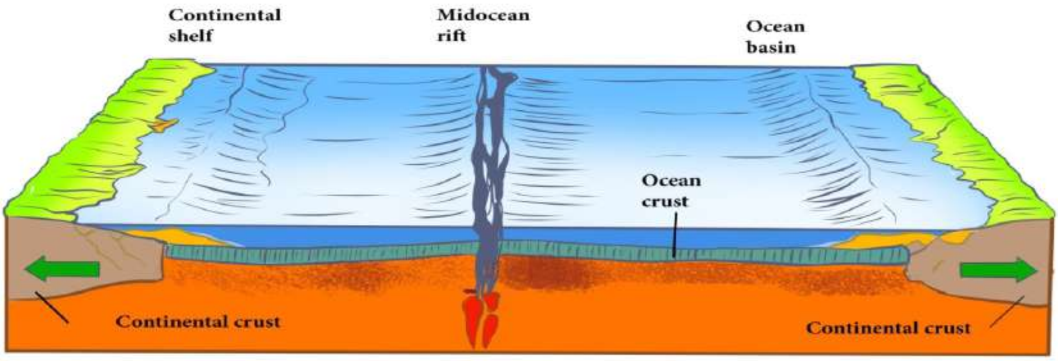



A B

***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3.35****Continental rupture and spreading (A: rift valley; B: New ocean)*

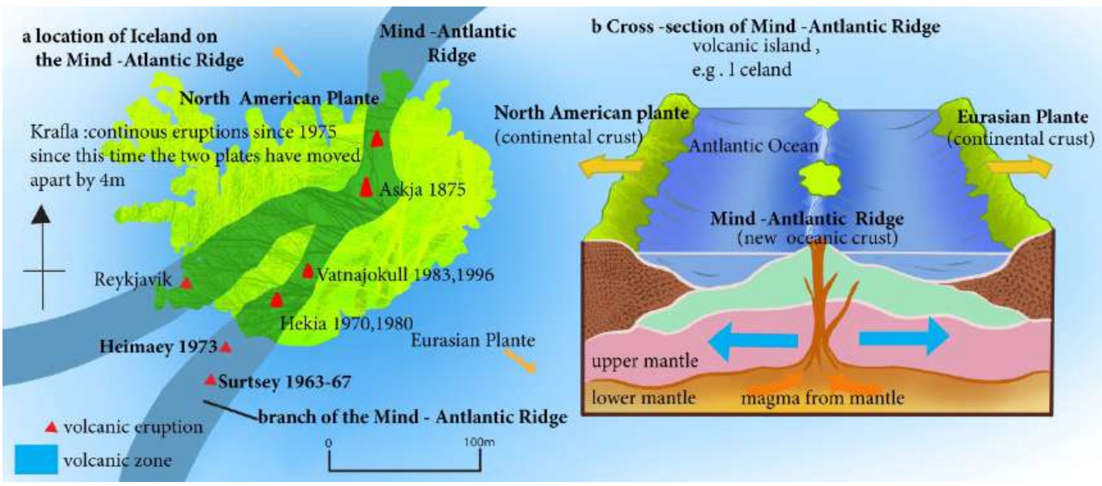
- The ocean basin can continue to widen until a large ocean has been formed and the continents are widely separated.
- The ocean basin widens, while the passive continental margins subside and receive sediments from the continents.
- As the plates diverge, molten rock or magma rises from the mantle to fill any possible gaps between them, creating new oceanic crust.




***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3. 36*** *Widening of ocean basin*

- The magma initially forms **submarine volcanoes** which may in time grow above sea-level. Volcanic islands are created by the submarine volcanism at the vertical of oceanic ridge, e.g. Iceland (see the figure below).



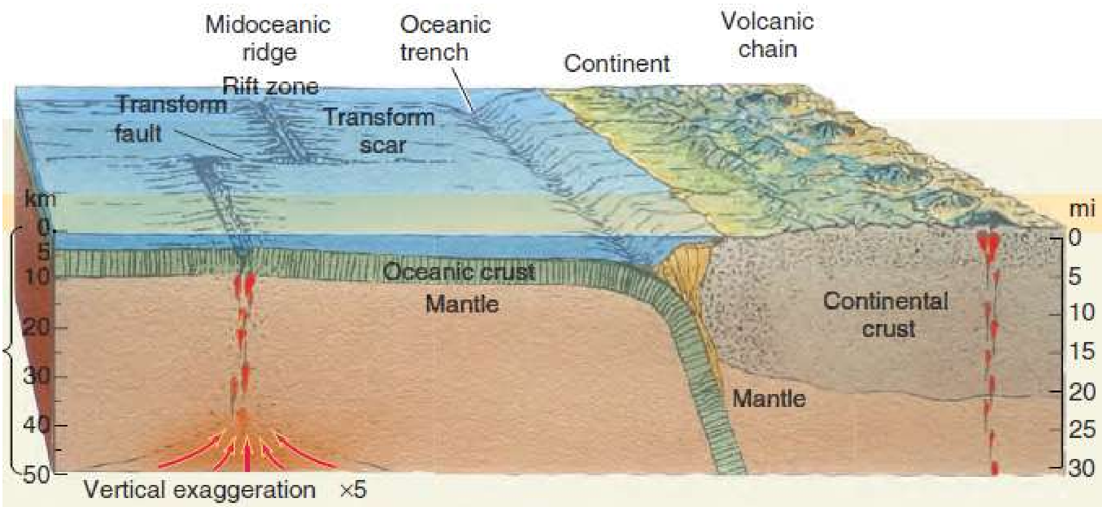

***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.*

***Figure 3.37*** *Location of constructive landforms on plate margins (e.g. Iceland)*

### ii. Destructive landforms

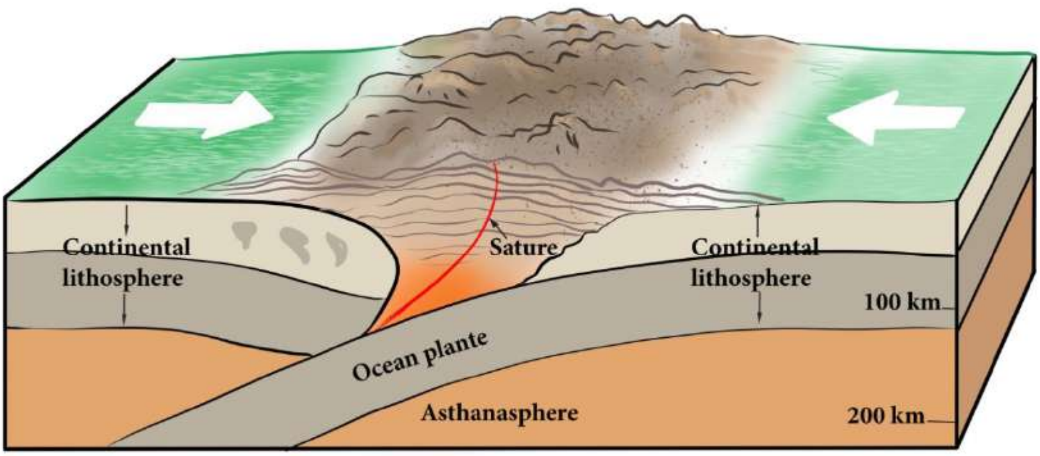
Destructive landforms occur where continental and oceanic plates converge. They are formed in the following ways:

- The oceanic plate that is denser is forced to dip downwards at an angle to form a subduction zone with its associated deep-sea trench.
- The sunk plate will melt and transformed into magma as the pressure and the temperature rise.
- The newly created magma will try to rise to the earth's surface. Where it does rich surface volcanoes will occur. This process will either create a long chain of **fold mountains (**e.g. the Andes**)** or, if the eruptions take place off shore, an **Island arc** will be created(**e.g. Japan, Caribbean**).




***Source:*** *Strahler, A. (2011). Introducing Physical Geography, 5th Ed. Boston: John Willey and & Sons Inc.*

***Figure 3.38*** *Folded mountain chain formed by subduction at the convergent plates boundary*




***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes*

***Figure 3. 39*** *Mountain chain formed by collision between two continental crusts*

**iii. Passive or conservative margins:** Passive continental margins are:

- The areas which are lacking active plate boundaries at the contact of continental crust with oceanic crust.
- The transform faults which are large cracks produced at right-angles to the plate boundary because neither landform is constructed nor destroyed.

Application activity 3.4

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.
4. Explain the processes that lead to constructive and destructive landforms

## 3.5. Major plates and effects of plate tectonics

Learning activity 3.5

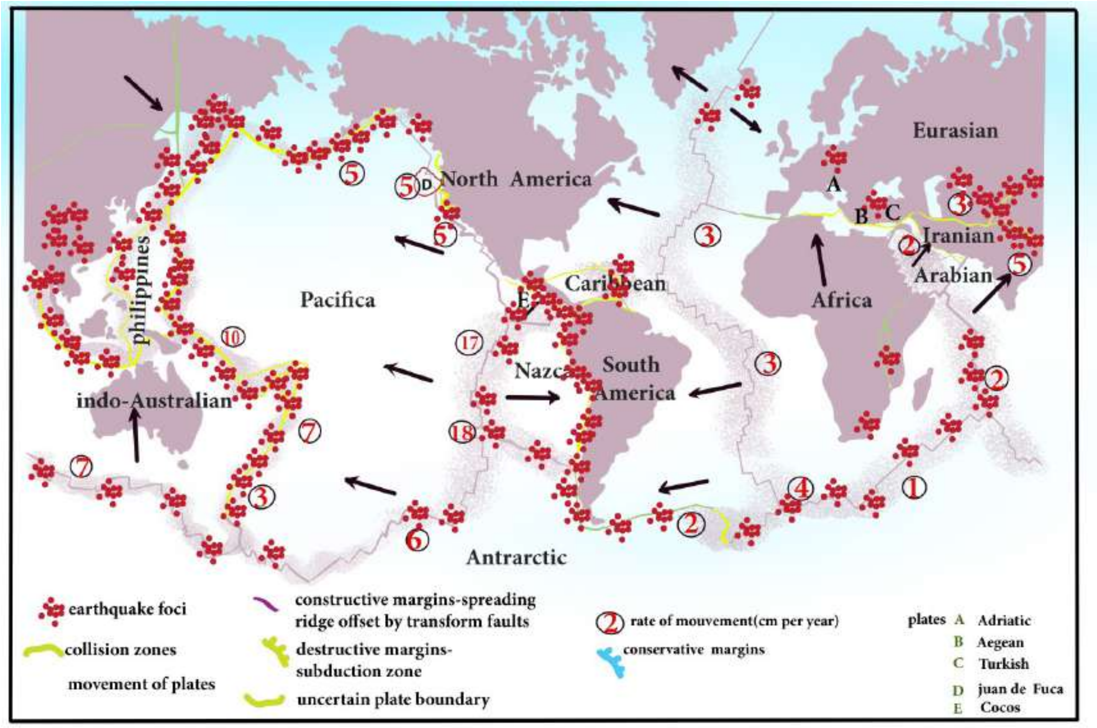
1. Make research using books and a printed hand out and represent on the world map the major tectonic plates.
2. Identify the effects of the plate tectonic?

### 3.5.1. 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).




***Source:*** *Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes*

***Figure 3. 40*** *Distribution of tectonic plates and their margins*

### 3.5.2. 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.

**Source:** *Pinterest. (2010, January 12). pinterest. Retrieved February 24, 2018.*

***Figure 3. 41****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.

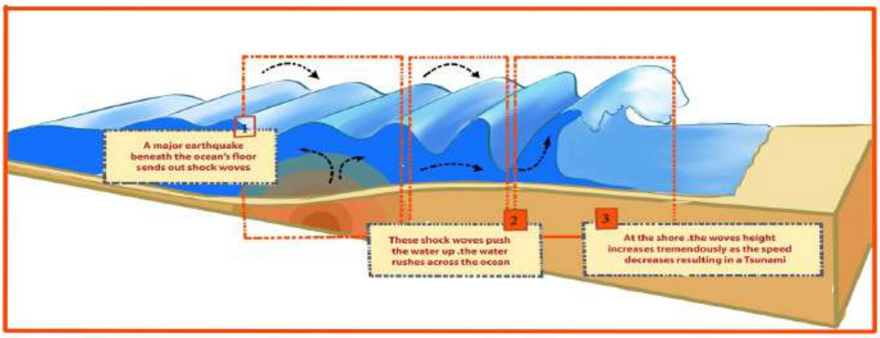
**Source:***Brown, L. A. (2017, April 24). Sciencing.com. Retrieved February 11, 2018*

***Figure 3. 42*** *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 sometime be imperceptible when their magnitude is low.




***Source:*** *Glencoe. (1999). Earth Science: Teacher Wraparound Edition. Westerville: McGraw-Hill.*

***Figure 3. 43*** *Movement of tsunami shock waves*

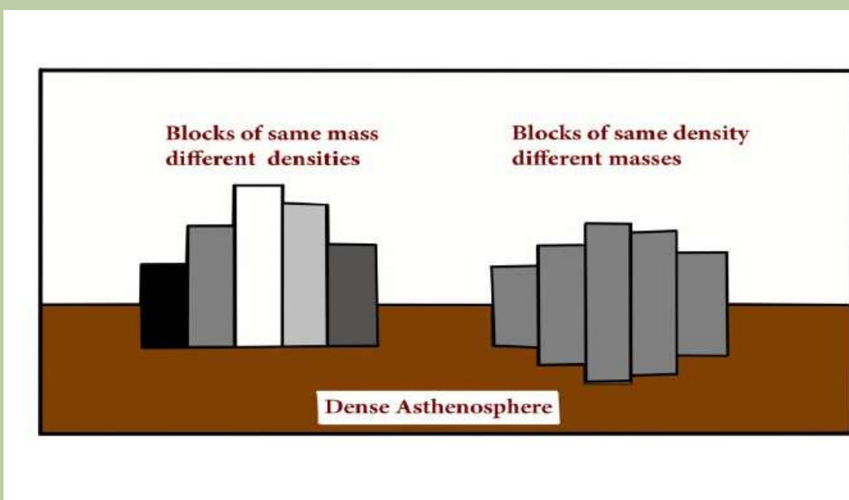
## Application activity 3.5

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

## 3.6. The theory of Isostasy

## Learning activity 3.6

1. Make research and explain the isostasy theory.
2. Explain isostasy based on the figure below.



### 3.6.1. Meaning of Isostasy

The concept of Isostasy comes from "iso" = equal, and "stasis" = equilibrium. It describes how various continental and oceanic crusts, stay in equilibrium over the asthenosphere. The following are the main characteristics of isostasy:

- By isostasy, the lighter crust must float on the denser underlying mantle.
- It explains how different topographic heights can exist on the earth's surface.
- Isostatic equilibrium is an ideal which states where the crust and mantle would settle in equilibrium in absence of disturbing forces.
- Isostasy theory is concerned with vertical movements of plates which depend on lithospheric masses.
- The loading of crust by ice or sediments may cause the subsidence of lithosphere, whereas the discharge resulting from ice melting or erosion may cause the uplift of lithospheric compartment.
- The waxing and waning of ice sheets erosion, sedimentation, and extrusive volcanism are examples of processes that perturb isostasy.
- Isostasy controls the regional elevations of continents and ocean floors in accordance with the densities of their underlying rocks.

### 3.6.2. Main theories of Isostasy

There are two main theories which have been developed to explain how Isostasy acts to support mountain masses.

i. **Pratt's theory:** The theory stipulates that there are lateral changes in rock density across the lithosphere (crust). If the mantle below is uniformly dense, the less dense crustal blocks float higher to become mountains, whereas the denser blocks form basins and lowlands.

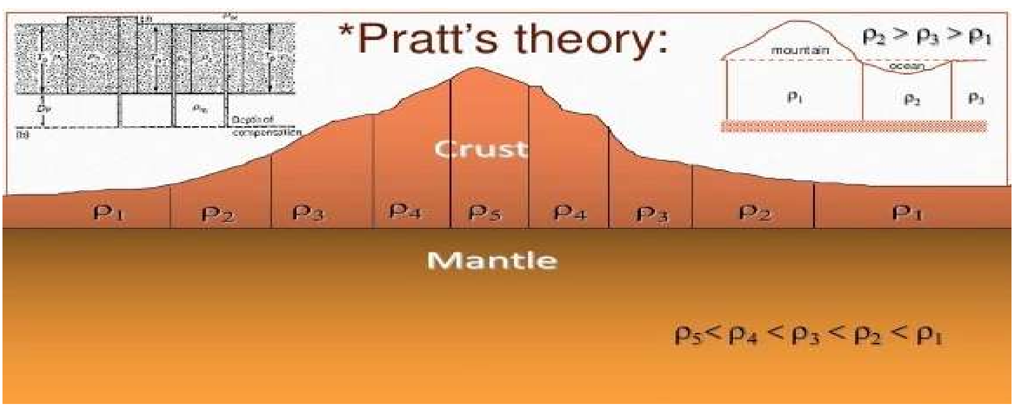



*Figure 3. 44 Pratt's isostasy theory diagram*

ii. **Airy's theory:** According to Airys's theory, the rock density across the lithosphere is approximately the same but the crustal blocks have different thicknesses. Therefore, mountains that shoot up higher also extend deeper base into the denser material beneath.

Both theories predict a relative deficiency of mass under high mountains. Airy's theory is now known to be a better explanation of mountains within continental regions, whereas Pratt's theory essentially explains the difference between continents and oceans, since the continent crust is largely of granitic composition which is less dense than the basaltic ocean basin.

## Application activity 3.6

Referring to Pratt's theory and Airy's theory, explain the principle of Isostasy.

## End unit assessment

1. What is the contribution of Wegner's theory and others 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 4
# EXTERNAL LANDFORM PROCESSES AND RELATED FEATURES

# UNIT 4: 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 features resulting from external processes and their relationships with human activities.

Introductory activity

Observe the photograph below and explain the processes that affected the rock shown

### 4.1. Weathering

#### 4.1.1. Types and processes of weathering

Learning activity 4.1

a. Making good use of the diagrams below explain the processes involved in both physical and chemical weathering.

b. Make a research and compare the processes of soil formation and the processes of weathering

**a. Definition of weathering**

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

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

**b. Types of weathering**

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.

**1. Physical weathering**

Physical weathering refers to the breakdown 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**:

i. **Thermal expansion or insolation weathering**

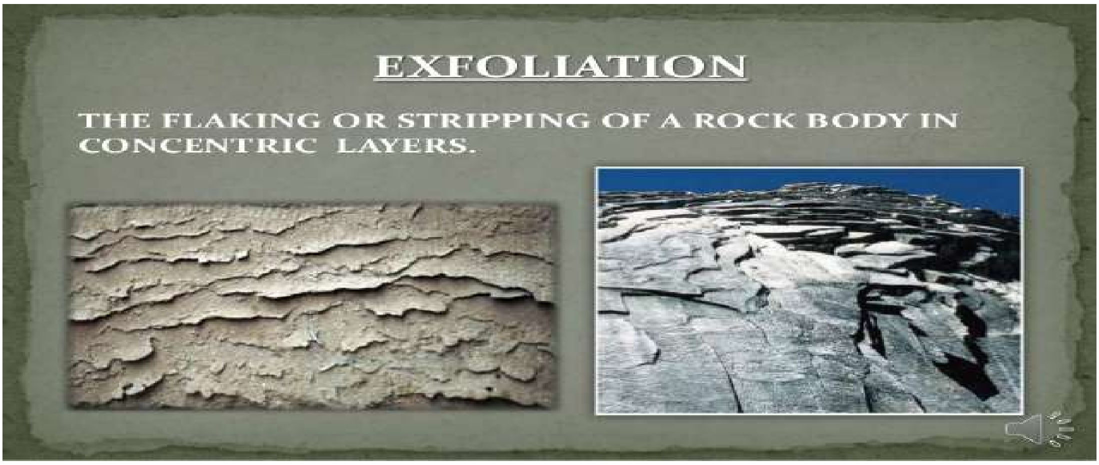
This process is caused by the changing of temperature ranges which causes differential heating of minerals forming the rock. When heated dark minerals expand, faster than others resulting in cracking and fragmentation of the rock.

***Source:*** *https://www.bing.com/images/search?q=Block+desintegration*

***Figure 4. 45*** *Block disintegration due to change in temperature*

i. **Exfoliation**

This occurs when there is expansion of rocks during the day and contraction of rocks during the night due to repeated temperature changes. It 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.




***Source:**https://www.bing.com/images/ Exfoliation&FORM*

***Figure 4. 46** Exfoliation*

ii. **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.

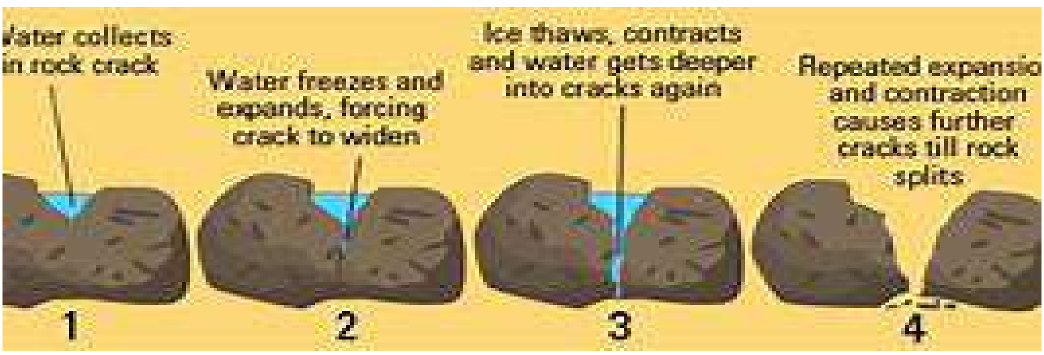



*Figure 4. 47 Steps of frost weathering*

iii. **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 pressure, which causes the materials below to expand and crack parallel to the surface.

*Figure 4. 48 Fractures of rock due to the pressure release*

iv. **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.

***Source:*** *https://www.bing.com/images/ Salt+crystallization*

***Figure 4. 49*** *Salt crystallization in rock joints*

v. **Shrinkage weathering**

Some clayey 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 volume. During dry seasons, they massively lose this water through evaporation and they contract. This process is known as shrinkage. This alternating expansion of these rocks during the wet season, and contraction during the dry season, creates stresses and later cracks the rock.

vi. **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).

### 2. 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:

**i. 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.: $4FeO + O_2 \longrightarrow 2Fe_2O_3$

(Ferrous oxide)(Oxygen) (Hematite)


***Source:**https://www.bing.com/images/ oxidation+&simid*

***Figure 4. 50** Oxidation*

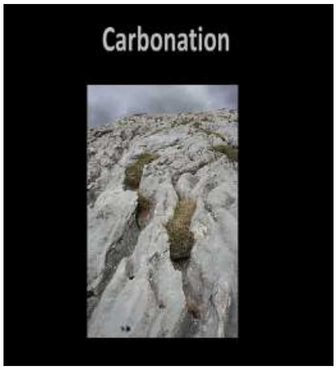
**ii. Carbonation** occurs on rocks which contain calcium carbonate, such as limestone and chalk. This takes place when rain combines with carbon dioxide or an organic acid to form a weak carbonic acid.

$H_2O + CO2 \longrightarrow H_2CO_3$ (weak carbonic acid)

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

$CaCO_3 \quad + \quad H_2CO_3 \longrightarrow Ca(HCO_3)_2$

(Limestone) (Carbonic acid) (Calcium bicarbonate)




***Source:** https://www.bing.com/images/ Carbonation&simid*

***Figure 4. 51** Carbonation*

**iii. 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.

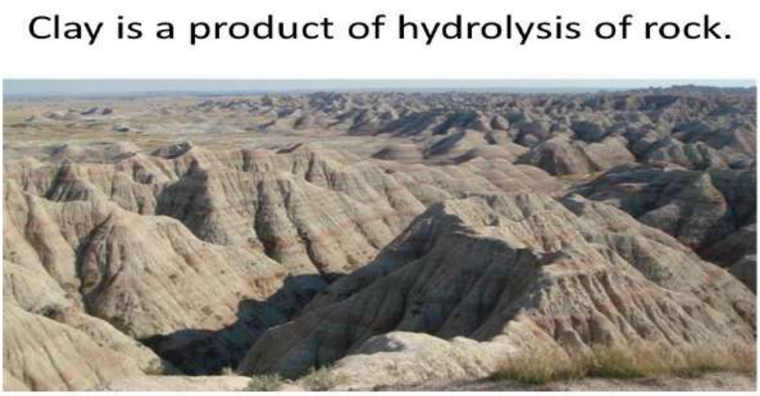
***Source:https:**//www.bing.com/images/search?q=+Dissolution&qs*

*Figure 4. 52 Dissolution*

**iv. 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. $K_2Al_2O_3\ 6SiO_2 + H_2O \rightleftharpoons Al_2O_3\ 2SiO_2\ 2H_2O$

(Feldspar) (Water) (Kaolin)




***Source:*** *https://www.bing.com/hydrolysis.png&exph*

***Figure 4. 53*** *Hydrolysis*

**v. Hydration:** Hydration is one of the major processes of chamical 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. $2Fe_2O_3 + 3H_2O \rightleftharpoons 2Fe_2O_3 . 3H_2O$

(Hematite) (water) ( Limonite)

*Figure 4. 54. The area that experienced the hydration*

**vi. 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. $NaCl + H_2O \rightarrow Na^+, Cl^-$ (dissolved ions with water).

**vii. Chelation:** Chelation 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 is a form of chemical weathering by plants.

*Sourcehttps://www.bing.com/images/ chelation&simid*

*Figure 4. 55 Chelation*

### 3. 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.

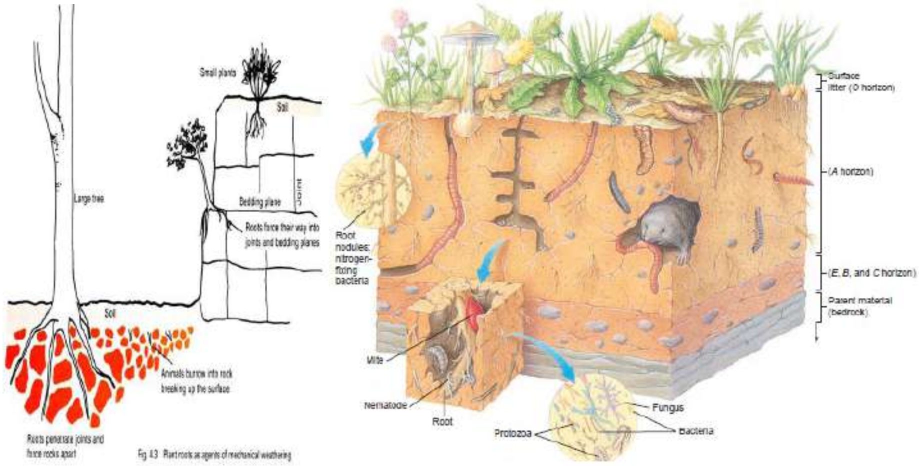
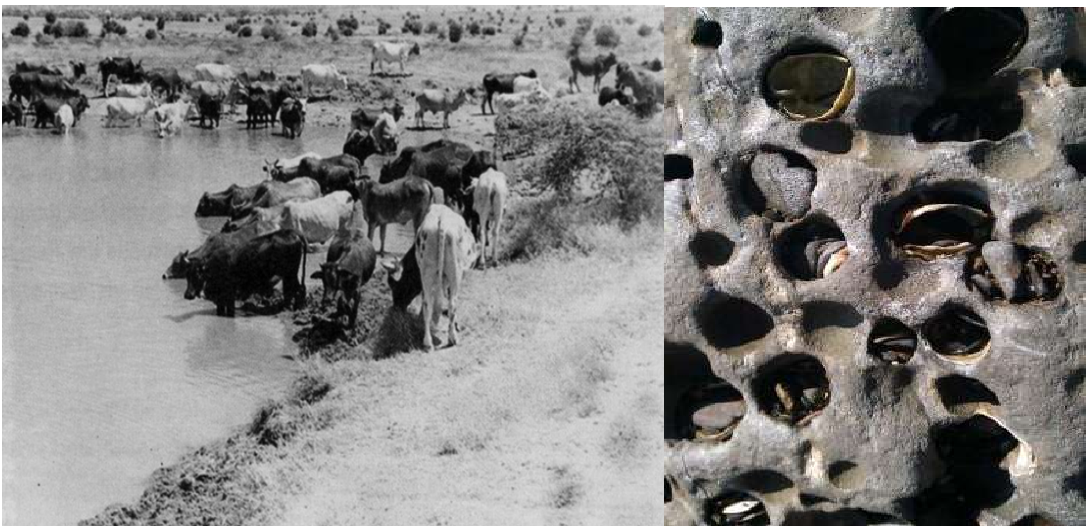



*Figure 4. 56Impact roots of trees and earth animals on weathering of rocks*

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.



***Source:*** *https://www.bing.com/images/Animals+create+bores+into+a+rock&simid*

***Figure 4. 57*** *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 geomaterials (rocks).

*Figure 4.58 Human activities cracking the rocks*

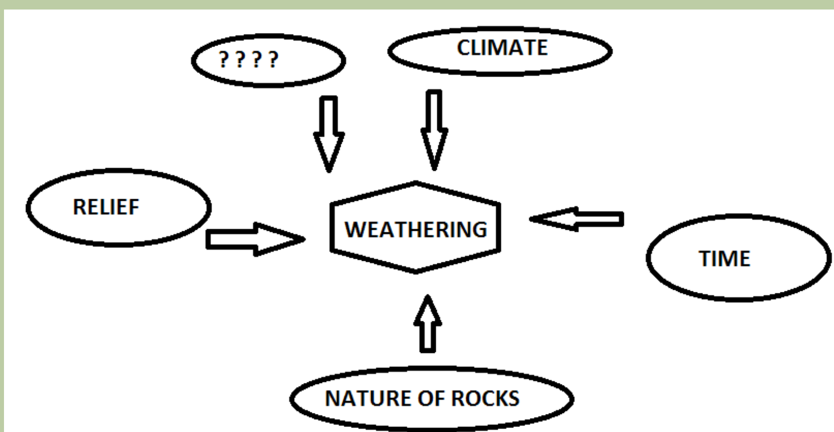
Application Activity: 4.1

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

## 4.2. Factors influencing weathering and interdependence of physical and chemical weathering

Learning activity 4.2

Using the illustration below, identify the missing factor and explain how it influences the rate of weathering.




A number of factors are required for weathering to occur in any environment. The major factors of weathering include:

#### 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 lee ward 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 weatheringThe 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 4.2

Make a field study around your school and explain how relief and nature of the rock have influenced the rate of weathering.

## 4.3. Weathering in limestone regions

### Learning activity 4.3

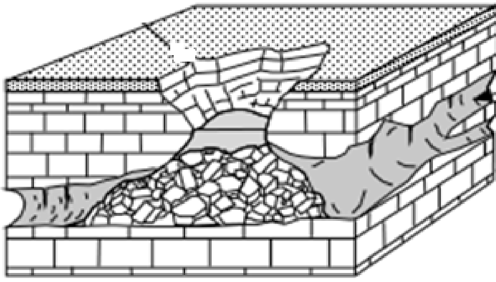
1. Differentiate the types of weathering.
2. Describe the type of rock associated with limestone regions.

*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.

**i. 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.




*Source: https://www.google.com/ Caverns&source*

***Figure 4. 59*** *Caverns*

### ii. 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.

### iii. 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.

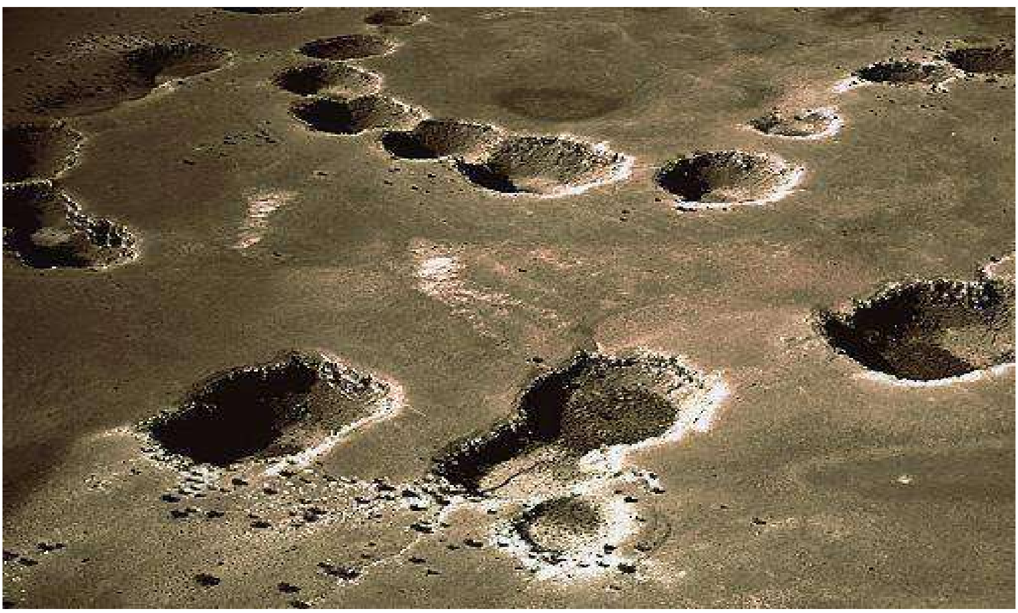


*Figure 4. 60 Uvala*

**iv. 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.

**v. Stalactites**

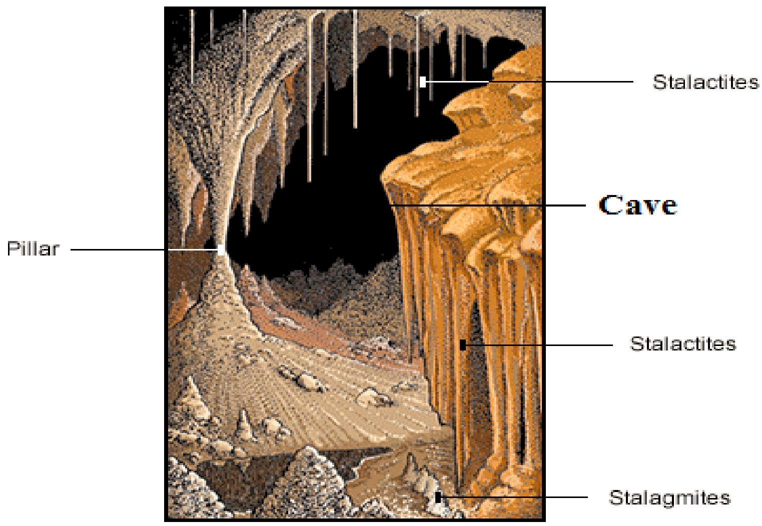
Stalactites are protrusions on top of limestone cave formed as results of water dissolving some rocks which form a solution that leaks from the roof.

**vi. 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.

**vii. 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.




***Source:https:**//ww w.google.com/search?q=Stalagmite,+stalactite+and+pillar&source*

***Figure 4. 61** 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.

### Application activity 4.3

In groups make a field trip to any limestone region, observe karst landforms and present your findings in class.

## 4.4. Weathering in humid tropical and arid regions and resultant landforms

### Learning activity 4.4

Choose any climatic region (Humid tropical/Arid) and identify the type of weathering which will dominate the area

### 4.3.1. Humid tropical regions

The tropical climate is characterized by high amount of rainfall (more than 1000mm) and high temperature of up to and (more than 18° C) respectively. Weathering is favored in equatorial and tropical regions where the wetness and high temperature are permanent. During the rainy season, chemical weathering dominates through the process of hydration, hydrolysis, solution, oxidation, and reduction. In areas with alternating seasons, chemical weathering is temporary interrupted during drought periods because of lack of moisture. Physical weathering processes such as exfoliation, granular disintegration and block disintegration dominate. Therefore, in tropical (savanna) climate, both physical and chemical weathering processes dominate in dry and rainy seasons alternatively.

### 4.3.2. Arid and desert regions and resultant landforms

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

## 1. Erosional features

### i. 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.

***Source: https:****//www.bing.com/images/ Inselberg&simid*

***Figure4. 62*** *Inselberg*

### ii. Bornhardts

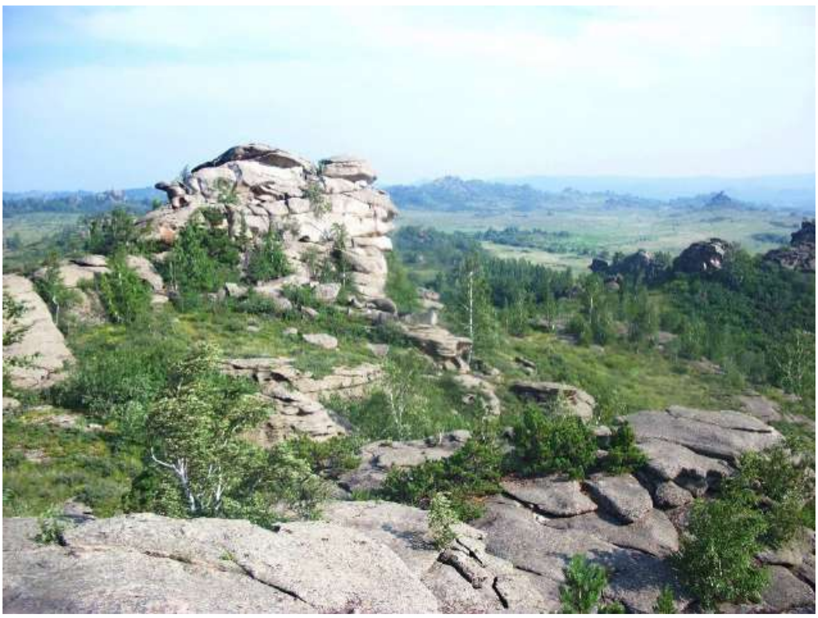
These are dome-shaped and steep-sided rocks that rise up to 30 meters. They are massive rock, commonly granite comprised of bare rock that stretches several hundred meters. They take many shapes such as oranges. A good example of where Bornhardts are found is Central Australia.

**Source:** *https://www.bing.com/images/ Bornhardts&simid*

***Figure 4. 63*** *Bornhardts*

### iii. 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.

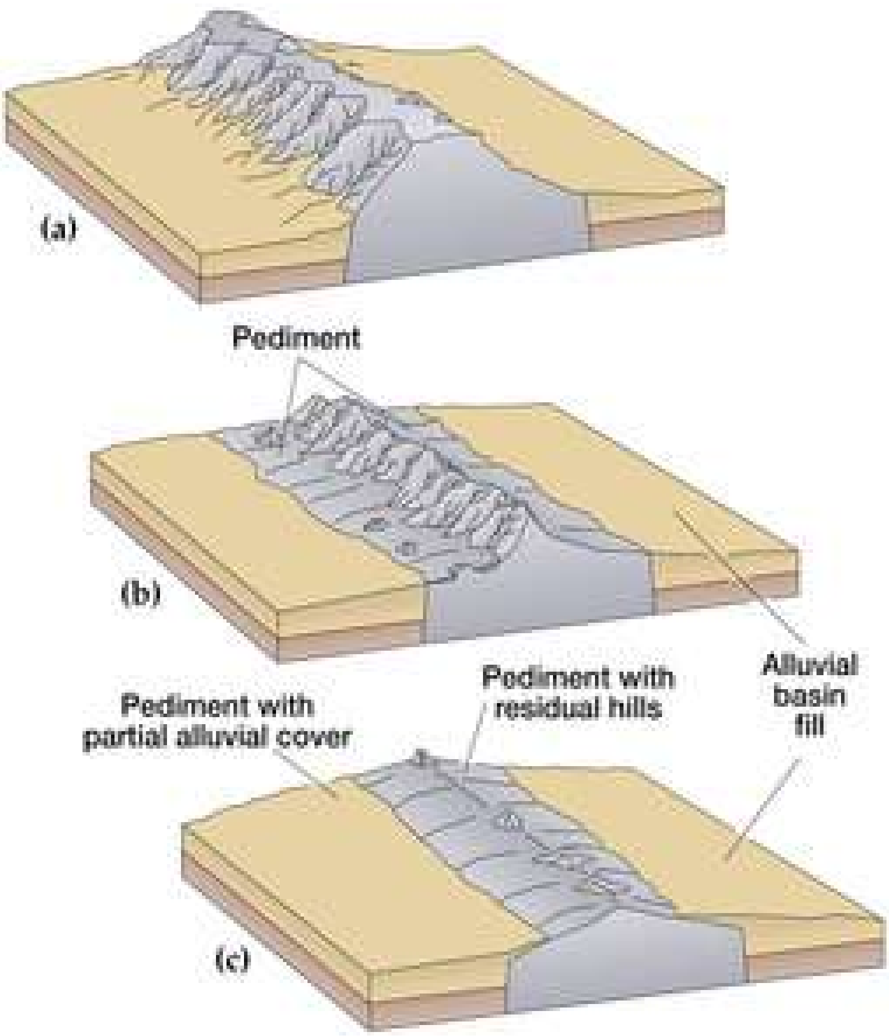


**Source:** *https://www.bing.com/images/Tor&simid*

***Figure 4. 64*** *Tor*

#### iv. 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.




***Source:*** *https://www.bing.com/images/ Pediment+&simid*

***Figure 4. 65*** *Pediment*

#### v. Deflation basins

Depressions are formed in the deserts due to removal of sand through the process of deflation and are called deflation basins or blow-outs, or deserts hollows. The depth of deflation is determined by groundwater table.

Figure 4. 66 Deflation basins

### vi. 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.

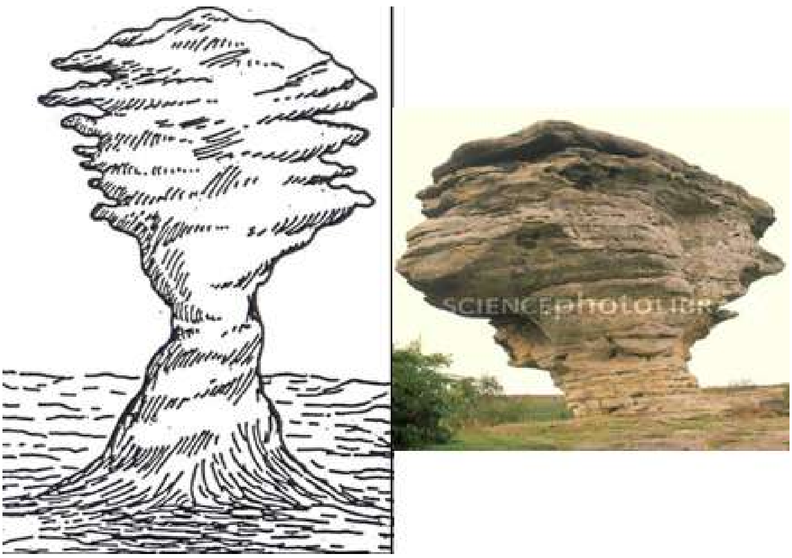



Figure 4. 67 Mushroom rock

### vii. 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.

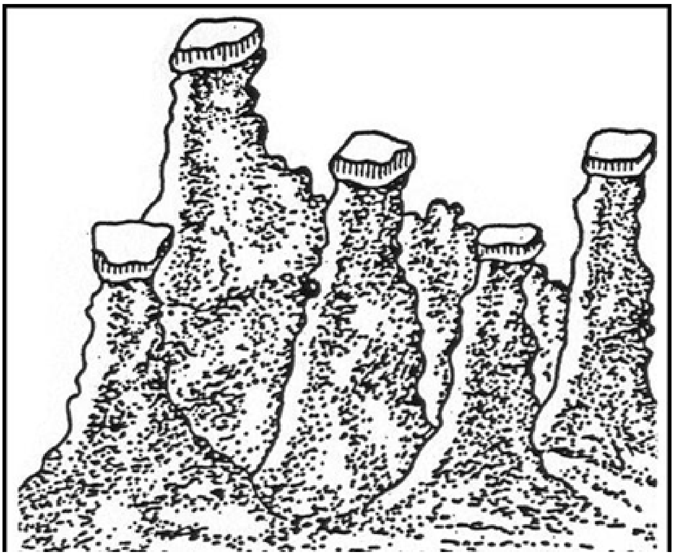


*Figure 4. 68 Demoiselles*

**viii. 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.

**ix. 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.

***Source:** https://www.bing.com/images/ yardang*

***Figure 4. 69**Yardangs*

### x.Reg

Reg is a desert surface armored 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.

*Source: https://www.google.com/reg*

*Figure 4. 70 Reg*

### xi.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).

## 2. Depositional features in desert

### i. 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.

**Source:** https://www.google.com/ Barchans&source

**Figure 4. 71**Barchans

- **Seifs**

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

**Source**:https://www.bing.com/images/ Seifs&simid

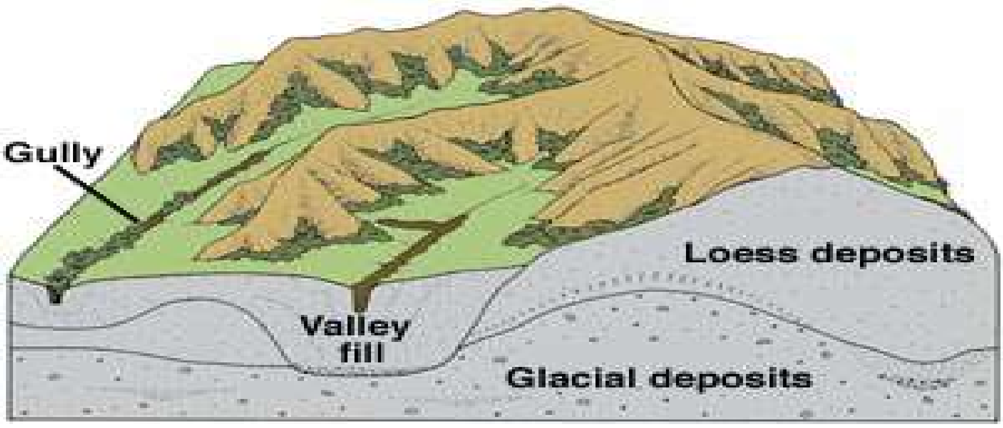
**Figure 4. 72** Seifs

- **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.

**ii. Loess**

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




*Source:https://www.bing.com/images/ Loess&simid*

*Figure 4. 73 Loess*

**iii. 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.

***Figure** 4. 74 Erg*

## Application activity 4.4

Explain the reasons why the erosive power of wind is high in arid regions than in tropical regions.

## 4.5. Weathering in the glaciated (cold) regions

### Learning activity 4.5

Observe the photographs provided below and answer the questions that follow:

**Photograph A** **Photograph B**

1. Explain the difference between photograph A and B.
2. Why is the top of mountain in photograph A white in colour?

### 4.5.1. Definitions

**A glacier** is a mass of ice of limited width, which moves outwards from a central area of ice accumulation. In other words, a glacier is a mass of ice produced by the accumulation and compression of snow, which moves slowly downhill or sea ward due to its weight.

**Glaciation or glacial activity** refers to the work done by glaciers or moving ice. It is a process of movement of ice usually from mountain tops downhill which leads to erosional and depositional glacial landforms. Snow/ice is formed when temperature falls under 0°C.

The permanent ice sheets occur in **Greenland, Antarctica**, and on high mountain tops. The level above which there is perpetual snow cover is called **a snow line**.

In temperate regions, ice accumulation occurs in winter as the temperature falls under 0°C, and melts later in summer. In tropical regions, snow accumulates on top of mountains of about 4800m above sea level.

### 4.5.2. Types of glaciers

The main types of glaciers include the following:

i. **Valley glaciers:** these are also called alpine or mountain glaciers. They move down slope and occupy former river valleys under the influence of gravity and size. e.g. Glaciers on Rwenzori, Kilimanjaro, and Mount Kenya.
ii. **Continental glaciers:** are alternatively called ice sheets or ice caps. These cover large areas of the plateau surface. They accumulate from a common area and spread towards continental margins with massive movement. e.g.: Glacier found in the polar regions of Greenland, Antarctica, Arctic, Northern Canada and north Western Europe.
iii. **Piedmont glaciers**: these are produced when mountain glaciers move down below the snow line and spread in the low lands of foot hills of glaciated mountains. They merge to produce large mass of ice.
iv. **Cirque glaciers:** these are small accumulations of ice which occupy Cirque basins on the mountain sides.

### 4.5.3. Types of glacial flow

Glacial movements are categorized into two types: **gravity flow** and **Extrusion flow.**

#### a. Gravity flow

In this process, glaciers move down slope under gravity and it usually affects low-lying valleys. This kind of gravity flow includes the following various types:

i. **Plastic flowage**: ice usually behaves as an elastic brittle solid. When more ice accumulates, internal stress forces the ice to spread and therefore to move like a highly viscous liquid.
ii. **Regelation**: when ice accumulates, pressure is created inside the ice sheet. This pressure forces some ice to melt and this molten water moves down-slope. When this water derived from the melting of ice reaches in an area of low pressure, it freezes again and solidifies to produce ice.
iii. **Intergranular translation**: this involves the movement of crystals or granules downslope due to pressure from overlying ice. Melt water lubricates these ice crystals making it easy for them to slide past each other.

#### b. Extrusion flow

As the accumulation of snow on ice caps increases, there will be an automatic side-ways displacement of ice in all directions following increased accumulation. Hence ice does not flow necessarily down slope as under gravity flow. It flows in all directions as a thick porridge spreads in all directions as more is added. This is how ice sheets which cover large areas of plateau surfaces move.

Application activity: 4.5

Using examples distinguish between valley glaciers and continental glaciers.

## 4.6. Factors influencing the formation and movement of glaciers

Learning activity 4.6

Why is glaciation dominant in high altitude regions?

There are many **factors** that influence the formation of glaciers in an area. The most important are briefly described in the following paragraphs:

**The effect of altitude**: Following the principle of altitude increase and temperature decrease, glaciers usually form in areas of higher altitudes. e.g. Everest, Kilimanjaro mountains.

- **The factor of latitude:** Areas that lie astride the equator within the tropics have high temperatures that limit ice accumulation. On the other hand areas far away from the equator have low temperature which favor ice formation.
- **Precipitation of snow:** Glaciers are formed from the condensation of water vapor. This results in the formation of ice crystals which fall as snow. The progressive accumulation and their compaction result in thick and continued glaciers that cover the surface.

The rate at which glaciers move is different from glacier to glacier and is determined by a number of factors. The most important are highlighted below:

- **Nature of slope:** when the slope is steep enough, glacier moves faster than when slopes are gentle.
- **The amount of ice or size of the glacier**: when the glacier thickness is big, there will be more pressure to generate quick motion than when the thickness is low.
- **Temperature:** The glaciers are faster in warm climate conditions due to the presence of enough melt water than in regions of low temperatures. High temperatures quickly produce melt water, which lubricates the ground for quick basal slippage and intergranular translation.
- **The amount of load:** Load is the eroded materials carried by a moving glacier. The more the load the slower the glacier due to increase in friction and the lesser the load the faster the glacier will be.

## Application activity 4.6

Make research on other factors that influence ice accumulation and make a class presentation.

## 4.7. The work of glaciers and resultant landforms

## Learning activity 4.7

From the experience you acquired in previous lessons, make a difference between ice and glacier

### 4.7.1. Processes associated with glacial erosion

Glaciers perform a triple function. These are erosion, transportation, and deposition.

Many processes are associated with glacial erosion but the most important are the abrasion, plucking and the frost shattering. They are detailed below:

- **Abrasion** also known as grinding process is the sandpapering effects of angular material embedded in glacier as it rubs the valley sides and floor. Glacial abrasion is caused by the rock debris embedded in the glacier.
- **Plucking** is also referred to as sapping or quarrying. It occurs when the ice at the base and sides of the glacier freezes onto rock outcrops. The rocks are then pulled and carried away by the moving ice.
- **Frost shattering**: this process produces much loose material which may fall from valley sides onto the edges of the glacier to form lateral moraine.

### 4.7.2. Landforms produced by glaciers

There are two types of landforms performed by glacial processes:

1. **Glacial erosional features**

The most common glacial erosional landforms include:

- **Cirque**: also called **corrie** is a steep-sided rock basin with a semi-circular shape. It starts from a small depression which is gradually enlarged. Frost shattering helps shatter the rocks on the edges of the depression and as they break, the depression is enlarged.

- **Arêtes:** an arête is a narrow ridge with steep sides developing between two corries.
- **Pyramidal peak:** A pyramidal peak also called **horn** is a surviving top mountain mass that is not yet worn down by erosion. It is shaped like a pyramid hence the term "pyramidal peak". It is formed at the junction of arêtes.
- **Tan**: also called **tarn**, is a cirque lake produced when the ice melts and the melt water occupy the cirque depression.
- **U-Shaped valley** or **glaciated trough:** is formed when a glacier passes through a pre-existing river valley to a characteristic of U shape profile. The over deepening and widening of these former river valleys is a product of abrasive action of ice using large amounts of moraine as its tool.
- **Hanging valleys:** these are valleys associated with glacial troughs. They are small valleys whose floors are found at higher level than the floor of the main valley to which they are tributaries. The floor of the main valley is at a lower level due to greater erosion than the floor of tributary valleys where there is less erosive power.

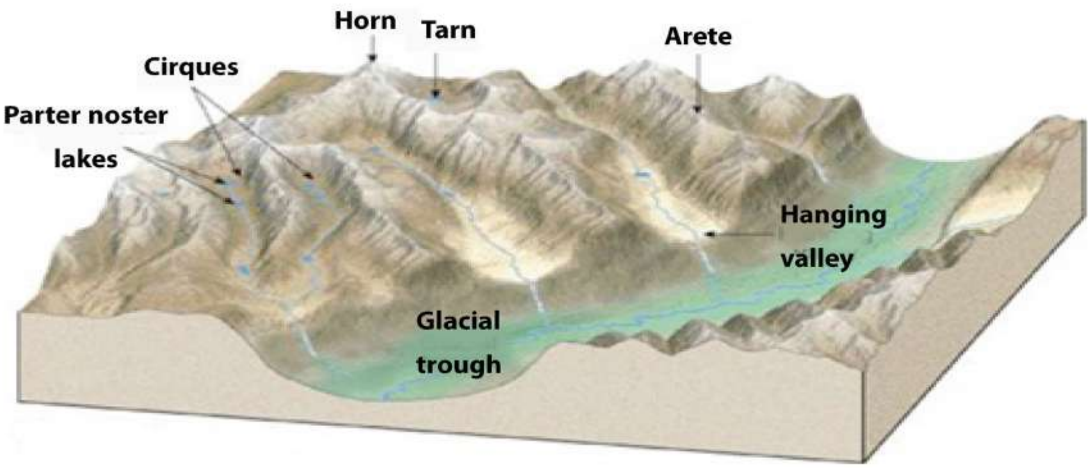


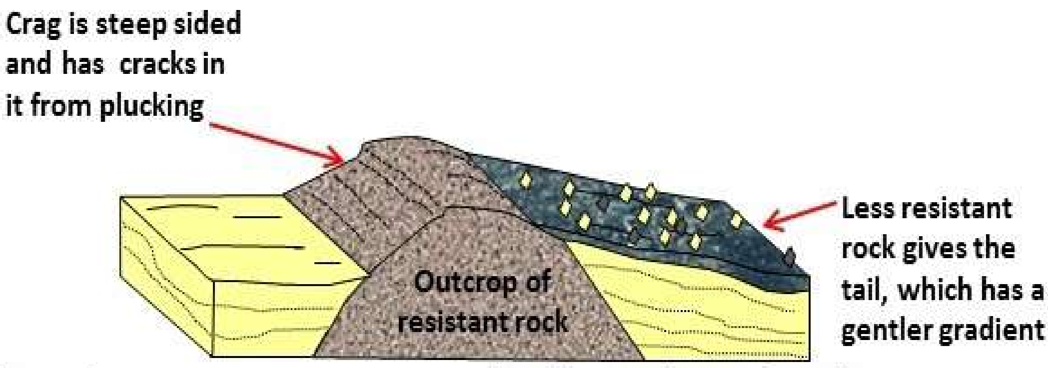

*Figure 4. 75 Features of glacial erosion*

- **Ribbon lakes:** the floor of a glacial trough is often eroded very unevenly, and long depressions may be formed at the U-shaped valley floor. These depressions may become sites of long narrow lakes called Ribbon lakes, for example, Lake Noir in France.
- **Roche montane (roche moutonée)**: this is a mass of more resistant rock that projects above the general level of a glaciated valley floor. In most glaciated valleys, it is possible to find rock surfaces that have been grooved and scratched.

***Source:*** *https://www.bing.com/images/ Roche+montane&simid*

***Figure 4. 76*** *Roche montane (rohe moutonée)*

◊ **Crag & Tail:** This is an elongated rock mass which is formed when a flowing glacier meets a resistant rock protecting a soft rock on its leeward side. The soft rock on the leeward side is called a tail.




***Source:https****://www.bing.com/images/ Crag+and+tail&simid*

***Figure 4. 77*** *Crag and tail*

### 2. Glacial depositional features

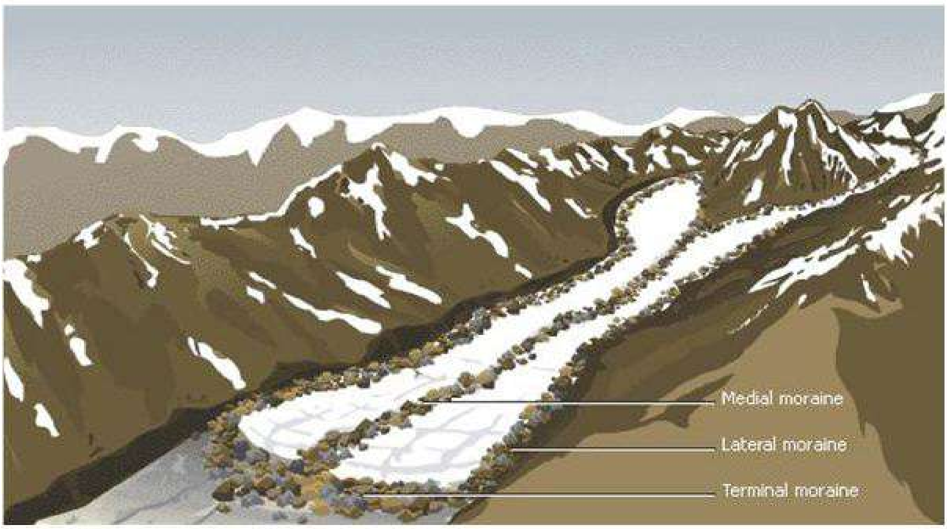
Deposition of debris is among processes performed by **glaciers.** Debris are preferably deposited in depression or lowlands. Glacial deposits are generally called drifts. They include sands, gravels and rock boulders...

The major glacial depositional features are:

- **Moraines**

They refer to materials (debris) carried and later deposited by a glacier as it stagnates or decay. Moraines can be classified into the following types:

- **Terminal moraine:** these are deposited on the mouth of a glacier.
- **Lateral moraine:** these are deposited on the sides of a glacial trough and from elongated ridges on the sides of valley gorges.
- **Medial moraine**: These are materials that were originally carried by the valley sides of two small valleys which after emerge into one valley. These materials found themselves in the Centre of a glacier.
- **Ground moraine:** This type of moraine covers the entire width of the valley floor.




***Source:*** *https://www.google.com/search?q=moraine&source*

***Figure 4. 78*** *Moraine*

- **Till plains:** these are extensive lowland areas covered by till or a till covered plain.
- **Fluvial glacial deposits:** Fluvial glacial deposits are those materials deposited by melt water from a stagnant glacier. They lead to the formation of the following depositional landforms:
- **Outwash plain:** is a wide gentle sloping plain which is composed mainly of sand and gravel which were deposited by unevenly melt water
- **Kame:** is an irregular mound of sand and gravel deposited by melt water, they are short lived and can collapse any time.
- **Kame Terrace:** is a flat topped ridge formed between a valley glacier and the valley slopes. It is composed of materials deposited by melt water streams

flowing laterally to the glacier.

- **Esker:** is an elongated, narrow ridge which is made up of sand and gravel.
- **Kettle holes:** is a depression or hole formed by glacial deposits when a block of ice detached from the main glacial while the latter is retreating.
- **Drumlins:** these are low, rounded smooth, elongated mounds or hills of till rising up to 50m or 1km long. They are products of glacial deposits which flattened the landscape

Application activity 4.7

a. Account for the limited coverage of glaciation in East Africa.

b. Make a research and illustrate the major glacial depositional features.

## 4.8. Impact of glaciation on the landscape and to human activities

Learning activity 4.8

Using the experience acquired in previous lessons, identify different human activities carried out in glaciated mountainous regions.

There are many impacts of glaciation on the landscape and human activities. Some are positive while others are negative. The main impacts are described below:

### 4.8.1. Positive impacts

- **Crop farming:** the till and outwash plains contain fertile soils. These are some of the richest agricultural areas in the world.
- **Livestock rearing:** the glaciated uplands provide suitable grazing lands since they form fine benches on which pastures thrive in summer.
- **Tourism:** glaciated landscape has features such as arêtes, pyramidal peaks and cirques that attract tourists.
- **Natural harbors:** fiords provide ideal sites for the development of natural harbors, for example, the port of Rotterdam in Netherlands, natural habours in Norway and Sweden.
- **Fishing grounds:** fiord coastlines such as those in Norway provide suitable fishing grounds since they are deep and well sheltered.
- **Provision of water:** glacial lakes provide water for domestic and industrial use.

- **Transportation:** glacial lakes provide natural waterways, for example, the Great Lakes of North America.
- **Mining:** glacial erosion exposes minerals to the surface making their exploitation easy, for example, gold and copper in the Canadian Shield of North America.
- **Generation of hydro-electric power:** waterfalls formed by rivers flowing through hanging valleys are suitable for the generation of hydro-electric power, for example, in Switzerland.

### 4.8.2. Negative impacts

- **Production of bare land:** in some instances, the land surface has been scrapped and polished to bare rock. Such regions are of no economic use.
- **Discourage settlement:** the cold temperatures especially at high altitude limit settlement and other economic activities. They therefore remain as wastelands.
- **Transport barrier:** the rugged landscape produced by glaciers makes it difficult to establish infrastructure such as roads and railways.
- **Hindrance to agriculture:** sand and gravels deposited on outwash plains make the land unsuitable for agriculture.

### Application activity 4.8

Make research using geographical documents and internet on negative effects of glaciation apart from those mentioned in the content.

## 4.9. Mass wasting

### Learning activity 4.9

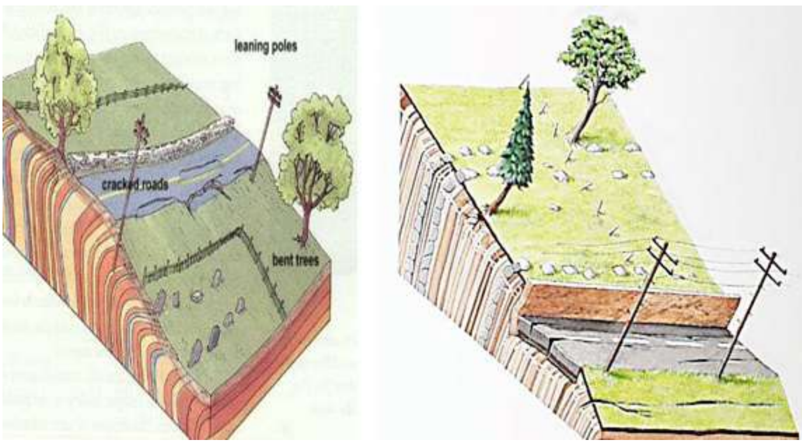
Observe and explain the phenomena that occurred in the photograph below

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

### 4.9.1. 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 climate**.** 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.




***Source:*** *https://www.bing.com/images/ Soil+creep&simid*

***Figure 4. 79*** *Soil creep*

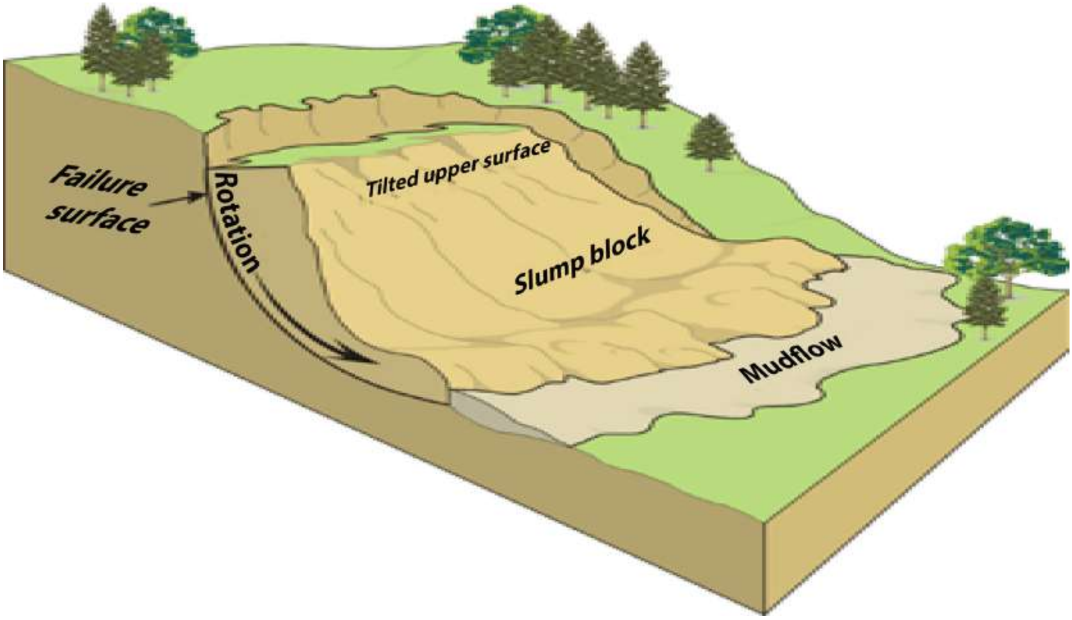
- **Solifluction**: This is limited to glaciated mountainous regions and cold climatic areas where thawing causes the saturated surface layer to creep as a mass over underlying frozen ground.

***Source:***https://www.google.com/search?q=Solifluction&source
***Figure 4. 80*** *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.

### 4.9.2. 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.




***Source:*** *https://www.bing.com/images/ Mud+flow&simid*

***Figure 4.81*** *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.

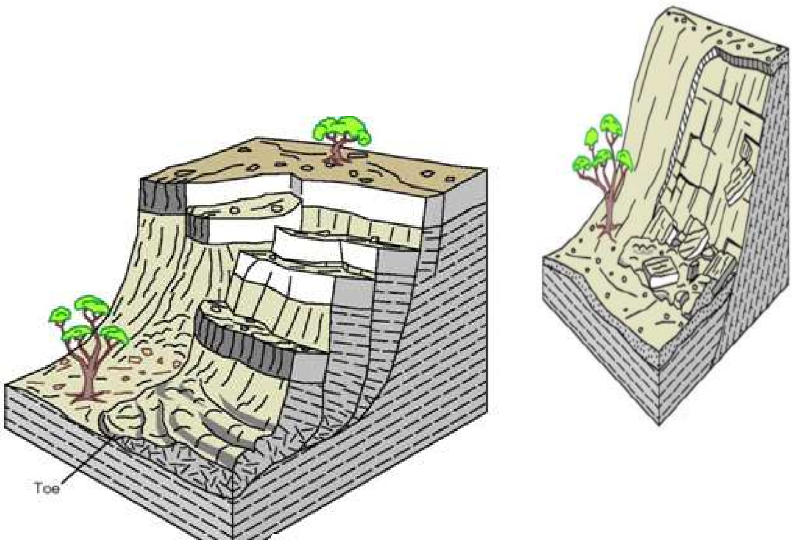



*Figure 4. 82 Slump (left) and rock slide (right)*

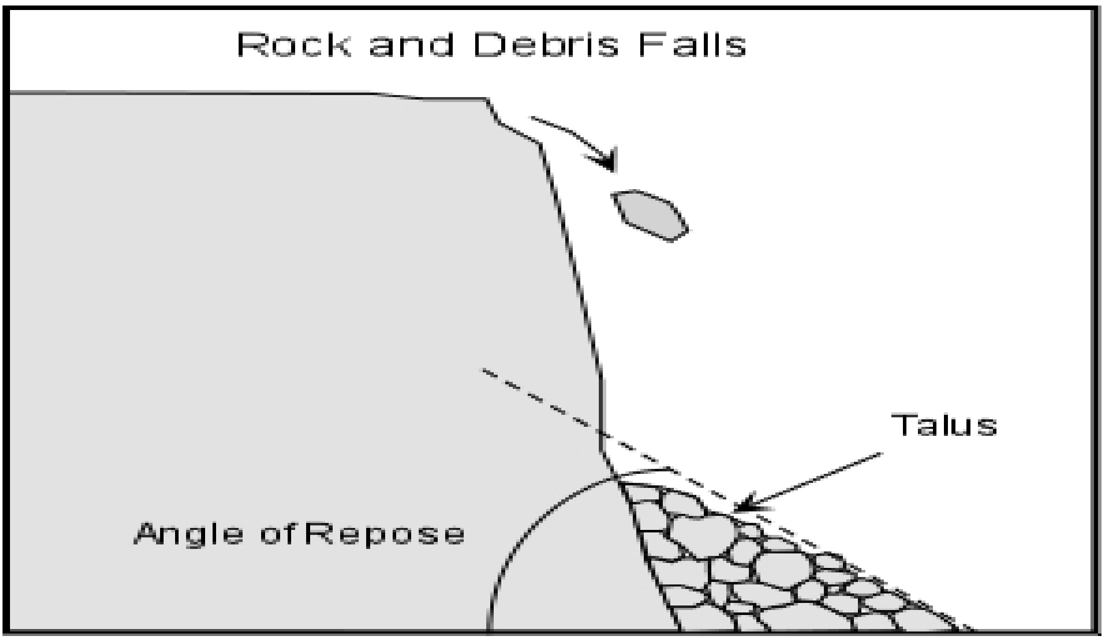



*Figure 4. 83 Rock fall*

**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.

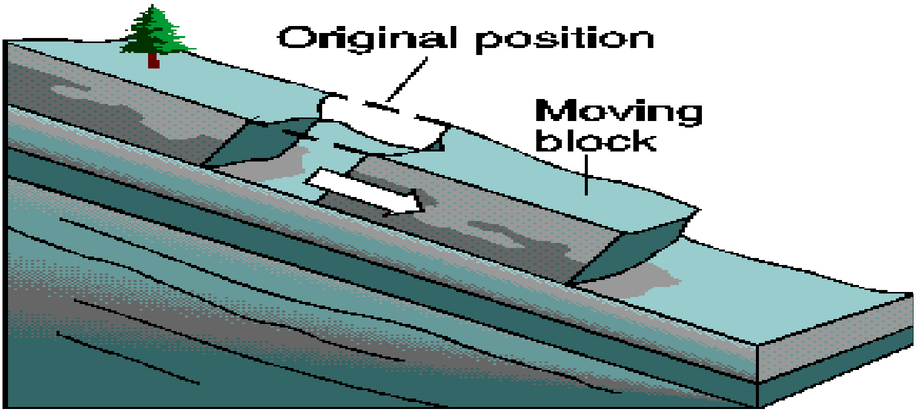



*Figure 4. 84 land slide*

Application Activity 4.9

Make research and analyze the types of mass wasting common on hilly areas of Rwanda.

## 4.10. Causes, effects and control measures for mass wasting

Activity: 4.10.

Observe the photograph below taken in Gakenke district and describe the phenomenon that took place.

### 4.10.1. 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.

### 4.10.2. 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.

It is noticed that 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 4.10

Make a field trip to observe different cases of mass wasting in your area. Analyse its causes and propose the sustainable measures to control it.

## 4.11. The relationship between weathering landforms and human activities

### Learning activity 4.11

Are landforms resulting from weathering important in your area? Support your answer.

Weathering affects human activities in various ways as follows:

- Weathering provides a basis for the development of construction industry in an area. e.g. marrum soil and laterite are good for road construction.

- Weathering can also produce landforms that offer important touristic opportunities.
- Weathering facilitates soil formation, this directly provides a basis for the development of agriculture in the region.
- Weathering affects limestone regions (calcium carbonate) that are important for cement production.
- Building stones in urban areas are subjected to the weathering processes as natural outcrops but with additional influences.
- Weathered shales also produce good brick clays, whereas the weathered basalt produces fertile soils based on montmorillonite.
- On weathered rocks, weathering often improves the grade of economic deposits by concentrating desirable elements such as copper around the water table.

### Application Activity 4.11

Make research in your area; describe how weathered landforms have benefited the people for their sustainable development.

### End unit assessment

1. Describe the main causes of mass wasting that usually occur in north-western part of Rwanda. How does the community work (umuganda) contribute to the reduction of mass wasting in your area?
2. With reference to East Africa explain the formation of glacial landforms in mountain areas.
3. How have topography and parent rock influenced the rate of weathering in your area?
4. Make a field trip in your local environment and explain how the weathering landforms identified in your area affect positively and negatively human activities.
5. Referring to above questions suggest ways of sustainable environmental protection.

# UNIT 5

## WAVE EROSION AND DEPOSITION

# UNIT 5: WAVE EROSION AND DEPOSITION

## Key unit competence:

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

### Introductory activity

Use the pictures provided below and answer the following questions:

1. What is the type of water body represented on the pictures above?
2. Identify the coastal landforms found on both pictures.
3. Explain the factors of the formation of the coastal landforms identified on the map at right.
4. According to you, do you think the level of water in ocean is always the same? Justify your answer.
5. If you need to be a business man / woman at the coastal regions, explain the business opportunities that you may carry out there and the challenges you can face.

## 5.1 Coastal landforms: definition of key terms

### Learning activity 5.1

1. Using internet and different books, research and describe the difference between the following terms related to coastal landforms:

   a. **Coast**

   b. **Shore**

   c. **Wave**

   d. **Longshore drift**

2. Identify the parts of a wave

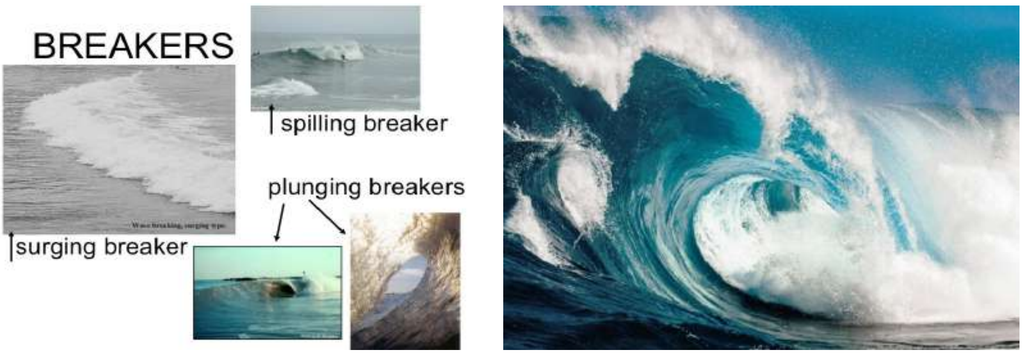
Definition of key terms:

Below are defined different terms associated with the 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.

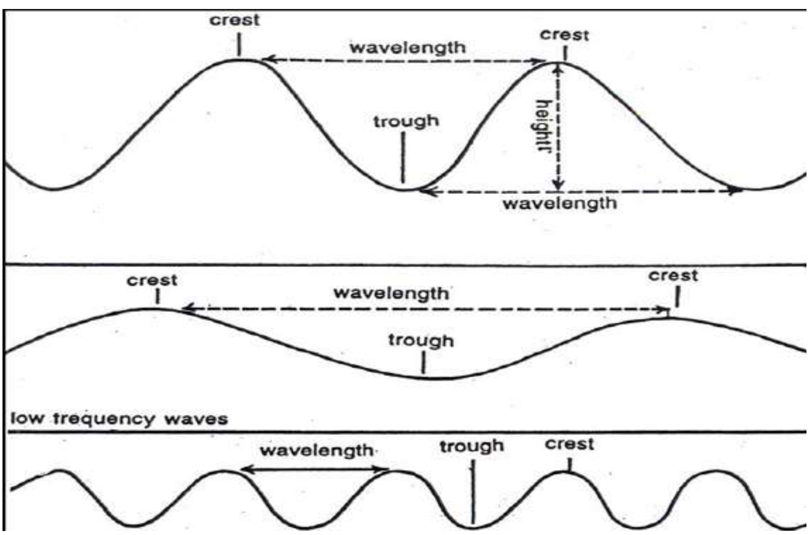
*Source: https://costaricaexperts.com/destinations/caribbean/*
*Figure 5.85 Coast*

- **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 (see the figure below). Waves are created by the transfer of energy from the wind blowing over the surface of the sea. When waves appear with high frequency they demonstrate the short wave-lengths. When they appear with low frequency they demonstrate long wave-lengths. However, there are special waves like Tsunamis that result from sub-marine shock waves by earthquakes or volcanic activities.




*Source : (© mit.edu) https://www.marineinsight.com/environment/a-comprehensive-list-of-different-types-of-sea-waves/*

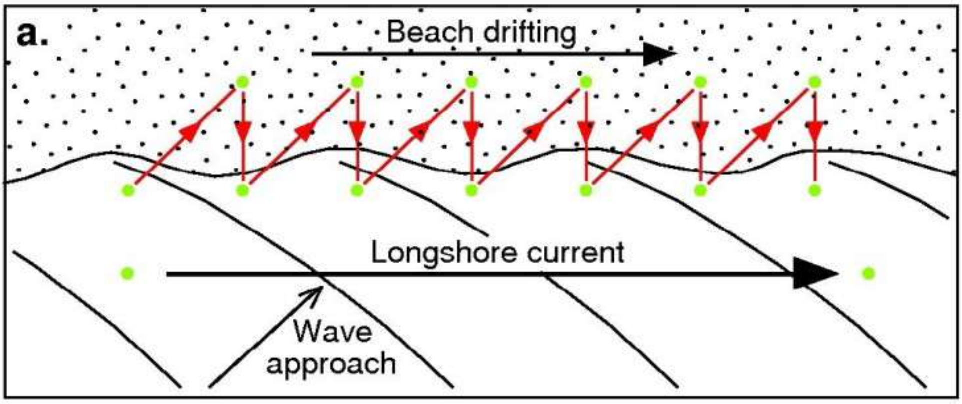
*Figure 5. 86 Waves*




*Source: JKF Geography students' book for senior 5*

*Figure 5. 87 Structure of wave*

- **Longshore drift:** This refers to the movement of sediments along the shore in a zigzag pattern. Sediments produced by the erosive action of waves or sediments transported by the river systems are moved by ocean waves and ocean currents to form beaches. Sediments are as well moved offshore onto the continental shelf. Most waves reach the shore at an angle of about 10° but this can change depending on the wind direction. Each successive wave moves sand at an angle along the beach face. Consequently, currents within the surface zone flow along the shore as longshore drift (see the figures below).



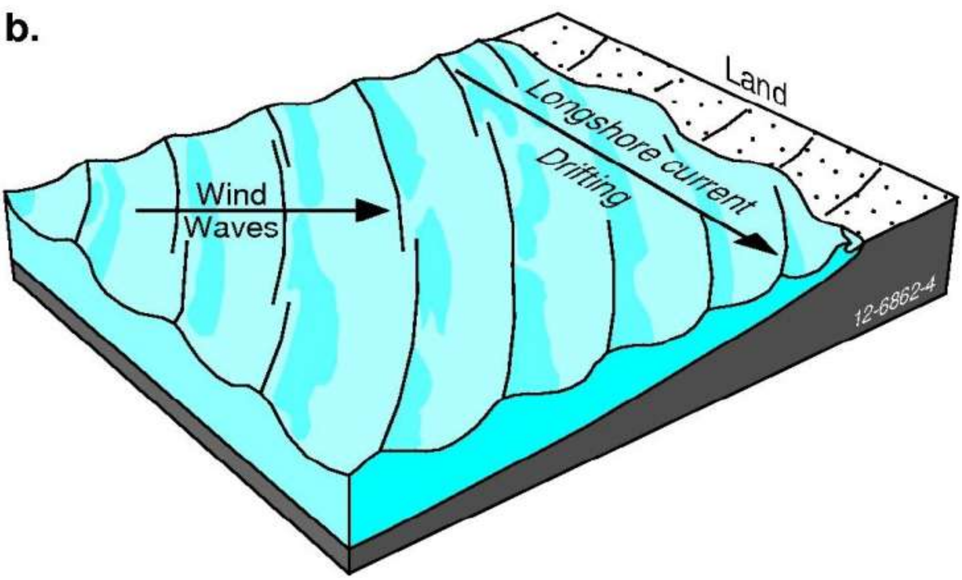




*Figure 5.88 The action of longshore drift*
*Source: http://geophile.net/Lessons/coasts/coasts_02.html*

## Application activity 5.1

1. By using a diagram, demonstrate the parts of a wave.

2. Differentiate a shore from a longshore drift.

3. If you find an occasion to visit the Indian ocean coast in East Africa, describe the coastal features you would be interested to discover.

## 5.2 Types, factors and action processes of waves

## Learning activity 5.2

1. Using internet and other resources, describe the types of waves.
2. A coast may have the steep slope like cliff or gentle slope like beach. Explain different ways by which waves may hit the coast depending on its slope.
3. Visit a water body in your local area, observe the waves movement and do the following:

i. Find out the causes of wave movement
ii. Identify the direction of wind on water surface
iii. Determine the direction of waves in water
iv. Describe the effect of wind on wave

4. Explain how waves can cause erosion along the coast.

### 5.2.1 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. They are of two types:

(i) **Plunging breaker:** The wave reaches a steeper beach and curls, moving over a pocket of air. It travels very fast.

(ii) **Spilling breaker:** The wave reaches a sloping sandy beach, dispersing the energy over a large area.

- **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.

### 5.2.2 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 decreases, wavelength decreases, and height increases. Waves therefore 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.

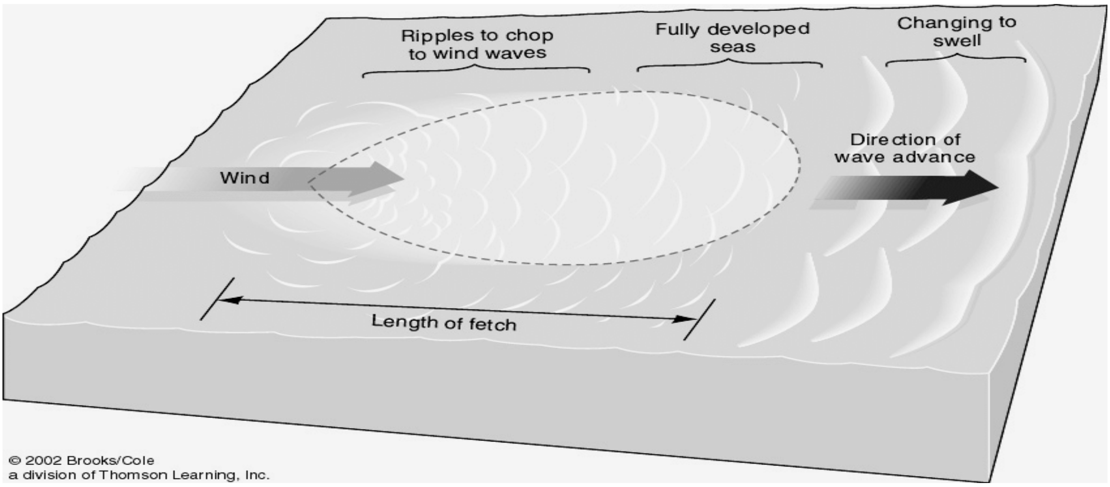



*Figure 5.89 Factors determining the strength of waves*

### 5.2.3 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 cases, sea arches, and sea stacks can form
- **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 5.2

1. Explain the wave action processes.
2. Why do you think in some areas the wave action processes may occur differently in nature?
3. Carry out a research in your local region to identify if there are wave actions taking place.
4. Describe the particularities of Tsunami compared to other types of waves.
5. Explain the impact of wind and tides on the strength of the waves.

## 5.3. Formation of coastal landforms

## Learning activity 5.3

1. Observe the following picture showing a coastal landform and answer the questions that follow

   a. What are the major factors for this landform to be formed?

   b. Water level on photograph may increase or decrease. What are the causes of such phenomena?

2. Using the internet and other geographical resources, describe the following:

   i. Wave erosion features

   ii. Wave deposition features

### 5.3.1. Factors influencing the formation of coastal landforms

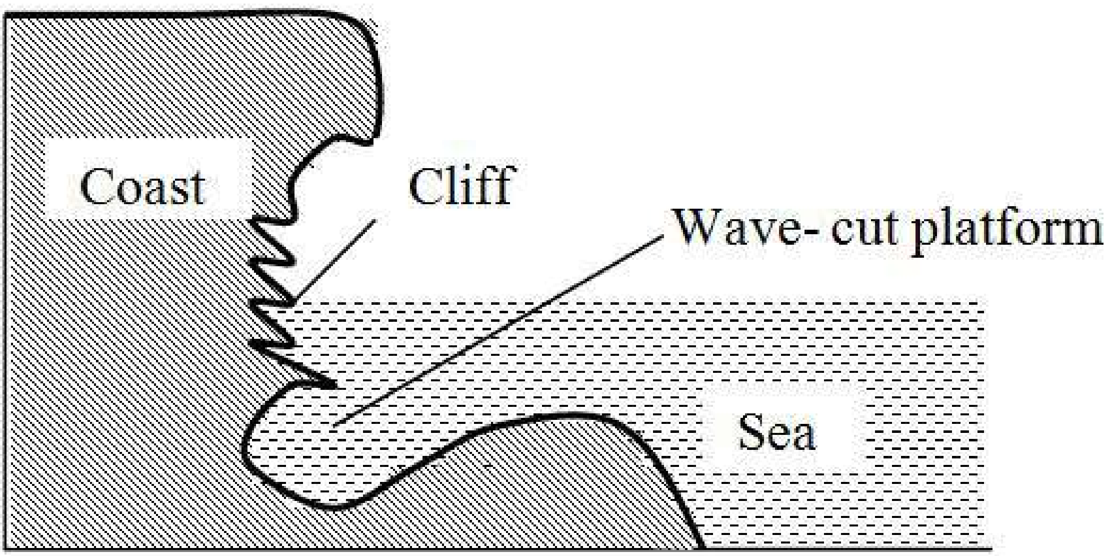
The following are the major factors influencing the formation of coastal landform:

- **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 keep redefining the shoreline of coastal landforms.
- **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.
- **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.

### 5.3.2 Landforms produced by wave erosion

The coastal features formed due to marine erosion by sea waves and other currents and solution processes include cliffs, caves, indented coastline, stacks, chimneys, arch, inlets, 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 face 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.

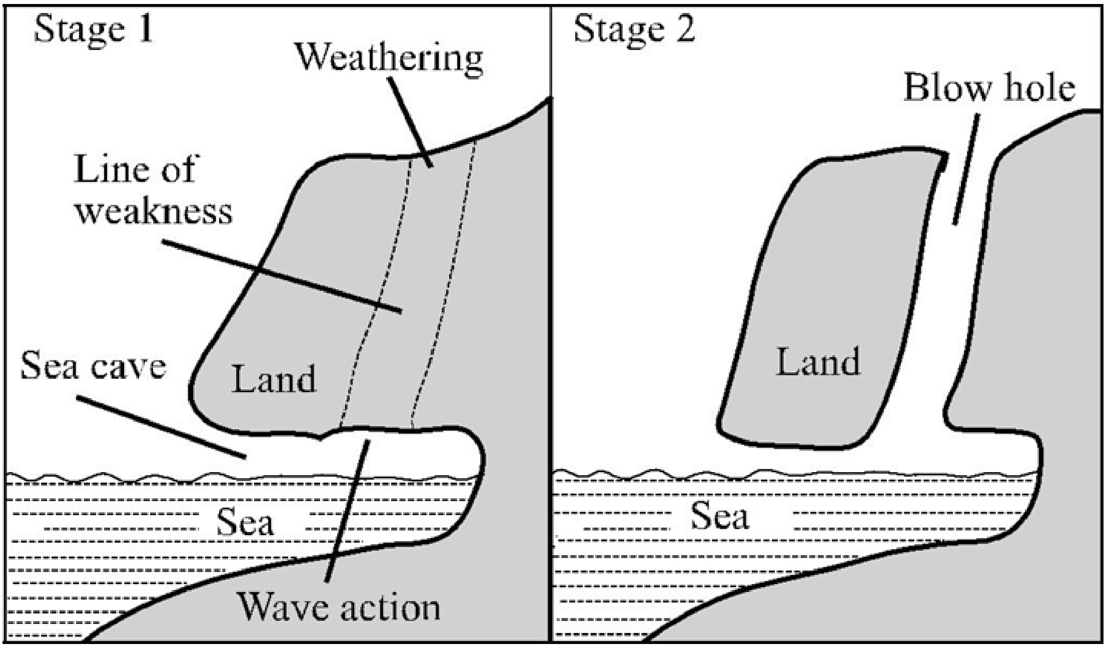



Source: JKF Geography students' book for senior 5

*Figure 5. 90: 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.

- - **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.




*Source: JKF Geography students' book for senior 5*

*Figure 5.91 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.

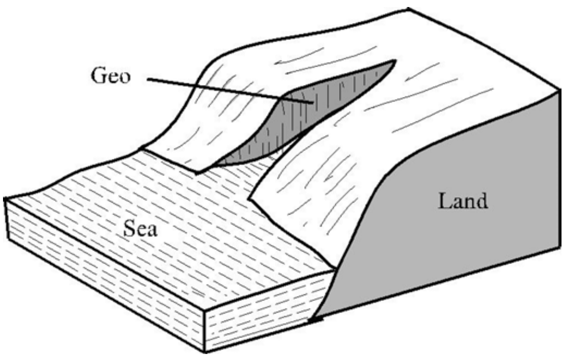
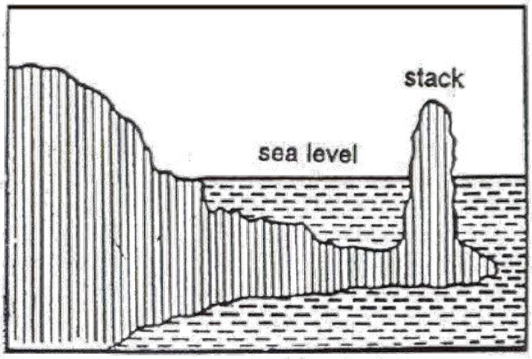



*Figure:5.9.2 Geo*

*Source: JKF Geography students' book for senior 5*

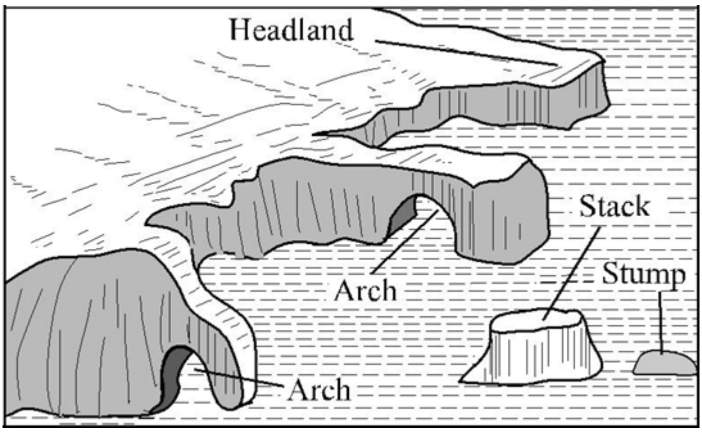
- **Stack/ Column/Pillar:** A stack is an isolated rock monolith or pillar rising steeply from the sea. It is a former part of the adjoining land that has become isolated from it by wave erosion, probably after having formed part of a marine arch.




*Source: JKF Geography students' book for senior 5*

*Figure: 5.9.3. 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.



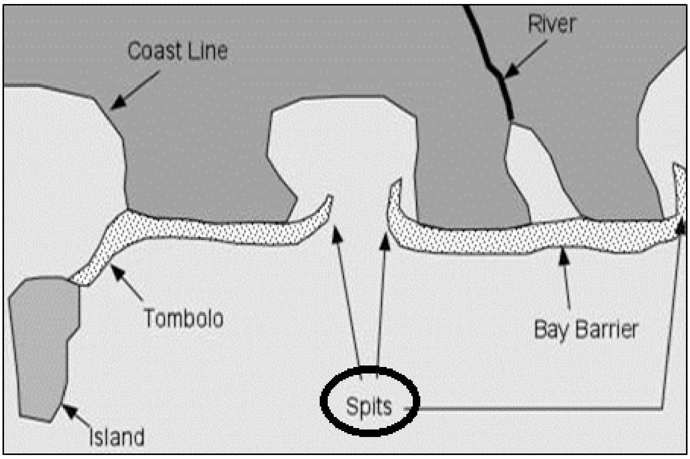

*Source: JKF Geography students' book for senior 5*

*Figure 5. 92 Sea arch*

### 5.3.3 Landforms produced by wave deposition

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.

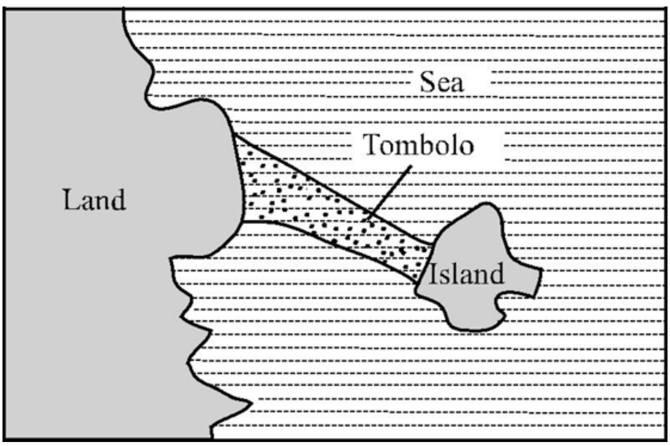
- **Spits:** A spit is an embankment composed of sand and shingle attached to the land on one end and projecting seaward. It may form parallel to the coast and stretch several kilometers. It may also grow at an angle across an estuary. Spits are formed when materials are transported and deposited by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




*Source: JKF Geography students' book for senior 5*

*Figure 5.93 Spits*

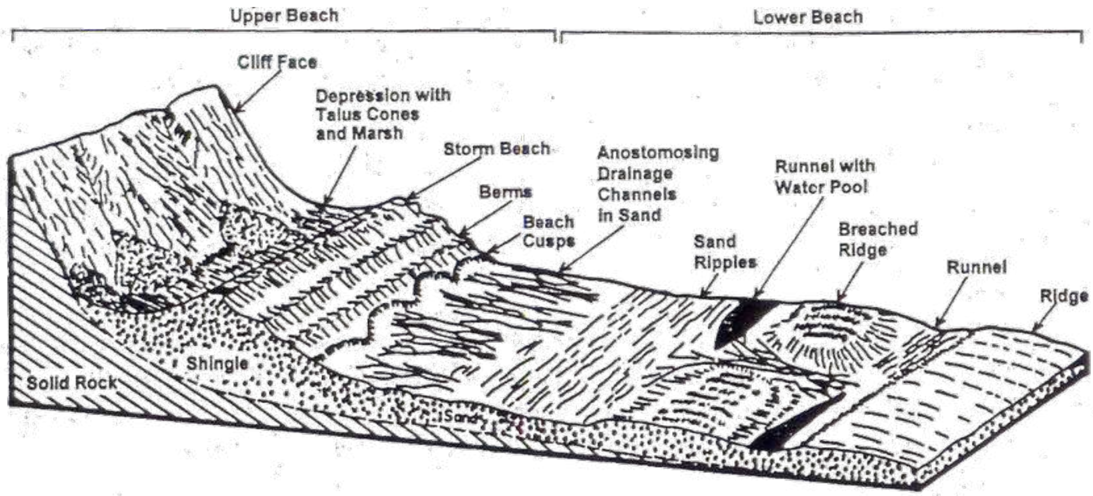
- **Tombolo:** It is a spit which grows seawards from the coast and joints to an island.




*Source: JKF Geography students' book for senior 5*

*Figure 5. 94 A Tombolo*

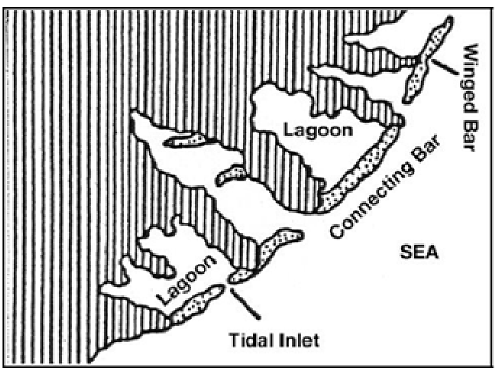
- **Beaches:** A beach is located on a wave-cut platform of solid rock and is generally of a low gradient with a gently concave platform. Beaches may extend for hundreds of kilometers. Beaches are classified into: *sand beach*, *shingle beach*, and *boulder beach*.

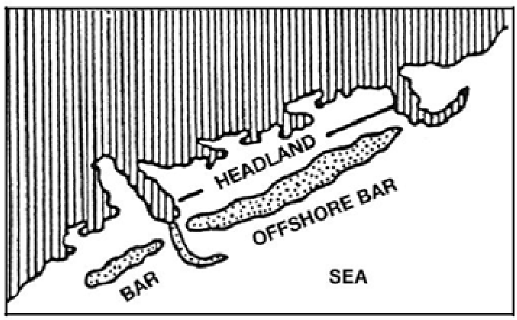



*Source: JKF Geography students' book for senior 5*

*Figure 5.95 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*.

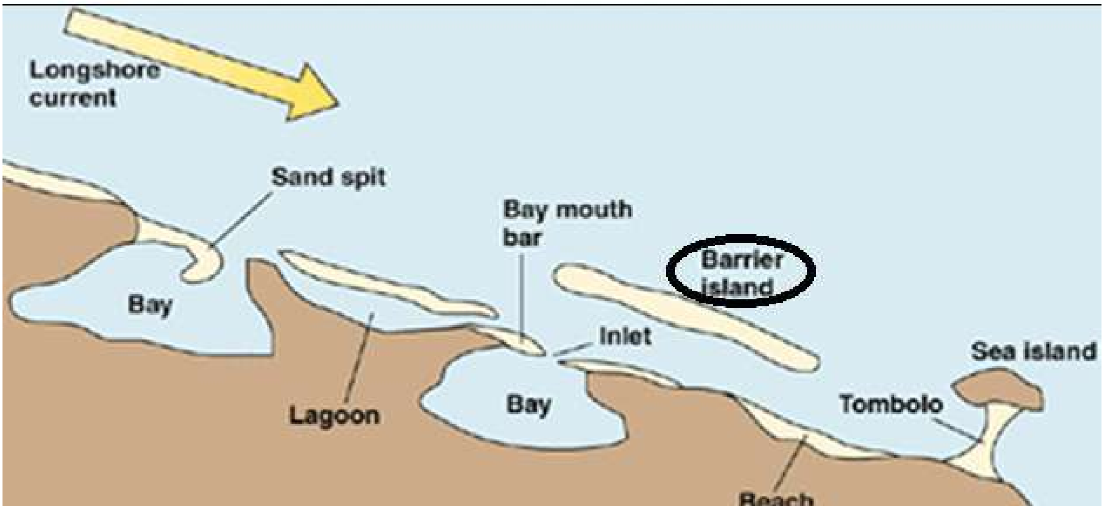



*Source: JKF Geography students' book for senior 5*

*Figure 5. 96 Bar*

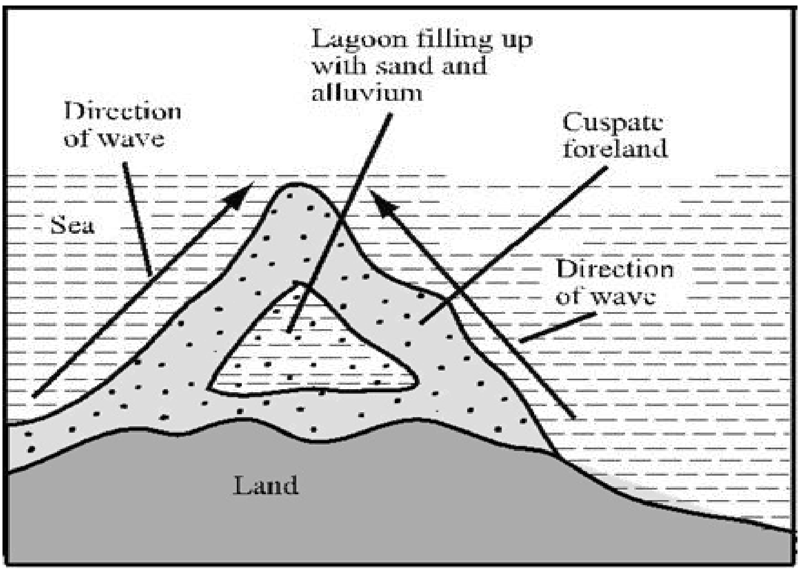
- **Barrier Islands:** Barrier Islands are long, offshore islands of sediments tending parallel to the shore. They form long shorelines adjacent to gently sloping coastal plains, and they are typically separated from the mainland by a lagoon. Most barrier islands are cut by one or more tidal waves.




*Source: JKF Geography students' book for senior 5*

*Figure 5. 97 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.




*Source: JKF Geography students' book for senior 5*

*Figure 5. 98 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.

Source: http://www.acris.nynhp.org/guide.php?id=9866

Figure 5.99 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.

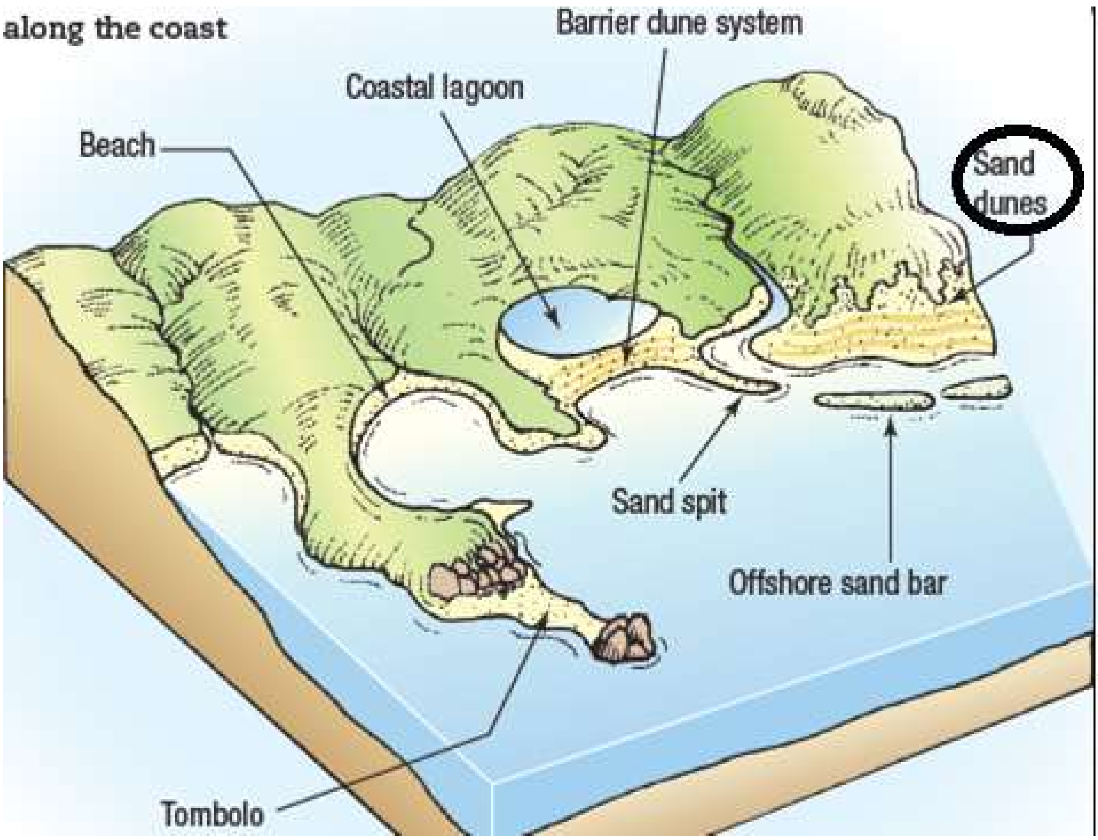



**Figure 5.100** Coastal dunes

## Application activity 5.3

1. Describe landforms produced by wave deposition.
2. Explain the factors influencing the formation of coast landforms.
3. Describe the formation of features produced by wave erosion.
4. According to you, which landforms are likely to find around lake Kivu?

## 5.4 Importance of coast landforms produced by wave action

### Learning activity 5.4

Observe the following picture and describe the economic activities that can be carried out in this area.

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.

- The peculiar characteristic of coastal environments is their dynamic nature which results from the transfer of matter, energy and living organisms between land and sea systems, under the influence of primary driving forces that include short-term weather, long-term climate, secular changes in sea level and tides.
- 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.
- It is estimated that 90 percent of the world's fish production is dependent on the nature of coastal landforms.
- The coastal landforms attract people as at present, two-thirds of the world's cities with a population of 2.5 million or more are situated near tidal estuaries.

### Application activity 5.4

1. Give five examples of cities located in coastal areas, including at least two located in East African Community.
2. Describe the main activities that are related to the Lake Kivu.

## 5.5. Types of coasts

### Learning activity 5.5

1. Make your own research using internet or other geography resources and identify different types of coasts.
2. Describe the areas subjected to fiords coasts.

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

### 5.5.1. 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:

i. ***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.

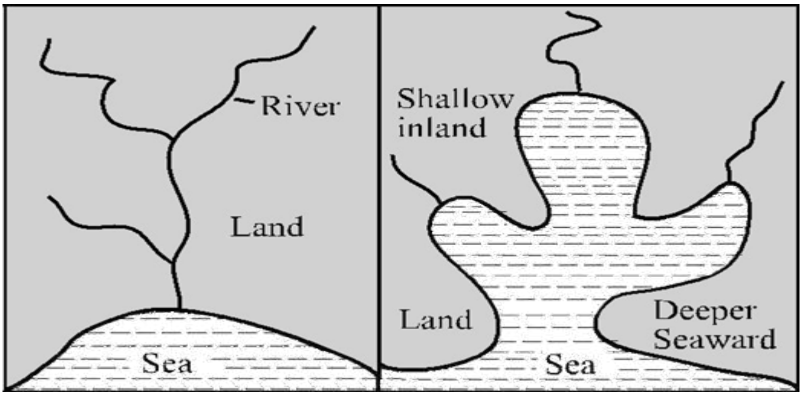
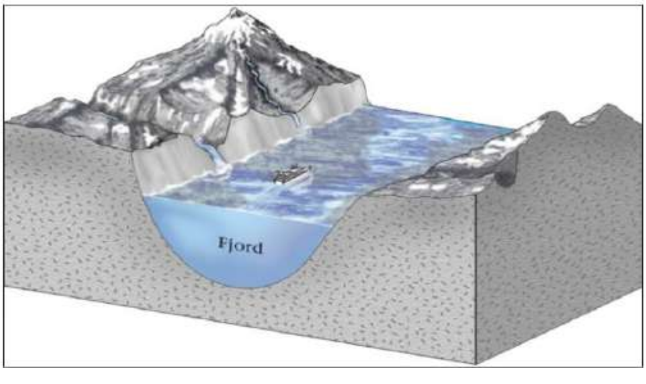



***Figure 5. 101*** *Ria coasts*

***Source:*** *JKF Geography students' book for senior 5*

ii. **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.




***Source:****https://clipartxtras.com/categories/view/fjord-landform-drawing.html*

***Figure 5. 102*** *Fiord*

iii. **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.

***Figure 5. 103*** *Dalmatian or longitudinal coast*

### b. 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.

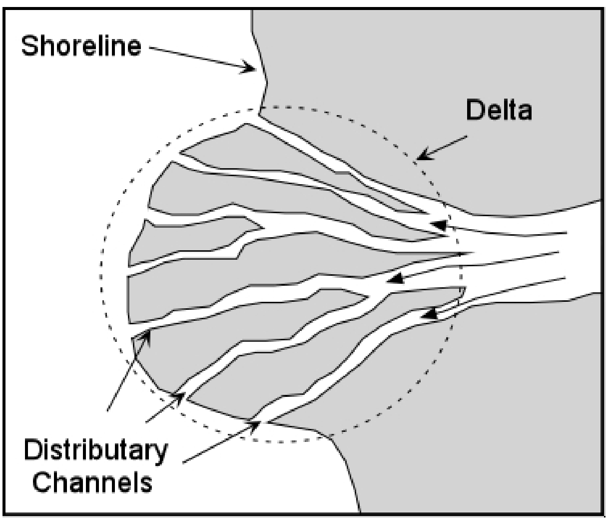



*Figure 5. 104 Submerged lowland coasts*



## 5.5.2. Emerged coasts

Emerged coasts comprise emerged highlands coasts and emerged lowland coasts.

### a. Emerged upland coasts

The chief feature of an emerged upland coast is a *raised beach or cliff-line*, found above the present zone of wave action. The coastlines are revealed as distinct notches in the slope, backed by a cliff, often with distinct *caves*. They are fronted by a wave-cut rock platform covered with each material such as shell banks and shingles. Many parts of the world show evidence of this emergence. The western coast of Malta is a typical example of emerged upland coast.

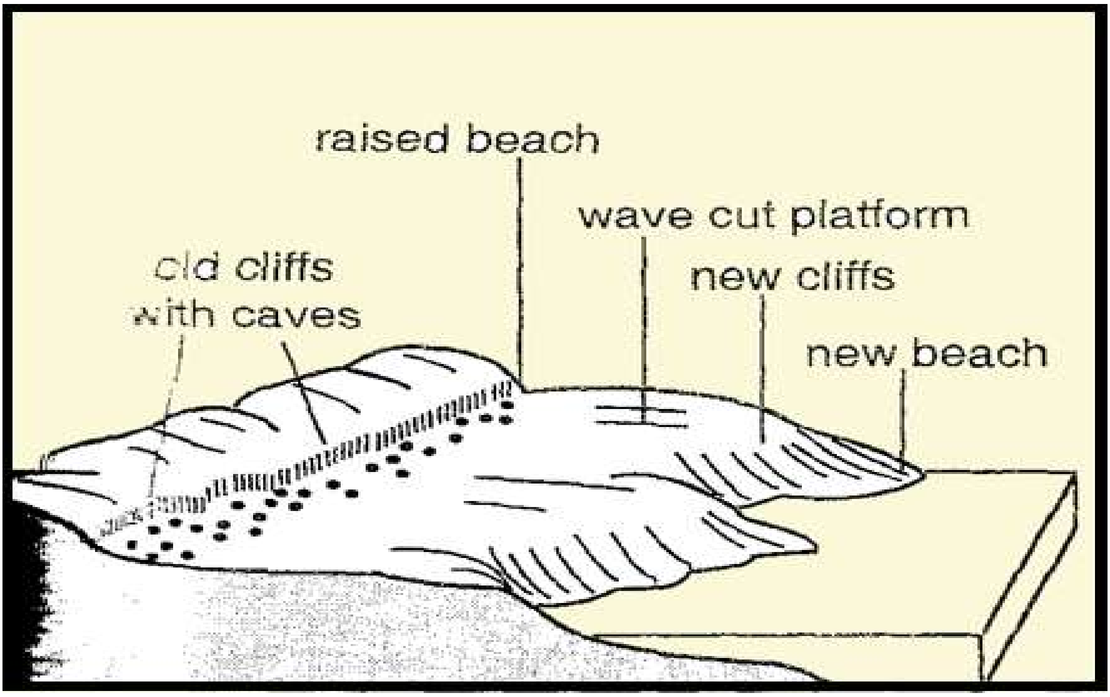



*Figure 5. 105 Emerged upland coast*

### 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 coasts are: the northern shore of the Gulf of Mexico and the southern shore of the Rio-de-la Plata in Argentina.

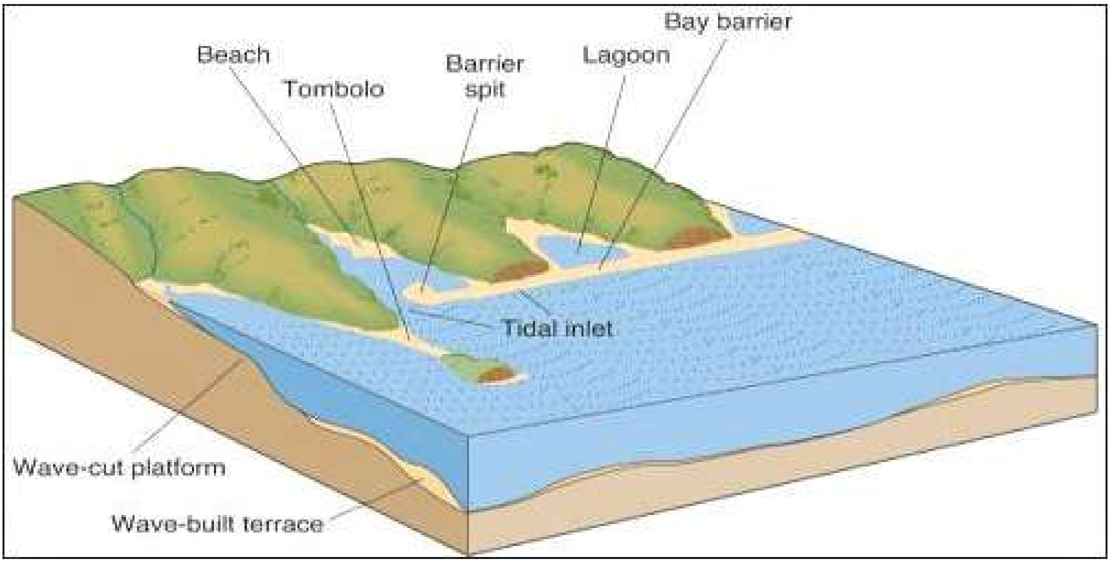



*Figure 5. 106  Emerged lowland coast*

## Application activity 5.5

1. With help of diagrams describe different types of emerged coasts.
2. In a field trip at the lake shore in Rwanda (if any), indicate the type of the visited submerged coast, and describe its characteristics.

## 5.6 Coral reefs

**Learning activity 5.6**

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

*Source: © Genny Anderson*

1. What do you think are the elements that constitute a coral reef?
2. Make research on internet and find out the illustrations of the process of coral reefs formation.
3. What do you think are the problems related to coral reefs?

### 5.6.1 Nature, types and formation of coral reefs

Coral reefs are significant submarine features. They are formed due to the accumulation and compaction of skeletons of dead marine organisms known as **coral polyps**. Coral polyps thrive in the tropical oceans. Numerous coral polyps live at a place in groups in the form of a colony.

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

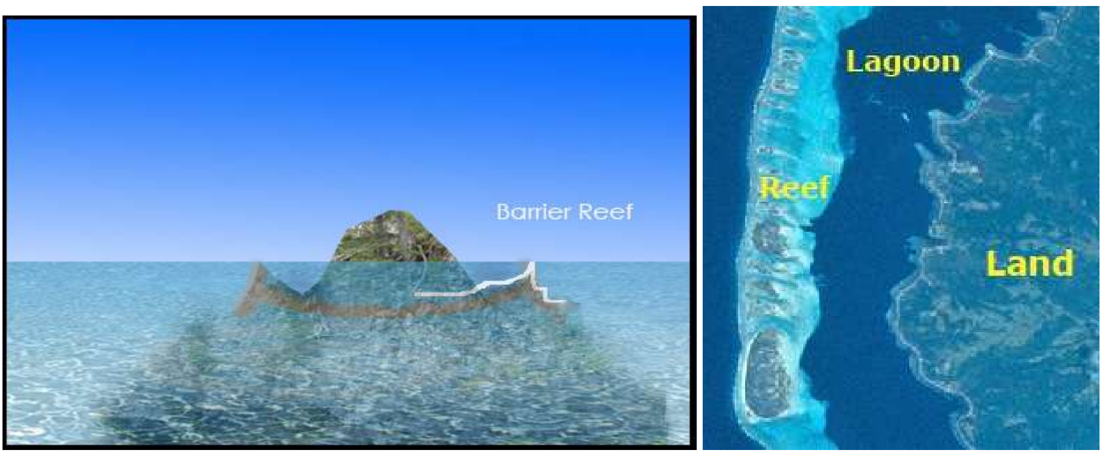
#### a. Types of coral reefs

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.

i. ***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.


*Source: https://www.leisurepro.com/blog/scuba-guides/understanding-the-different-types-of-reefs/*
*Figure 5. 107 Fringing reefs*

ii. ***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.

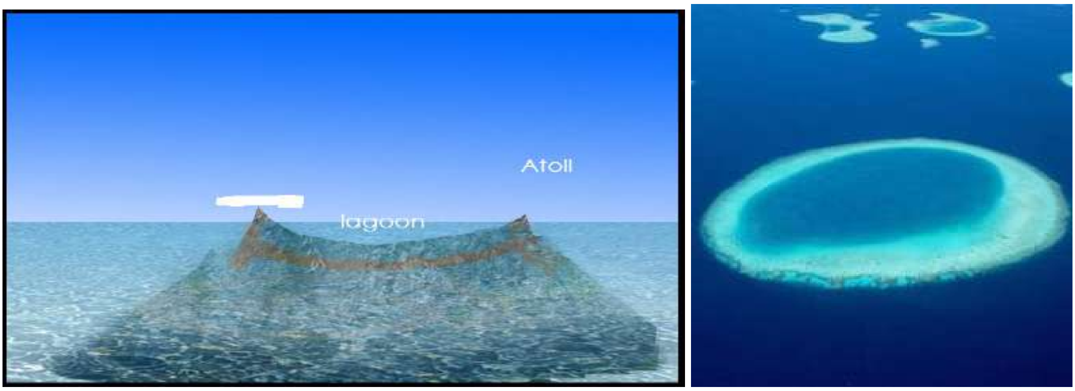



*Source: https://www.leisurepro.com/blog/scuba-guides/understanding-the-different-types-of-reefs/*
*Figure 5. 108 Barrier reefs*

iii. ***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.

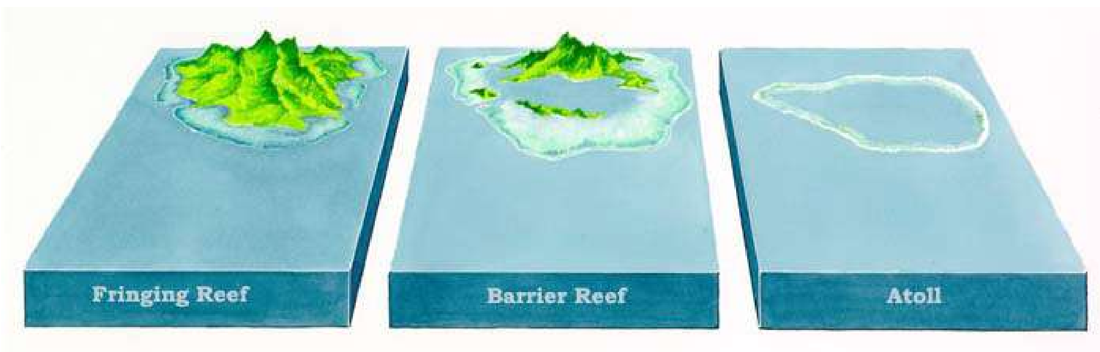



*Source: https://www.tahitiheritage.pf/atoll-anaa-tuamotu/*
*Figure 5. 109 Atoll*

**b. Formation of coral reefs**

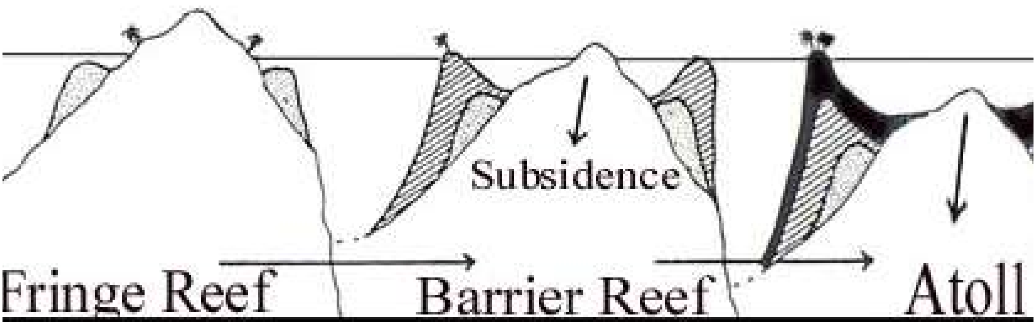
i. The process of coral reefs formation

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.




*Source: http://www.marinebio.net/marinescience/04benthon/crform.htm (LJF images)*
*Figure 5. 110 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 and 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.




***Source:*** *http://www.coexploration.org/bbsr/coral/html/body_reef_formation.htm*

***Figure 5.111*** *Formation of coral reefs*

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 is injurious to 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.

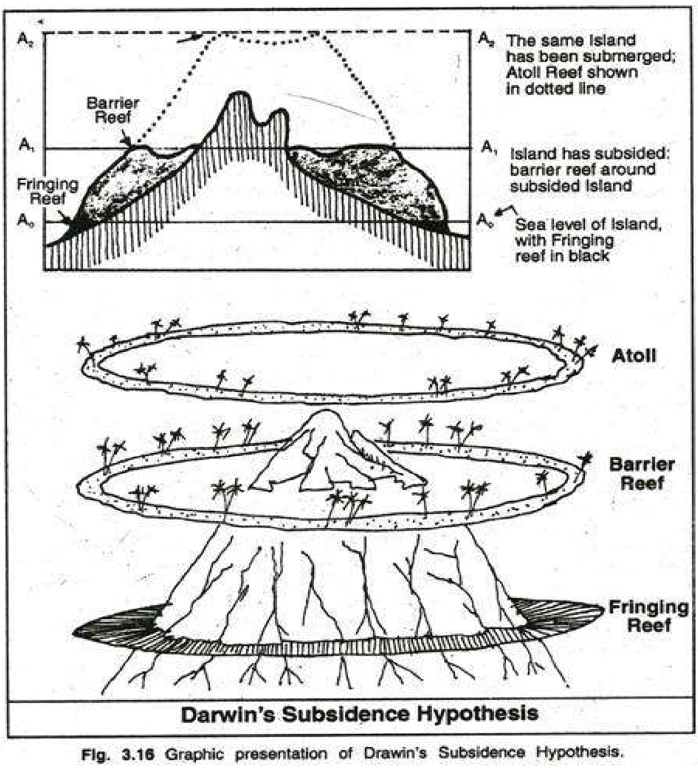
### 5.6.2 Theories of the origin of coral reefs

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.

#### a. Darwin's 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.




***Source:**http://www.yourarticlelibrary.com/geography/oceanography/ cor al-reefs-ideal-condition-types-and-theories-of-origin-of-corals/32218.*

***Figure 5.112** Darwin's Subsidence theory of the origin of coral reefs*

### b. Murray's antecedence theory

The Antecedent-Platform or uplift theory for the origin of coral reefs holds 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.
- Murray agreed that atoll coral reefs formed when the tops of islands were undergone wave action resulting to a platform.
- Platforms originating below the depth limit of reef corals were veneered with tuffaceous limestone and built to the zone of reef-coral growth by organisms other than corals, chiefly foraminifera and algae.

### c. Daly's 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

### 5.6.3. 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 tourism curios has resulted in over fishing of not only deep-water commercial fish, but key reef species as well. This affect 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 coral bleaching as happened during the 1998 and 2004 El Niño years, 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.

### 5.6.4 Impact and problems related to coastal landforms

Coastal 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.

Application activity 5.6

1. Using illustrative graphics, differentiate the types of coral reefs.
2. Explain the conditions for coral reefs formation.
3. Identify the problems related to coral reefs.
4. Establish the similarities of the subsidence, antecedence and glaciated control theories of coral reefs formation.
5. Describe the economic importance of coral reefs.

## 5.7 Isostatic and Eustatic changes on the coast

Learning activities 5.7

1. Basing on your knowledge on the concept of isostasy, do you think it can be related to the isostatic and eustatic changes on the coast? Explain.
2. Differentiate isostatic from Eustatic sea level change.

The sea level is not static, which causes the level on coast changing regularly. These changes are discussed below:

### 5.7.1 Isostatic change

***Isostatic* sea level change** is the result of an increase or decrease in the height of the land. When the height of the land increases, the sea level falls and when the height of the land decreases the sea level rises. Isostatic change is a local sea level change whereas Eustatic change is a global sea level change.

- During an ice age, isostatic change is caused by the build-up of ice on the land. As water is stored on the land in glaciers, the weight of the land increases and the land sinks slightly, causing the sea level to rise slightly. This is referred to as compression.

- When the ice melts at the end of an ice age, the land begins to rise up again and the sea level falls. This is referred to *decompression* or *isostatic rebound*.
- Isostatic rebound takes place incredibly slowly and to this day, isostatic rebounding is still taking place from the last ice age.
- *Isostatic* sea level change can also be caused by tectonic uplift or depression. As this only takes place along plate boundaries, this sort of isostatic change only takes place in certain areas of the world.

### 5.7.2 Eustatic Change

*Eustatic* change is when the sea level changes due to an alteration in the volume of water in the oceans or, alternatively, a change in the shape of an ocean basin and hence a change in the amount of water the sea can hold. *Eustatic* change is always a global effect.

During and after an ice age, *Eustatic* change takes place.

- At the beginning of an ice age, the temperature falls and water is frozen and stored in glaciers inland, suspending the hydrological cycle. This results in water being taken out of the sea but not being put back in leading to an overall fall in sea level. Conversely, as an ice age ends, the temperature begins to rise and so the water stored in the glaciers will re-enter the hydrological cycle; and the sea will be replenished, increasing the sea levels.
- Increases in temperature outside of an ice age also affect the sea level since an increasing temperature causes the ice sheets to melt, putting more water in the sea.
- The shape of the ocean basins can change due to tectonic movement. If the ocean basins become larger, the volume of the oceans becomes larger but the overall sea level will fall since there's the same amount of water in the ocean. Conversely, if the ocean basins get smaller, the volume of the oceans decreases and the sea level rises accordingly

### Application activity 5.7

1. Describe the isostatic and eustatic changes on the coast.
2. Describe the effects of Eustatic change on the environment.

## 5.8. Sea level change

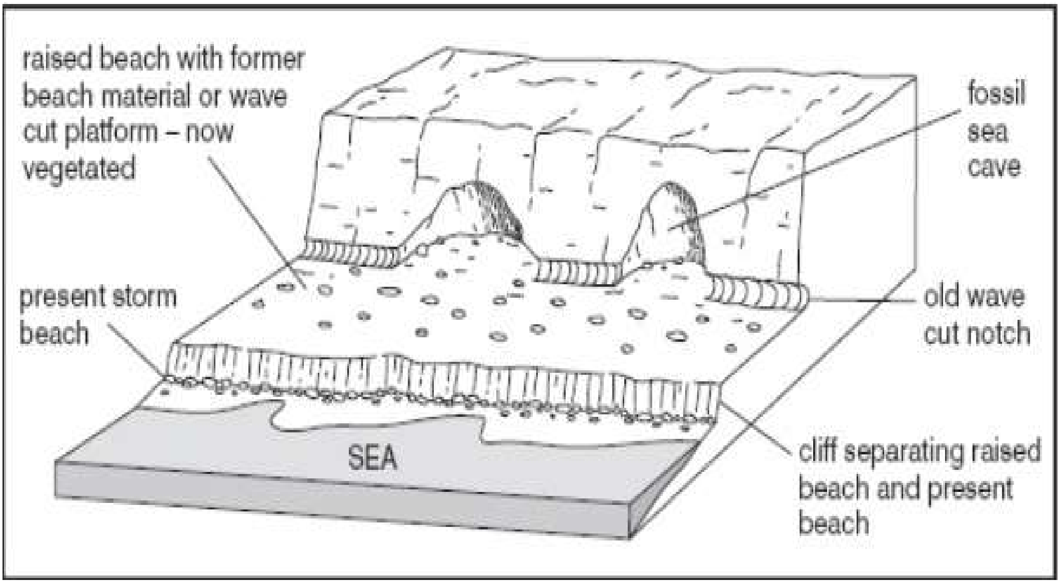
Learning activity 5.8

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 the features portrayed on this picture.

### 5.8.1 Meaning of sea level change and its resulting features

The sea level change is the variation and fluctuation of the sea level throughout time. On a day to day basis, the sea level changes from the tide action but the sea level also changes on a much grander time scale too. These changes in sea level are normally caused by ice ages or other major global events. The sea level change results from eustatic and isostatic changes. 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.




***Source:*** https://garsidej.wordpress.com/igcse/coastal-environments/

***Figure 5.113*** *Raised beach*

### 5.8.2 Types of sea level changes

There are two types of sea level changes which are:

- **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.
- **Fall of sea level**: This is referred to as 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.

### 5.8.3 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 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.

### 5.8.4 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.

### 5.8.5 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.

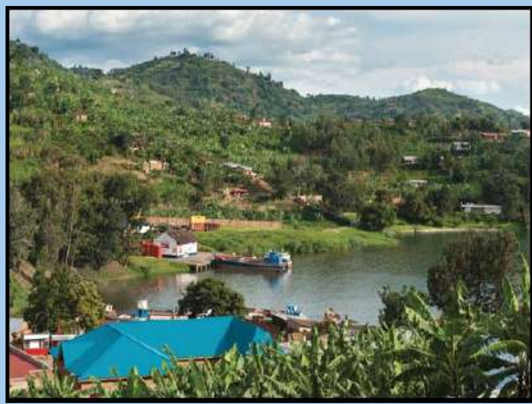
- **Interference with farming:** Those same freshwater sources we use for drinking also supply the water we use for irrigation. The problems here are the same: The intruding sea could make these groundwater sources saltier. Saltwater can stunt or even kill crops, but creating freshwater from saltwater 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 5.8

1. Explain the causes of sea level change
2. *Des*cribe the evidences of sea level change
3. Basing on the study of sea level change. Visit a local water body and identify the evidences of its water level change.
4. According to you, which feature is more attractive to tourism. Defend your view
5. Explain the environmental effects of sea level changes.

## 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 isostatic and eustatic change to the environment.
4. Although Rwanda is a landlocked country, it has many lakes which may change their water levels. Describe the effects of water level changes on human activities around these lakes.

# UNIT 6

## ROCKS AND MINERALS

# UNIT 6: ROCKS AND MINERALS

## Key unit competence:

By the end of this unit, I should be able to assess the economic importance of rocks and minerals.

### 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.

## 6.1. Rocks: Definition, types and characteristics

Learning Activity 6.1.
Observe the rock samples provided to you and identify their distinctive characteristics.

### 6.1.1. 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.

### 6.1.2. 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.

### 6.1.3. Characteristics of rocks

#### a. Characteristics of igneous rocks

Below are the characteristics of igneous rocks:

- Igneous rocks are hard, and water does not pass through their joints easily, that is why they are less affected by erosion;
- They 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 characterized basing on their classification. According to chemical and mineralogical characteristics, texture of grains, forms and size of grains, and the mode of origin, igneous rocks are classified as follows:

i. Classification based on the amount of silica
   - Acidic igneous rocks (having more silica: more 65% of $SiO_2$)
   - Basic igneous rocks (having low amount of silica: less than 45% of $SiO_2$)

ii. Classification based on the chemical and mineral composition
   - Felsic igneous rocks (composed of the dominant minerals of the light group, Silicon, Aluminum)
   - Mafic igneous (composed of the dominant mineral of dark group: magnesium and iron)

iii. Classification based on texture of grains
   - Pegmatitic igneous rocks, (very coarse grained igneous rocks) for example, granite
   - Phaneritic igneous rocks (coarse grained igneous rocks)
   - Aphanitic igneous rocks (fine grained igneous rocks)
   - Glassy igneous rocks (without grains of any size)
   - Porphyritic igneous (mixed grained igneous rocks)

iv. 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:

- Plutonic igneous rocks: are formed due to the cooling of magma very deep inside the earth.

- Hypabyssal igneous rocks: 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 sub-categories:

- Explosive type: The igneous rocks formed by a mixture of volcanic materials ejected during explosive or violent volcanic eruptions.

- 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.

Figure 6. 114 Common Igneous rocks

### b. Characteristics of sedimentary rocks

Sedimentary rocks have the following characteristics:

- Sedimentary rocks are the product of other rocks that have already formed;
- They appear in the form of layers or strata;
- They are formed from materials from the older rocks, plant and animal remains;
- Sedimentary rocks 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.

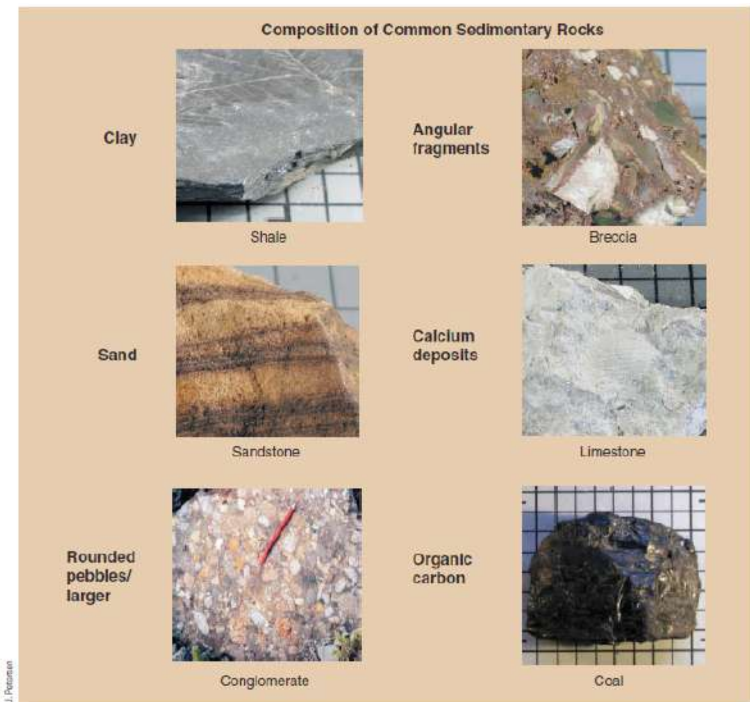


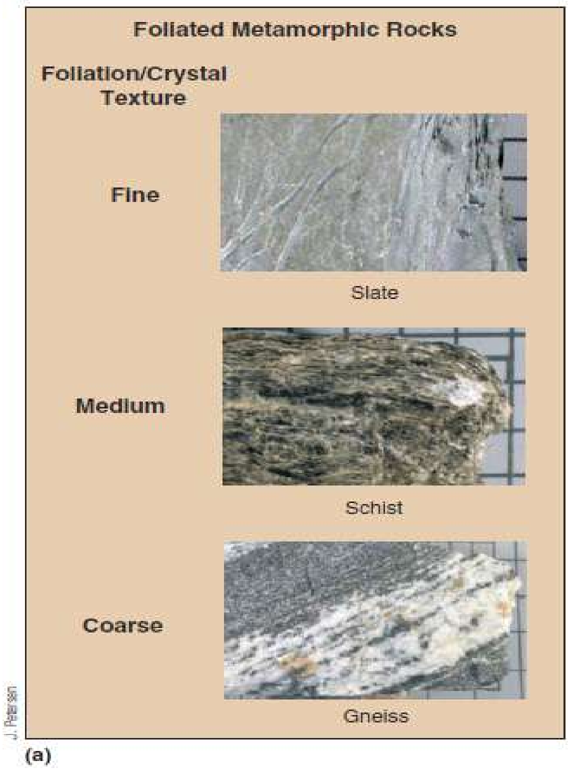

Figure 6.115 Samples of sedimentary rocks composition elements (Gabler et al, 2009)

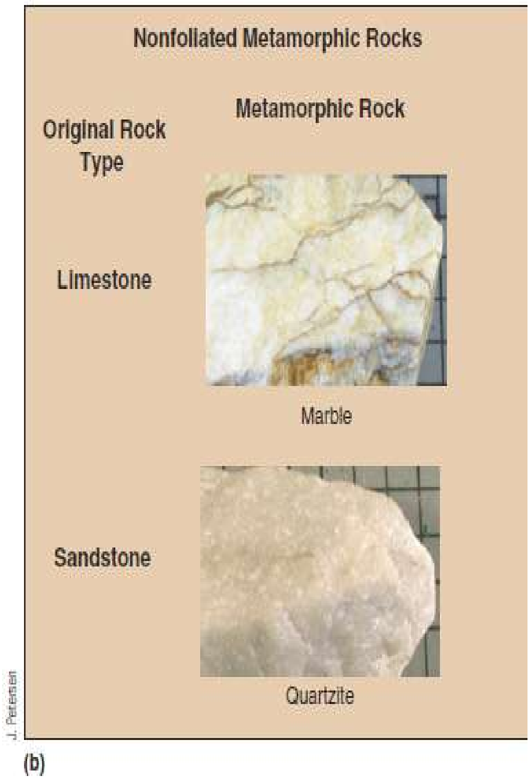
### c. Characteristics of Metamorphic Rocks

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.




*source: (Gabler et al, 2009)*

*Figure 6. 116. Foliated and non-foliated metamorphic rocks*

*Figure 6. 117. Foliated and nonfoliated metamorphic rocks*

Application activity 6.1.

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

## 6.2. Composition and properties of rocks

Learning activity 6.2.

Rocks are composed of physical and chemicals elements. Make a research on internet and in other geographical resources and describe the physical and chemical properties of rocks.

### 6.2.1 Composition of rocks

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

| 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. |

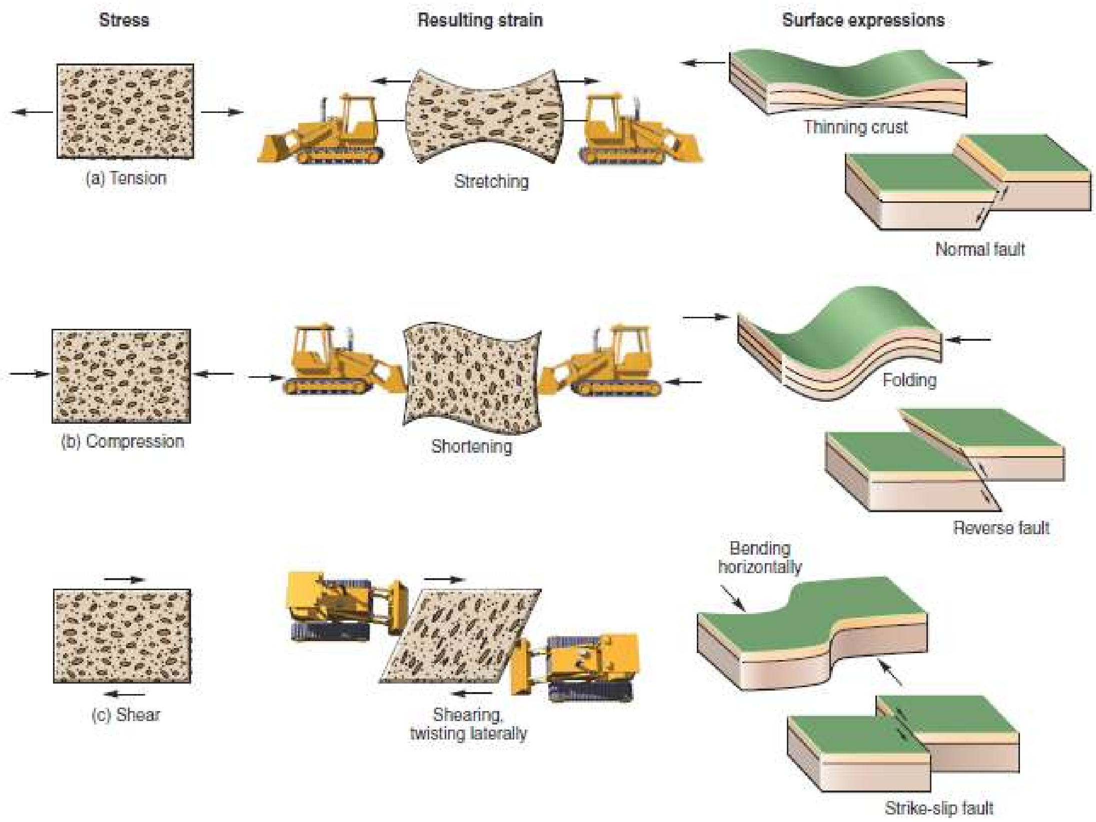
### 6.2.2. Properties of rocks

**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 (see the figure below).

- ***Stress*** refers to forces that constantly push, pull, or twist the earth crust. There are three types of stress: *tension* (stretching), *compression* (shortening), and *shear* (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.




***source:*** *(Christopherson et al, 2012)*

***Figure 6. 118.*** *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.

**Table 6. 2. 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.

**Table 6.3 Lateral representation of metamorphic rocks form beach to far sea shelf**

| Location | Beach | Near shelf | Far shelf |
|---|---|---|---|
| Metamorphic rock | Sandstone | Shale | Limestone |
| Chemical composition | $SiO_2$ | $SiO_{2,}$ $Al_2O_3$ | $CaCO_3$ |

## c. 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.

Table 6. 4. Families of igneous rocks and constituting mineral

| 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%)<br>• Higher resistance to weathering<br>• Increased potassium and sodium<br>• Lower melting temperatures<br>•Brighter coloration | **Feldspars**:<br>• Potassium feldspars: K, Al, Si<br>• (Orthoclase)<br>• Sodium Feldspars : Na, Al, Si (Plagioclase)<br>• Calcium feldspars:<br>Ca, Al, Si | Granite | Rhyolite |
| ***Mafic*** *minerals* (magnesium and iron): ***Basic rocks*** | Silica content (between 45% and 65%)<br>•Intermediate silica content<br>• Intermediate resistance to weathering<br>• Intermediate potassium, sodium, calcium, iron and magnesium<br>• intermediate melting temperatures<br>• grey coloration | **Mica**:<br>K, Fe, Mg, Al, Si (biotite: black; muscovite: white)<br>**Amphibolite**:<br>Fe, Mg, Al, Si, Ca, Na (complex) (hornblende: black) | Diorite | Andesite<br>Dacite (sodic feldspar) (Mount St. Helens) |

| | | | | |
|---|---|---|---|---|
| ***Ultramafic*** *minerals* (low silica content): ***Ultrabasic rocks*** | • Lower Silica content (**less than 45%**)<br><br>• Lower resistance to weathering<br><br>• Increased calcium, iron, and magnesium<br><br>• Higher melting temperatures<br><br>• Darker coloration | **Pyroxene**: Fe, Mg, Si (dark)<br><br>**Olivine**: Mg, Fe, SiO4 (dark green) (no quartz, no feldspars) | Gabbro<br><br>Peridotite | Basalt |

Application activity 6.2.

1. Referring to the properties of rocks, explain how rocks react to the stress and the resulting landscapes?
2. Identify a sedimentary rock in your local environment and describe the process under which it might have been formed.

## 6.3. Impact of rocks: advantages and disadvantages on the landscape and human

Learning activity 6.3

Make research using books and internet to explain briefly the advantages of rocks on landscape and society.

### 6.3.1. Advantages of rocks on the landscape and human being

i. Advantages of rocks on the landscape

Advantages of rocks on landscapes are multiple:

- 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.

ii. Advantage of rocks on human

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. The table below captures usages of rocks.

**Table 6. 5. Uses of rock**

| | |
|---|---|
| **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. |

### 6.3.2. Disadvantages of rocks on the landscape and human

i. Disadvantages of rocks on landscape

- 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 make minerals to absorb differently the heat. Dark-coloured minerals absorb much heat during daytimes and therefore expand, causing the cracking and fragmentation of rocks.

ii. Disadvantages of rocks on human

- 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, reg, 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 6.3.

1. Identify in your local environment the objects made from different rocks.
2. Observe your school buildings and describe different rocks used as construction materials.
3. With relevant examples, discuss the disadvantages of rocks on landscape and society.

## 6.4. Minerals

### Learning activity 6.4.

Use internet and books to search on the following:

1. Types and characteristics of minerals
2. The use of minerals to the society

### 6.4.1. Definition 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.

i. 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.
ii. 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".
iii. 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.
iv. Every mineral is ***an element*** or ***a compound*** with a chemical composition unique to that mineral.
v. 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:

**Table 6. 6 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. |

**Note. Fuels like oil are not minerals because, as explained above, they do not meet the following criteria of minerals:**

- Inorganic (Oil is organic)
- Naturally occurring
- Solid (Oil is a liquid, and natural gas is not solid)
- Have a specific chemistry (Oil is mixture of various hydrocarbons with varying chemistry)
- Internal crystalline structure

However, while Petroleum is not a mineral, it can contain mineral particles as sand which is not a mineral often contains Quartz which is a mineral.

### 6.4.2. 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**.

i. 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

ii. 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. The table below gives details on the main economic mineral ores.

**Table 6.3: Economic mineral and the corresponding mineral ore**

| Mineral | Ore mineral |
|---|---|
| Copper (Cu) | Chalcopyrite, Chalcocite, Cuprite, Malachite, Azurite, Native Copper |
| Aluminum (Al) | Bauxite (a mister) of Al-hydroxides) |
| Iron (Fe) | Hematite, Magnetite, Limonite, Siderite |
| Mercury (Hg) | Cinnabar |
| Tin (Sn) | Cassiterite |
| Gold (Au) | Native gold |
| Tantalum (Ta) | Tantalite-Columbite, Pyrochlore |
| Lead (Pb) | Galena |
| Zinc (Zn) | Sphalerite |
| Nickel (Ni) | Pentlandite |
| Chromium (Cr) | Chromite |
| Magnesium Mg) | Tale |

### 6.4.3 Physical properties of minerals

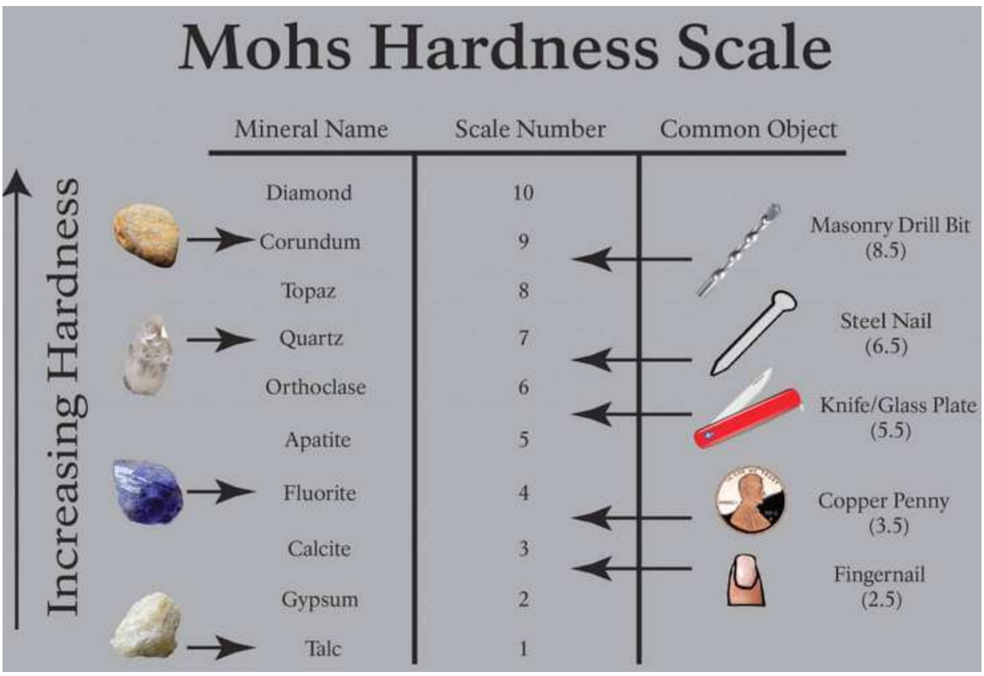
The most common minerals in earth's crust can often be identified in the field basing on their basic physical properties such as their form, hardness, fracture, cleavage, colour, streak, density, luster, mass, taste, odour, feel, magnetism as described below:

**i.** **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.


*Figure 6. 119 Some examples of crystal forms*

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

ii. **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.




*Source: National Parc Service. U.S Department of the Interior*

***Figure** 6. 120 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.

iii. **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.

iv. **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.

v. **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.

vi. **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.

vii. **Luster:** The amount and the type of reflection from the surface of a mineral determine its brightness. There are several types of luster, including the following:

- Metallic: The luster of ordinary metals.
- Vitreous: The brightness of broken glass, for example, quartz.
- Resinous: The luster resembling that of resin.

- Pearly: The luster of peal. This is commonly seen in minerals that present more or less platy surfaces.
- Silky: The luster similar to that of silk; generally shown by fibrous minerals like some varieties of asbestos.
- Adamantine: The luster of diamond.

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

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

x. **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.

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

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

xiii. **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.

### 6.4.4 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.

**Table 6. 7. 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: $CaCO_3$<br>Dolomite: $CaMg\ (CO_3)^2$ |
| | *Halides* | Sodium Chloride (NaCl) |
| | *Oxides* | Hematite $Fe_2O_3$, Goethite $2Fe_2O_3$, Limonite $FeO(OH).2H_2O$, Magnetite$Fe_2O_4$ |
| | *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 |

### 6.4.5 Value 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.

i. Value of minerals

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 value of minerals depends on the following various factors:

- **Chemical composition**: Minerals containing (a) rare metals, (b) rare earths, (c) several acid radicals have high value.
- **Rarity:** Rarity in minerals may be classified as due to the quality of the specimen being greatly superior to the average, or to the scarcity of the species, variety or form.
- **Commercial value:** If a mineral has only small commercial value this may be disregarded in its appraisal.
- **Form of a mineral:** Large, perfect crystals, with brilliant faces and many of them, or groups of such crystals, other things being equal, are the most valuable forms of minerals.
- **Beauty of a mineral:** Theoretically beauty is not a factor in scientific valuation, as it is an element of art rather than science, but practically it is one of the most important factors in determining the value of mineral specimens
- **Size of a mineral:** The mineral may be valued in proportion to their size, though crystals of fine quality increase in value much more than proportionally to their size.
- **Hardness of a mineral:** It has but slight mineralogical value, but it contributes much to the commercial value of gems and it is the chief property of value in the abrasives.
- **Unusual characteristics:** Freak specimens are always more valuable than those which lack unusual characteristics. Thus a twisted tourmaline should be worth two or three times as much as a simple crystal. A beryl broken, by nature into several pieces with quartz filling the space between the pieces, will be correctly appraised at several times as much as the same crystal in one piece.
- **Associated minerals:** While the associated minerals do not, as a rule, increase the value of a specimen, there are many instances in which they do. This is particularly true if the associates give a clue to the genesis of the mineral. Manufactured products from minerals

**Table 6. 8 Minerals and derived manufactured products**

| 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 6.4.

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

## End unit assessment

1. Describe the distinctive characteristics of igneous rocks, metamorphic rocks and sedimentary rocks and the places where they are found.
2. Explain the formation process of each major groups of rocks described above.
3. Discuss the economic importance of rocks and minerals.
4. What is the difference between the physical and the chemical properties of the rocks?

# UNIT 7

# CLASSIFICATION OF SOILS AND SOIL FORMATION

# UNIT 7: CLASSIFICATION OF SOILS AND SOIL FORMATION

**Key unit competence:**

By the end of this unit, I should be able to explain the factors and processes of soil formation.

Introductory activity 7:

Use internet and other geographical resources to research on factors and processes responsible for soil differentiation and formation.

## 7.1 Classification of major soil types of the world

Learning activity 7.1

Make research on:

a. The major types of soils in the world.

b. The difference between zonal soils, azonal soils and intrazonal soils.

Soil is the uppermost layer of the land surface that plants use and depend on for nutrients, water, and physical support. Soils consist of weathered rock mixed with organic material that is derived from decaying plants and animals. There are three major types of soils in the world, namely zonal soil, intrazonal soil and azonal soil.

### 7.1.1 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.

### 7.1.2 Intrazonal soils

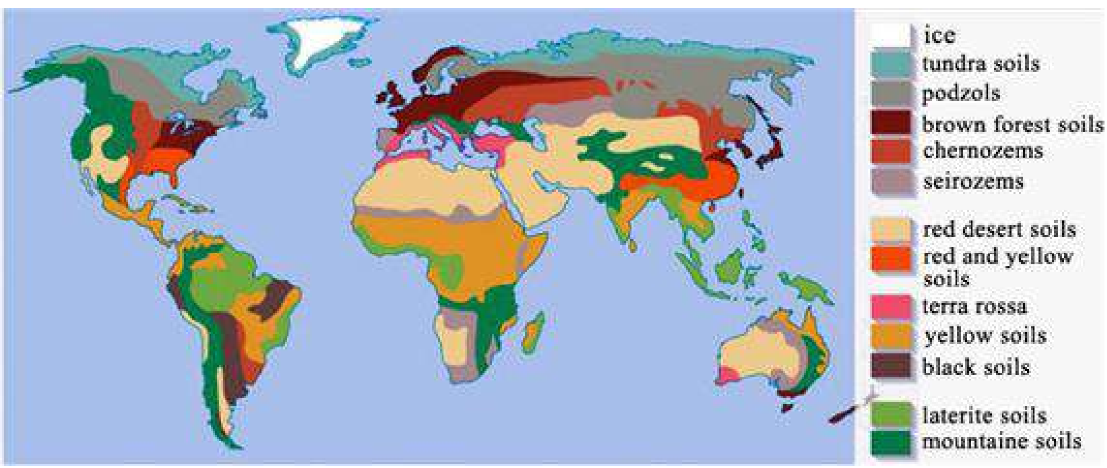
These are soils that mainly develop due to relief of the area and the nature of parent rock. These soils reflect the dominance of a single local factor, such as parent rock or extremes of drainage that prevail over the normal soil-forming factors of climate and living organisms. They are divided into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

### 7.1.3 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




***Source:*** https://www.tankonyvtar.hu/en/tartalom/tamop412A/2011-0038_38_david2_en/ar01s07.html

***Figure 7.121*** *Major soil types of the world*

Application activity 7.1

Make research on:

a. The major types of soils in the world.
b. The difference between zonal soils, azonal soils and intrazonal soils.

## 7.2. Distribution of the major types of soil in the world

Learning activity 7.2.

Use the world map or Atlas to locate the distribution of major soil types.

Climate is an essential factor in soil formation. Therefore, the world's major soil types are distributed following the world's climatic distribution.

### 7.2.1. Tropical soils

These include lateritic soils, red soils, black soils and deserts soils

- ***Lateritic soils***: These are reddish brown soils that are developed under humid tropical forest vegetation. These soils have granular dark reddish brown surfaces underlain by reddish friable clay B-horizons. This type of soil is found in regions with heavy rainfall where leaching is dominant throughout the year.
- ***Red soils***: These are soils that develop in a warm temperate moist climate under deciduous or mixed forests. They have thin organic mineral layers overlying a yellowish-brown leached layer resting on a red horizon. They are found in tropical areas where leaching takes place due to heavy rainfall.
- ***Black soils:*** These are found in humid tropical regions where the basalt rocks are common.
- ***Desert soils:*** These are soils that develop under sparse shrub vegetation in warm to cool arid climates. They have a light-colored surface soil, usually underlain by calcareous material and a hard pan layer. They are found in both arid and semi-arid regions. They are usually sandy and salty.

### 7.2.2. Temperate soils

i. *Podzols:* These are leached soils usually found in cool temperate regions.
ii. *Chernozems:* Chernozems also called black earth are found in extensive temperate grasslands and contain a lot of humus.
iii. *Brown earth:* These soils are found in temperate deciduous forested areas.

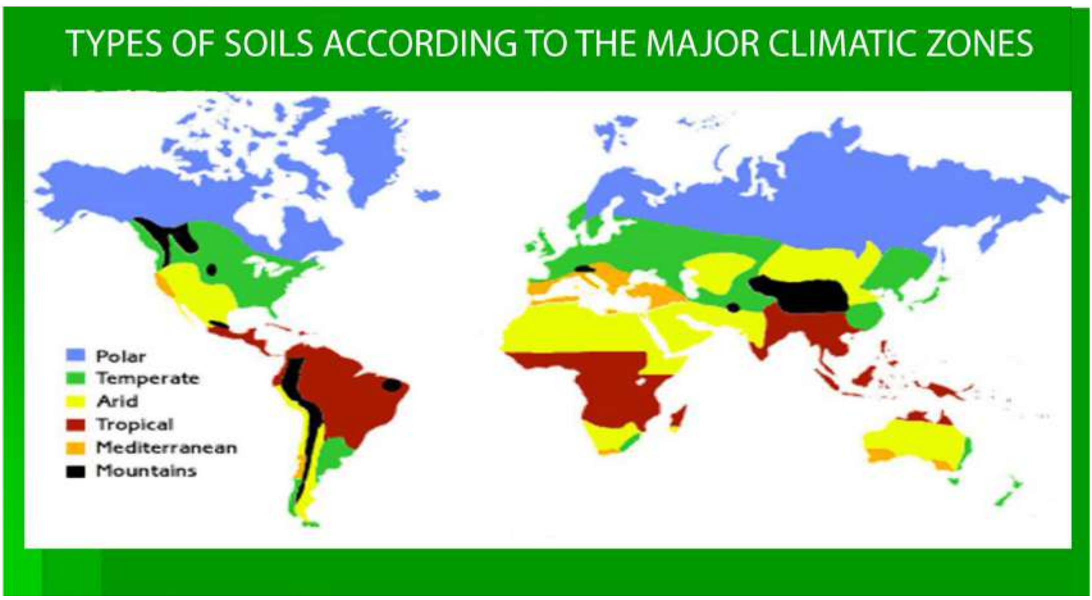
They are not leached.

### 7.2.3. Other soils

There are various types of soil whose characteristics are not determined by climate. These occur in many regions. They include:

i. *Mountains soils:* These are stony and unstable soils in highlands. They are usually eroded and transported to the lower valleys.
ii. *Saline soils:* They are found in areas where evaporation is dominant.
iii. *Peat soils:* They are found in water-logged areas. They contain dead vegetation which is partially decomposed because of the lack of oxygen in them.
iv. *Limestone soils:* They are common in limestone regions; when they are red they are called "*terra rossa*".
v. *Alluvial soils:* They are formed from deposited materials (sand, clay and silt) along the river banks and lakeshores.

The following map shows the major types of soils of the world according to the major climatic zones.




***Source***: *https://slideplayer.com/slide/6226057/*

**Figure** *7.122 Major soil types of the world according to climatic zones*

Application activity 7.2

1. Use the above information from the map to describe the major types of soils around your school
2. Draw a sketch map of the world and mark the major soil types

## 7. 3. Processes and factors of soil formation

Learning Activity 7.3.

Use internet and other geographical resources to research on the processes of soil formation

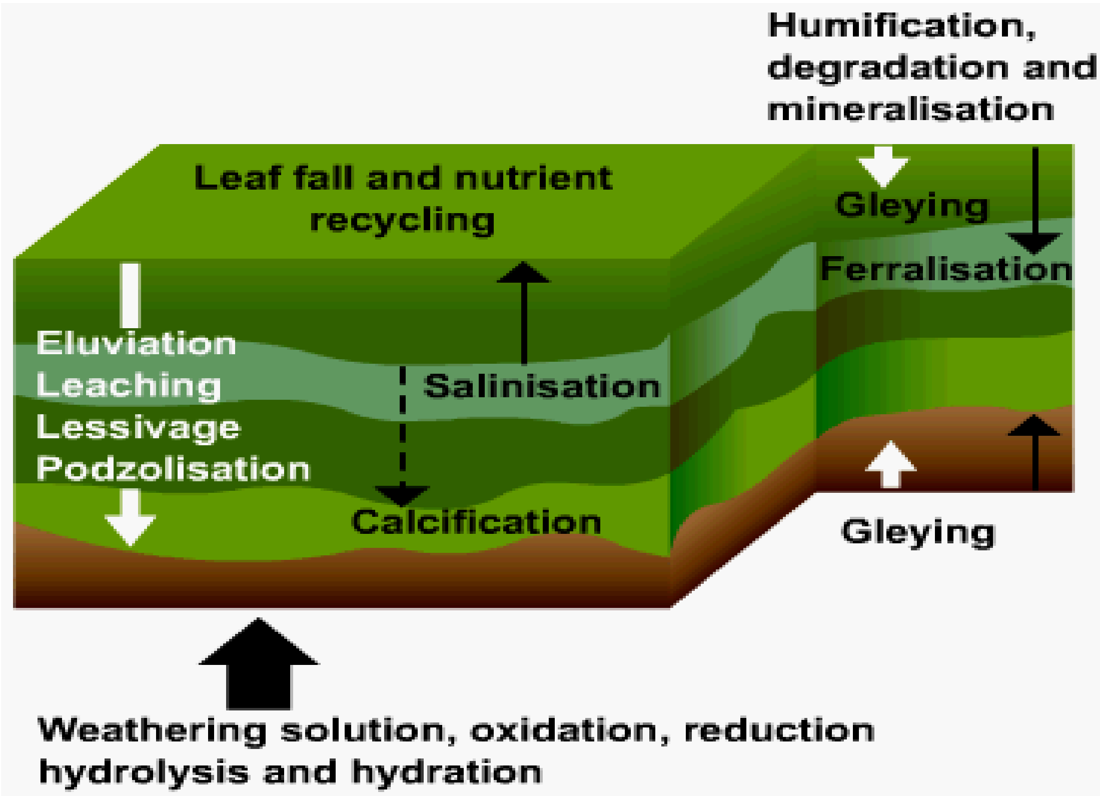
### 7.3.1 Processes of soil formation

Numerous processes are involved in the formation of soil or pedogenesis and the creation of the profiles, structures and other features described below by the combined effect of physical, chemical, biological and other processes working on soil parent material. 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.

i. ***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.
ii. ***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.
iii. ***Illuviation:*** This is the process of accumulation of clay, aluminum and iron usually from A and E horizons to B horizons.
iv. ***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.
v. ***Humification:*** Humification is the process by which organic matter is decomposed to form humus, a task performed by soil organisms.
vi. ***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.
vii. ***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.

***viii. 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.




*Source: © 2018 S-cool Youth Marketing Limited*
*Figure 7. 123: Processes of soil formation*

### 7.3.2 Factors of the soil formation

Learning activity 7.4.

Referring to the illustration below, explain the contributing factors to soil formation

*Source: ©2011-2018 Florida Center for Instrumental Technology*

Soil-forming factors are both *passive* (parent material, topography and time) and *dynamic* (climate, living organisms and man's activities). These factors work together as a system to form soils.

The major factors that influence soil formation are shown below**:**

i. Climate

The moisture (rainfall), evaporation and temperature changes determine the chemical reactions and physical breakdown of rocks. This results in soil profile development.

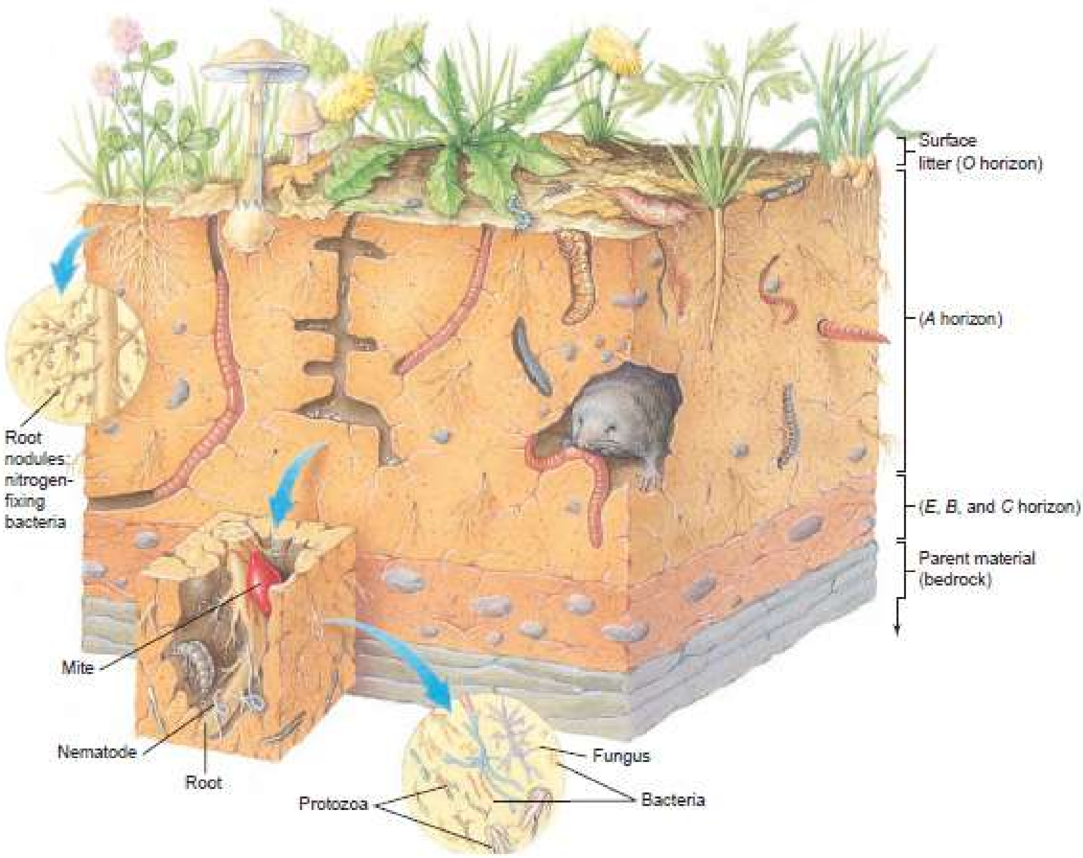
*ii.* ***Relief or topography***

Topography also affects soil formation. Slopes that are too steep cannot have full soil development because gravity and erosional processes remove water and materials. Flat areas encourage water percolation/infiltration which favors the development of deep soil profile, whereas steep relief accelerates water surface runoff, hence a shallow soil profile.

iii. The nature of parent rock

Physical and chemical weathering of rocks in the upper lithosphere provides the raw mineral ingredients for soil formation. These rocks supply the parent materials, and their composition, texture, and chemical nature help determine the type of soil that forms. A weathering of fine grained rock texture tends to form a shallow soil profile, while dark colored rocks are easily weathered and form deep soil profile. Clay minerals are the principal weathered by-products in soil.

Vegetation and the activities of animals and bacteria determine the organic content of soil, along with all that is living in soil (algae, fungi, worms, and insects). The chemical composition of the vegetation contributes to the acidity or alkalinity of the soil solution. For example, broadleaf trees when decomposed tend to increase alkalinity whereas needle-leaf trees tend to produce higher acidity. Also decay of plants and animals supply the soil in humus and nutrients. Animals contribute to soil development through breaking down of vegetation and rocks into small particles that form the soil. The figure below represents the diversity of life in fertile soil that contributes to soil formation and recycling.




*Source: http://geography.name/soil-development/*

*Figure 7. 124: Soil organisms*

iv. Time

All of the identified natural factors in soil development (parent rock, climate, biological activity, and topography) require *time* to operate. This determines the depth of weathering and the period of operation of soil formation processes.

v. Human factor

Human activities have a major impact on soils. The use of fertilizers changes the natural properties of soils. Soil erosion has greatly increased due to agriculture and construction. Approximately 1.2 billion hectares (3.0 billion acres) of Earth's soils suffer degradation through erosion caused by human misuse. An example of soil loss through sheet and gully erosion on a northwest Iowa farm One millimeter of soil lost from an acre weighs about 5 tons.  Planting on the contour prevents water from flowing straight down the slope and thus reduces soil erosion.

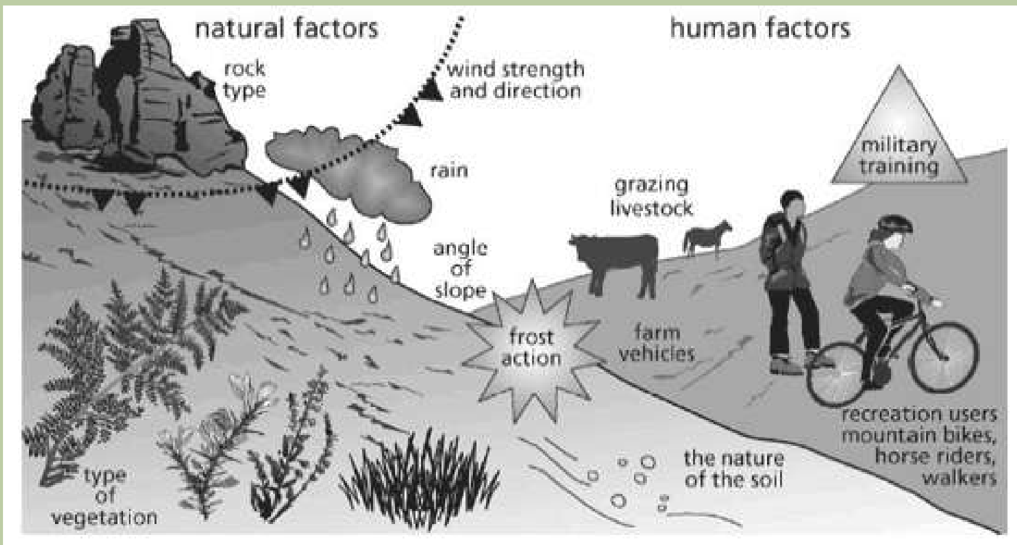
## Application activity 7.3:

1. Visit your local area and describe the soil formation processes in that area
2. Use the acquired knowledge from the above lesson and explain how different factors, namely climate, living organisms, parent rock, relief, time and man influence soil formation.
3. Which of the above processes (in 1 above) are the most predominant. Justify your answer.

## 7.4. Soil erosion

### Learning activity 7.4.

Use the illustration below and answer the following questions




***Source:*** *http://www.imsharma.com/2015/09/soil-erosion-causes-and-measures-to-prevent-soil-erosion.html*

1. Explain how environmental destruction by man has accelerated soil erosion in Rwanda.
2. Identify and explain the physical causes (Non-man made) of soil erosion shown in the picture.
3. Examine the effects of soil erosion on the environment.

### 7.4.1. Causes of soil erosion

When vegetation is removed from soil, the soil is exposed to the direct action of rain and wind. Rain and wind can erode the topsoil and carry it away, destroying the soil's structure. Also, without plants, soil development slows and sometimes stops because humus is no longer being produced.

Soil erosion is the physical removal or washing away of soil by several agents such as human activities (cultivation and building) and natural processes including running water, strong winds, moving glaciers, animals. Soil erosion occurs when overland flow moves soil particles downslope.

The causes of soil erosion are both man-made (human activities) and natural.

### i. Man-made causes

a. Over-cultivation of the land

Ploughing disrupts the soil. Every year, the world population increases by 93 million people and they need more food. Therefore, farmers plough more fields to produce more food. This increases pressure on our soil resources. Ploughing soil is the mechanical turning and loosening of soil to improve it for crops.

Soils have not always been managed effectively. Ploughing) soil removes the plant cover that holds soil particles in places, leaving soils open to wind and water erosion. This makes the land lose its fertility and becomes exhausted. Over cultivation is usually caused by increasing population and scarcity of land for farming and food production, and over-cultivation of available croplands.

b. Poor methods of farming

Growing of the same crops and constant ploughing of the land on steep slopes using poor methods of farming also encourages soil erosion especially in highland areas.

c. Deforestation

Because of population increase, there is great pressure on forests in order to get cultivable land and land for settlement. The high demand for fire wood and charcoal both in rural and urban areas has posed a great threat on the natural forests. This has led to wide scale deforestation hence severe soil erosion.

d. Bush burning

It is done in the dry season in nomadic areas, with the aim of improving the quality of pasture which will grow during the next rainy season. This instead destroys the soil cover, makes the soil exposed to all agents of erosion.

e. Rapid population increase

Today there is population explosion in most areas of the world especially in less developed countries. There is massive human pressure on land, vegetation in search of food, this leads to the removal of vegetation cover which accelerate soil erosion.

f. Overgrazing

It is a major cause of erosion in nomadic areas. It occurs as a result of overstocking of domesticated animals like cattle, sheep and goats. The animals are too many for the available land. They destroy all the grasses hence exposing the soil and this accelerates soil erosion especially water runoff and wind erosion.

### ii. Natural causes

#### a. Heavy rainfall

This is common in hilly areas where the speed of surface run off is high than infiltration. Rain drops take away the top soils to the valleys; e.g. North Western Rwanda.

#### b. Drought

The current climatic change has resulted into limited vegetation or no vegetation cover. This make the soil to be exposed to the agents of erosion (wind and moving water).

#### c. Winds

Wind takes away the top soil in areas with limited vegetation cover and trees which would act as wind breakers. This is common in arid and semi-arid areas which experience high temperature and too much sunshine.

#### d. River and wave action

Shorelines of lakes and oceans as well as banks of rivers are eroded by the waves and running water respectively. This accelerates the rate of erosion.

#### e. Steep slopes

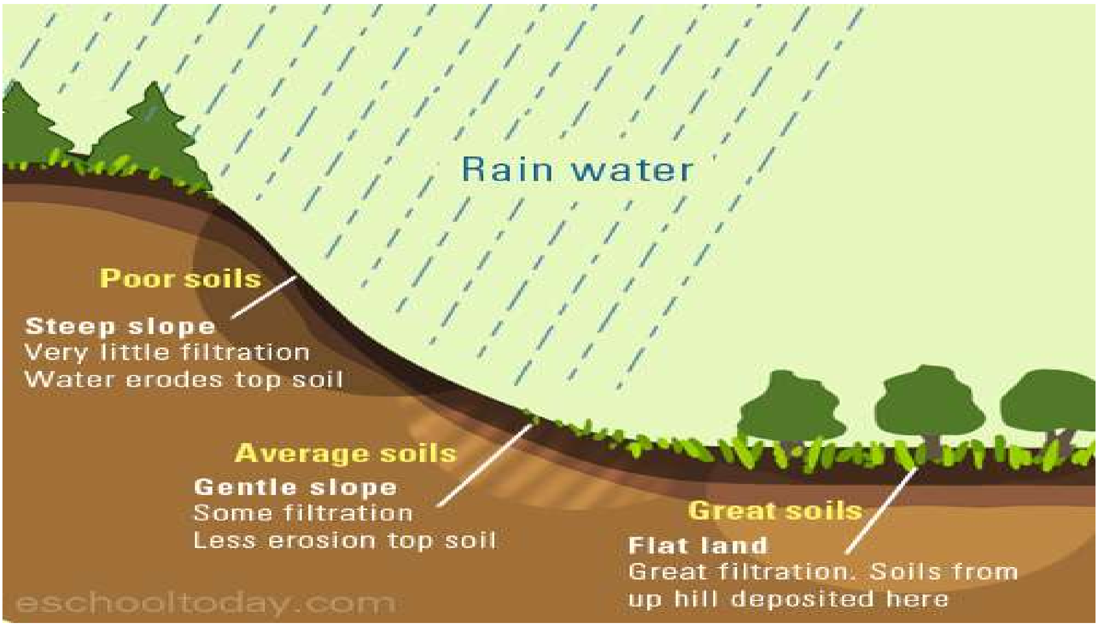
Steep slopes increase on the speed of surface run-off leading to high rate of soil erosion.

## 7.4.2. Areas of severe soil erosion

The following are areas of severe soil erosion:

i. Mountains and highlands with very steep slopes

Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface. Reduced infiltration due to soil compaction, crusting or presence of steep slopes increases the runoff. Runoff from agricultural land is greatest during rainy months when the soils are typically saturated.




*Source: © 2008-2017 eSchooltoday in association with BusinessGhana.com.*

*Figure 7. 125. Influence of relief on soil erosion*

The steep relief accelerates the rate of surface run off hence leading to soil erosion. This is common in mountainous and hilly areas. Severe erosion occurs in these areas because the speed of surface runoff is too high and takes away the top soil.

ii. Glaciated highlands

Moving ice and glacier on the major highlands carries away large quantities or eroded soil in form of moraine. This is deposited at the base of mountain and on outwash plains. Severe erosion by glaciers and melt water is common on most high and steep glaciated mountains.

iii. Desert and semi-desert areas

Soil erosion, is severe in desert areas because of limited vegetation cover. Very strong winds blow off the unconsolidated soil and detaches it from the ground. Soil is relocated elsewhere by strong winds where it is carried and deposited in other areas.

*Source: http://shamilysaidi.blogspot.com/2013/09/features-of-wind-erosion.html ©2018 al hudaa*
*Figure 7.126 Wind erosion in desert area*

### 7.4.3. Effects of soil erosion

The following are the effects of soil erosion:

i. Limited mechanized agriculture

The use of modern machines like tractors is made difficult because of gullies which affect their movement in farms, this in turn affect crop production.

ii. Destruction of crops

Soil erosion destroys crops on farmyards. The Wind erosion destroys the growing crops especially in hilly areas and at times transport them to the lower valleys. This is common in the northern province of Rwanda.

*Figure 7. 127 Crops destroyed by erosion in Gakenke*

iii. Low soil productivity

Soil erosion leads to the loss of soil nutrients which in turn affects the yields. The bare soil in hilly slopes can no longer support crop production.

iv. Famine

Soil erosion leads to vegetation destruction and this affects rainfall formation. This phenomenon limits agricultural productivity.

v. Change of the Landscape

It changes the landscape appearance and natural beauty of the areas affected because of presence of landslides, gullies and rills.

*Figure 7. 128 Landslide in Gakenke district*

vi. Siltation

The eroded materials at times are deposited on people's land or along river banks. Such silt displaces people and destroys their property. This is common in flat lands adjacent to hilly areas.

vii. Flooding

Floods cause great damages on communities and individuals. As most people are well aware, the immediate impacts of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases.

*Figure 7.129 Flooding in Bigogwe*

viii. Destruction of transport system

Roads are greatly destroyed because of soil erosion that results into gullies. These gullies are caused by surface run off in the affected areas. This limits movement of people, goods and services and requires urgent rehabilitation. This affects government's budget.

## Application activity 7.4.

1. Make a fieldwork study around your school and research on causes of soil erosion and analyze their impact on the environment.
2. Basing on your experience on soils and topography, compare the effects of severe soil erosion in the provinces of Rwanda.

## 7.5. Appropriate soil management and the conservation measures

Learning activity 7.5.

Explore the diagram provided below and answer the following questions:




**Terracing** **Agro-forestry**

1. Explain how the soil conservation techniques above are used to reduce soil erosion for environmental sustainability.
2. Make research on other appropriate soil conservation techniques not shown in the illustrations above.

The impact of soil loss on society is potentially disastrous as population and food demands increase. The techniques described in the following paragraphs present however some of management and soil conservation measures which enable humans to use efficiently and sustainably the soil. They are presented and briefly described as follows:

i. Agroforestry

This is a system of soil conservation where trees are planted around crops. Some trees add nutrients to the soil while others protect crops from wind. This practice is common in the northern province of Rwanda.

ii. Afforestation

It is a process of planting trees in a virgin land without any trees to create a forest. Trees as windbreaks are planted and they reduce the speed of wind hence reducing soil erosion. Therefore, afforestation is the creation of a new forest.

iii. Re-afforestation

It is the replanting of trees where they have been cut. This is usually done in steep slopes where erosion is rampant. In several areas in Rwanda, this act has been done under the system of countrywide tree planting. This has been done in order to protect the environment and conserve soils.

iv. Contour ploughing

It is the farming practice of planting across a slope following its elevation contour lines. These contour lines create a water break which reduces the formation of rills and gullies during times of heavy water run-off; which is a major cause of soil erosion. The water break also allows more time for the water to settle into the soil.

v. Crop rotation

It is a system of farming that involves growing of different types of crops in the same area in sequenced seasons. It is done so that the soil of farms is not used for only one set of nutrients. It helps in reducing soil erosion and increases soil fertility and crop yields.

vi. Terracing

It is a piece of sloped plane that has been cut into a series of platforms, which resemble steps, for the purposes of reducing erosion. This type of landscaping, therefore, is called terracing. Terraces are commonly used on hilly or mountainous terrain. Terraced fields decrease both erosion and surface runoff, and may be used to support growing crops that require irrigation, such as rice.

vii. Use of fertilizers

It is important for farmers to use both artificial and organic fertilizers where necessary. This improves the quality of the soils. Fertilizers help the soils to support vegetation which plays a great role in protecting soils against erosion.

viii. Mulching

Mulching is the process of covering the top soil with plant material such as leaves, grass, crop residues, straws etc. A mulch cover enhances the activity of soil organisms such as earthworms and reduces the movement of soil. As the mulch material decomposes, it increases the content of organic matter in the soil.

ix. Strip cropping

It is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion.

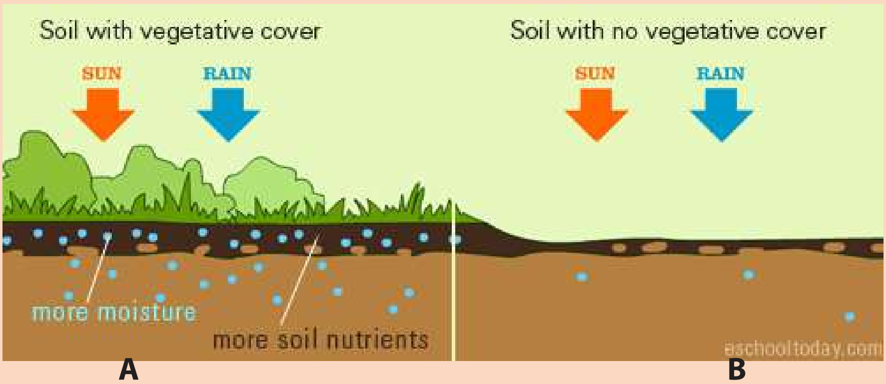
x. Dry farming

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

Application activity 7.5.

Make a field study in your local area and analyze the appropriate measures taken by the local community to conserve soil.

1. Discuss the role of community work (Umuganda) in conserving the soils for sustainable development in your area.
2. Study the illustration given below and answer the following questions:




a. Which area is mostly affected by soil erosion?

b. Explain how you would address the problems faced by people living in part B of the illustration.

*Source:* © *eSchooltoday.com*

## 7.6. Economic importance of soil

### Learning activity 7.6.

1. Conduct research and explain how soil has influenced the development of the activity shown in the photographs below.
2. Basing on the activity done above, discuss the role of soil in socio-economic activities

Soils are important to humans in various ways:

i. Agriculture

Soil has vital nutrients for plant growth. As a result, it is used in agriculture to nourish plants. The roots of a plant receive nutrients from the soil to help plants grow.

ii. Building

Some soils provide important materials for building purposes. Soil can be used as building materials such as sand and clay for, bricks, Tiles, block and concrete making. Soil compaction increases the density of the soil and improves the load support which is done as part of the building process.

iii. Pottery

Clay soil is used in making ceramics, or pottery. When water is added to clay soil, it can be used to create the ceramics. Any type of ceramic can be created with the clay soil, such as vases, bowls, cups or other sculptures.

iv. Medicine

Some soil types are commonly used in the production of anti-biotics. Microbes created in the soil are harmful to bacteria that is why soil is used in medicine. Medicines created by soil include skin ointments, tuberculosis drugs and anti-tumor drugs.

v. Mining industry

Some soils contain valuable minerals e.g. gold, diamond, etc. which helps in industrial development.

vi. Habitat for animals

Some soils act as homes for various organisms like insects, worms, termites and rodents and many others.

### Application activity7.6

Using the above information on importance of soils, conduct a field work study around your school and investigate the impact of soils on the community.

### End unit assessment

1. Deforestation in many parts of the world has resulted into severe soil erosion and its associated effects.
   a. Make a field study in your home area and evaluate the effects of soil erosion.
   b. Identify other major causes of soil erosion in your area.
2. 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.
3. Soil is a source of livelihood in the world because it is used in many ways. Apart from agriculture, how can you use soil for your own survival in your area?

# UNIT 8

## CLIMATE CHANGE

# UNIT 8: CLIMATE CHANGE

## Key unit competence:

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

### Introductory activity

1. Make a research on internet and other geographical materials to establish a relationship between the following concepts:
   - i. Climate change
   - ii. Global warming
   - iii. Green house phenomena
   - iv. Desertification
2. Basing on the knowledge acquired in the first question assess the consequences of climate change in Rwanda.
3. Which area of Rwanda is likely to experience the desertification? Give reasons supporting your answer.

## 8.1 Climate change: definition, causes and effects

### Learning activity 8.1.

1. What does climate change mean?
2. Referring to the pictures below, answer the following questions:



- i. What are the causes of climate change?
- ii. Describe the effects of climate change.

### 8.1.1 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.

### 8.1.2. 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.

**i. 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 the last two decades have experienced 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.

### 8.1.3 Effects of climate change

#### 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, Mount Kenya, and Kalisimbi.
- 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

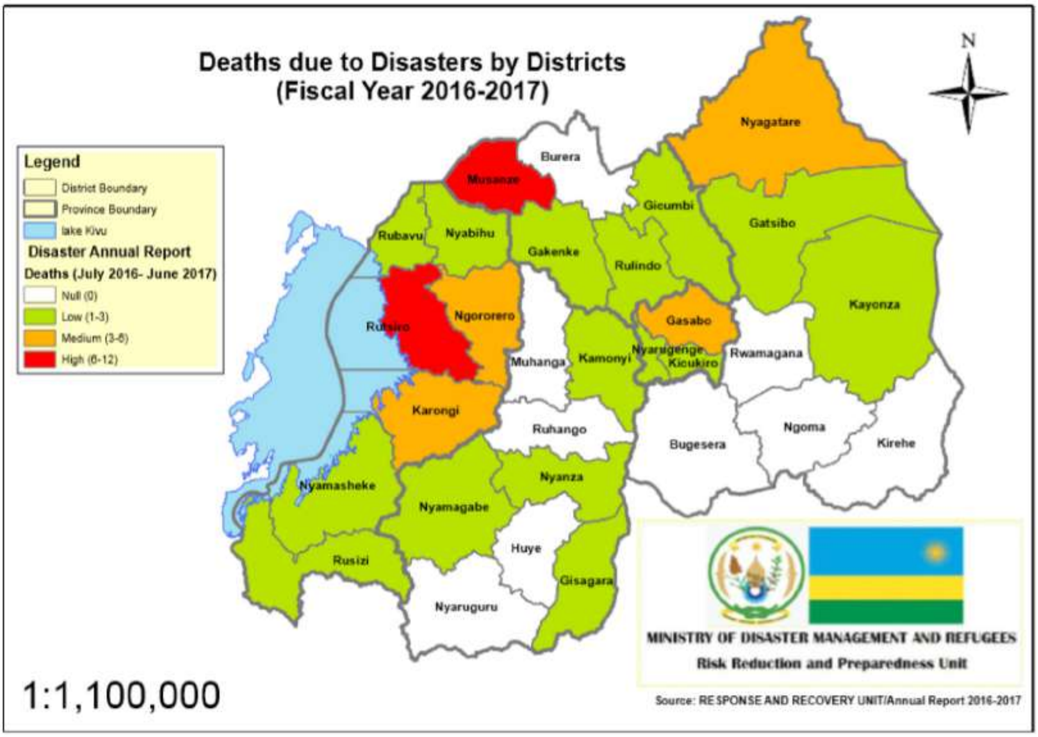
Rwanda experiences some rainfall events that cause unexpected flooding and catastrophic events such as landslides etc. These extreme events are attributed to climate change. The figure below represents some effects of extreme rainfall events of climate change in Rwanda.

*Source: The new times, Rwanda's leading daily.*

*Figure 8.130 Properties destroyed by floods in Nyabihu district*

The following are effects of climate change in Rwanda:

- Significant increase in precipitation 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 2$^{nd}$ and 3$^{rd}$ 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 20$^{th}$ 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 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.




*Source: Ministry of disaster management and refugees*

*Figure 8.131 Death due to disasters by districts (2016-2017)*

## Application activity 8.1

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

## 8.2. Global warming and green house phenomena

### Learning activity 8. 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.

### 8.2.1. Definitions of global warming and greenhouse phenomena

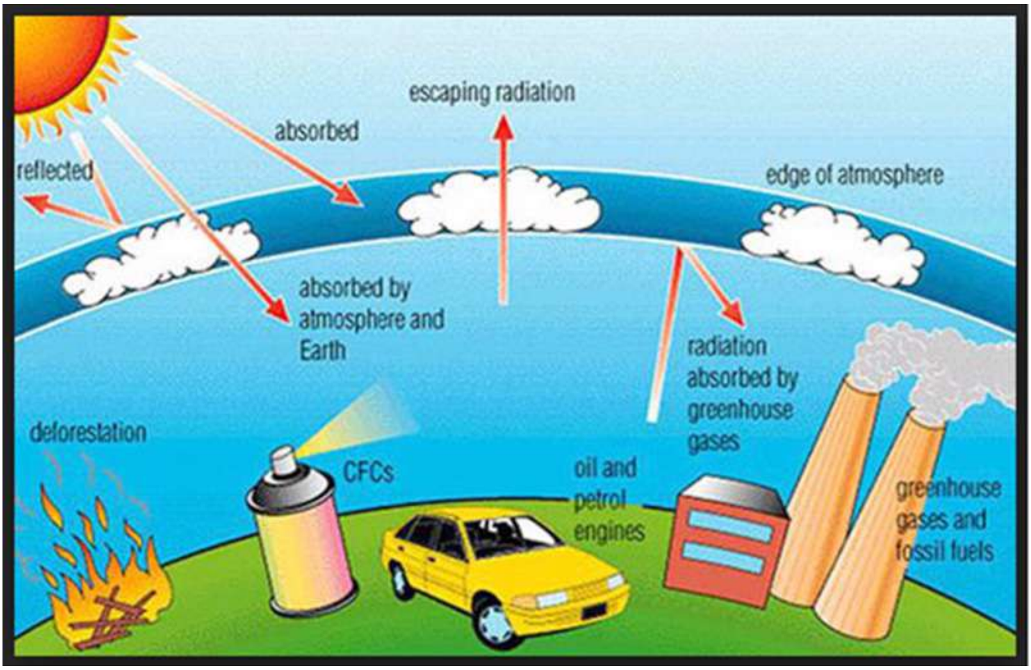
These two phenomena of global warming and greenhouse are related but are different.

- **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.

- **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.




*Source: Global New light of Myanmar*

*Figure 8. 132 Greenhouse phenomena*

### 8.2.2 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.

#### i. 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.

#### ii. 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. These oxides of the nitrogen destroy ozone layer even faster than other greenhouse gas and hence lets harmful ultraviolet rays enter atmosphere thus making earth warm and leading to the global warming.

#### iii. 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.

#### iv. 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.

#### v. 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**

**i. 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 becomes contributing factor of the global warming.

**ii. Depletion of ozone layer**

Depletion of ozone layers is an important factor that causes of 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.

**iii. 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.

### 8.2.3. Effects of global warming and green house phenomena

Effects of global warming and green house phenomena are multiple. Only the most important are briefly presented below:

**i. Increase in temperature**

The intense heat waves and rising temperatures are becoming more common as greenhouse gases are trapped in the atmosphere. The energy from the sun which is responsible for the earth's weather and climate is radiated back into space. While this happens the greenhouse gases (water vapour, carbon dioxide, and other gases) trap some of the outgoing energy and retaining the heat. The greenhouse effect thus leads to a rise in temperature on, and as it becomes stronger, more heat is trapped within the planet.

**ii. Melting of ice and rising sea levels**

Warm surface temperatures cause glaciers, polar ice shelves and other ice bodies to completely destabilize and melt. This in turn increases the amount of water in the world's oceans thus contributing to a rise in sea levels. Consequently, some low-lying areas experience increased flooding.

**iii. Extinction of some animal species**

Warming temperature of water bodies, desertification and deforestation can all contribute to the irreversible impact on natural habitat and thus threaten endangerment and even extinction of some plants and animals. As an example; the polar bear is considered to be an endangered species whose numbers are falling because of their inability to adapt to the volatile temperature changes in the Polar Regions.

**iv. Migration of animals**

All animals live in regions with extremely specific climate and geological conditions, such as temperature and rainfall patterns, that enable them to survive and reproduce. Any change in the climate of the specific habitat can affect the animals that exist there, as well as the overall makeup of the environment. Some species respond to warmer climatic conditions by migrating to cooler locations. For example, some North American animals have moved to the farther north of the region or to higher elevations to meet their requirements.

**v. Effects on human health**

Changes in weather conditions can lead to health conditions ranging from heat-related heart and respiratory problems to malaria. Droughts, floods and warmer temperatures combine in order to create an apt habitat for insects and creatures such as mosquitoes and other disease-carrying agents which causes dangerous diseases and sometimes leading to the death.

**vi. Storms**

The phenomenon of global warming is bound to increase the degree of severity in terms of storms. Warmer temperatures and warmer ocean waters would increase the intensity of these storms thus leading to a high number of devastating hurricanes. On observing the pattern of storms in the past decade it can be noted that the frequency has literally doubled. Along with floods comes loss of lives, damage to property, resources.

**vii. The failure of ecosystem**

An increase in greenhouse gases can cause drastic and irreversible changes both in the upper atmosphere and within the planet thus affecting its every component including land, water, air, plants and the processes that occur at all these levels. If not becoming extinct, animals and plants move away to non-native habitats when the very ecosystems that they were adapted to for survival lose its quality or probably even disappear.

**viii. Economic collapse**

The results of climate change have a direct relationship with a nation's economy. Natural disasters such as hurricanes and floods as an effect of the global warming process end up becoming a costly affair for the government in terms of clean-up costs, property damage and rehabilitation costs.

**ix. Droughts**

A warmer climate owing to global warming will eventually lead to diminishing water supplies and pathetic agricultural conditions in turn resulting in crop failures. If these water shortages are persistent it will cause a lot of disruptions in global food production by affecting agriculture and is thus causing starvation.

**x. Occurrence of wars**

Hostilities and conflicts amongst countries are constantly on the rise as nations are competing and ruthless when it comes to acquiring resources. An important example of this is the conflict in the Darfur region situated in Sudan or the Somalian war with roots in the reduction of its natural resources due to the sole reasons of climate change. It is clear that the increasing number of wars that commence on the foundation of food and water scarcities may lead to uncontrollable levels of aggression, insecurity and regional instability.

## Application activity 8.2

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 greenho*use.*

## 8.3 Adaptation and mitigation measures for climate change

## Learning activity 8.3

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

### 8.3.1 Adaptation measures for the 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.

The following are some of them:

- **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 consist 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:** By 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.

### 8.3.2 Mitigation measures for climate change

Mitigation measures for climate change consist of actions to limit the magnitude and or 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 reduce 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. Reducing this energy means, in the case of using water for cooling, lower water demand.

- **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.
- **Cropland 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 8.3

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.

## 8.4 Climate change and desertification

Learning activity 8.4

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

*Source: http://www.unisdr.org/archive/25321*
*Figure 8.133 Drought threat in the Horn of Africa 2012*

### 8.4.1. 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.

### 8.4.2. Causes of desertification

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

- **Less rainfall** (total amount) and **increased drought** (frequency and intensity). As a consequence, rivers and water bodies might dry up leading to the decrease of protective vegetation cove.
- **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 cause 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.

### 8.4.3 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 drylands for farming. These marginally productive regions are overgrazed, the land is exhausted, and groundwater is over drafted.

### Application activity 8.4.

1. Observe the picture below showing the drought that happened in a dry area in Rwanda 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 such phenomenon 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.

## 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. Indicate the most affected areas by that problem? Suggest the sustainable strategies to address the problem of desertification.

# UNIT 9

# GLOBAL DRAINAGE SYSTEMS

# UNIT 9: GLOBAL DRAINAGE SYSTEMS

## Key unit competence:

By the end of this unit, I should be able to investigate the economic importance of 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:

   a. Drainage system, a river and associated terms like river discharge, river velocity, catchment area, a river divide and a river basin.

   b. How does a river erode, transport and deposit its load?

2. Referring to the nearest river or Lake in your local environment or near your school explain the usefulness of drainage systems.
3. Discuss why there is need to conserve drainage systems.

## 9.1. River system

### Learning activity 9.1

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?

### 9.1.1. Definition of a river and the associated terms

**A river** is a natural wide flow of water across the land. 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 gradient or slope:*** Is the angle of slope between the vertical drop in relation to the horizontal distance of a river.
- ***Catchment area*****:** A river catchment is an area from which a river derives its water. This can be an upland or mountain.

### 9.1.2 Types of rivers

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

- ***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.

### 9.1.3 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. The rock particles carried by a river collide against each other and break into smaller particles.

b. **River transportation:** Rivers transport refers to the carrying away of eroded material downstream. 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.

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.

### 9.1.4: 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.

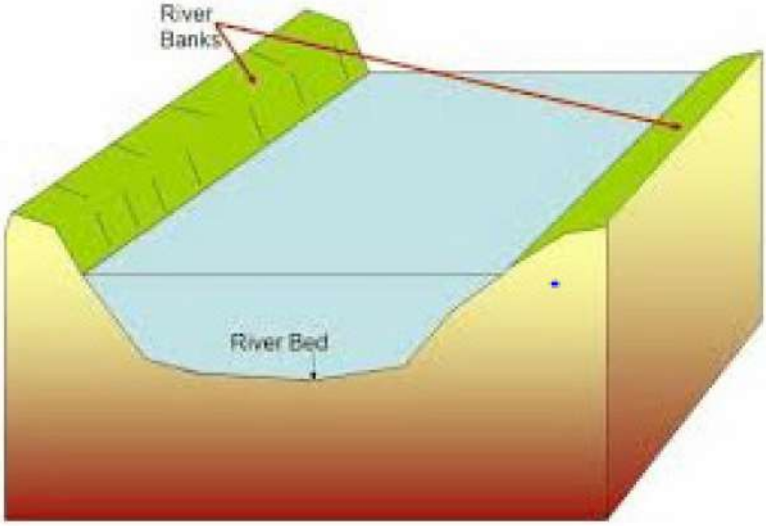
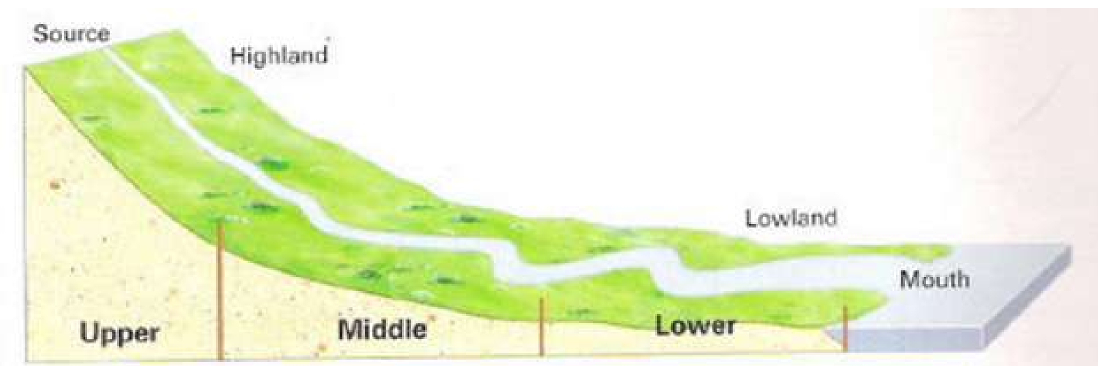



***Figure 9.134*** *A cross profile of a river*

- Long 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




***Source:*** *©Brandnewmomblog.com-2018*

*Figure 9.135 Long profile of a river*

The following are the characteristic features of successive stages:

- **Youthful stage:** This is also known as the **torrent** or **upper stage** of a river.
  - The gradient at this stage is steep. Therefore, the river flows very fast.
  - The main river gradually deepens its valleys.
  - The main type of erosion is vertical. The valleys are narrow and deep.
  - The features found in this stage include gorges, rapids and waterfalls. .
- **Mature stage**: it is also known as the **valley stage** or the **middle course**.
  - This is the stage between the upper and lower courses of the river.
  - The gradient is reduced. Therefore, the speed of the water is also reduced.
  - The main type of erosion is lateral. Therefore, the river begins to widen its channel. There is also some deposition of materials or 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**: This is also known as the **plain stage** or **lower course or senile stage**.
  - The gradient of the river is very gentle. Therefore, the river flows slowly.
  - There is a lot of evaporation at this stage.
  - 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.

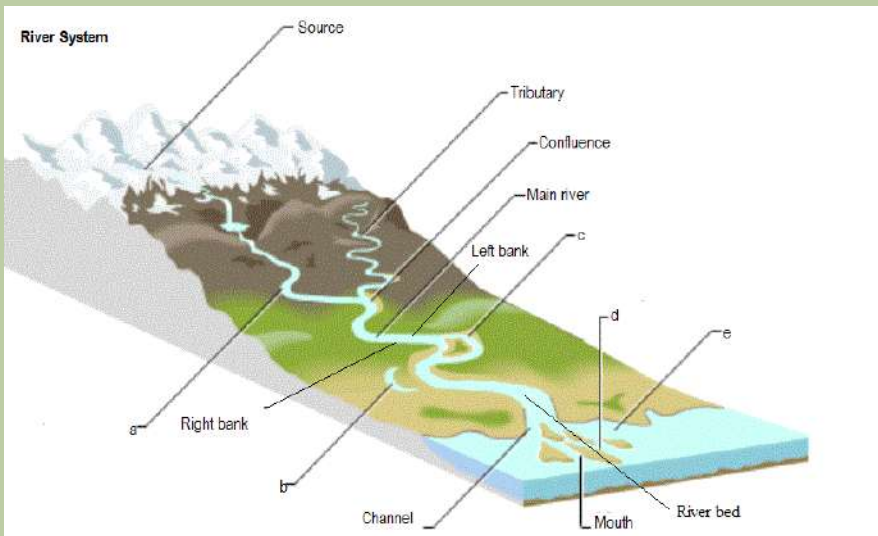
## Application Activity 9.1:

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.

## 9.2. Formation of the major landforms associated with a river profile

### Learning activity 9.2:

Observe the diagram below and answer the following questions.




i. Name the landforms labelled by: a, b, c, d and e;
ii. Apart from the features named above, what are other landforms created by a river?

### 9.2.1 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**

***Waterfalls*** abrupt movements of water or simply sudden descents of water due to abrupt breaks in the longitudinal course of the river. Water falls are mostly caused by variations in the relative resistance of rocks, relative difference in topographic reliefs, fall in the sea level and related rejuvenation and earth movements. 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.

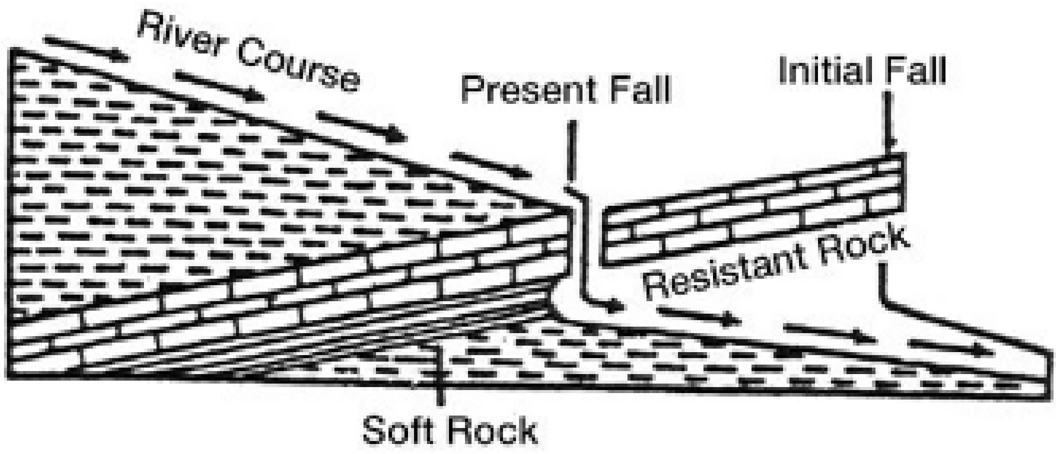
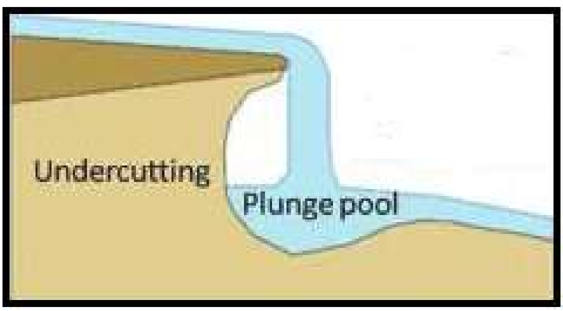



*Figure 9. 136 Waterfall and rapid*

### 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.

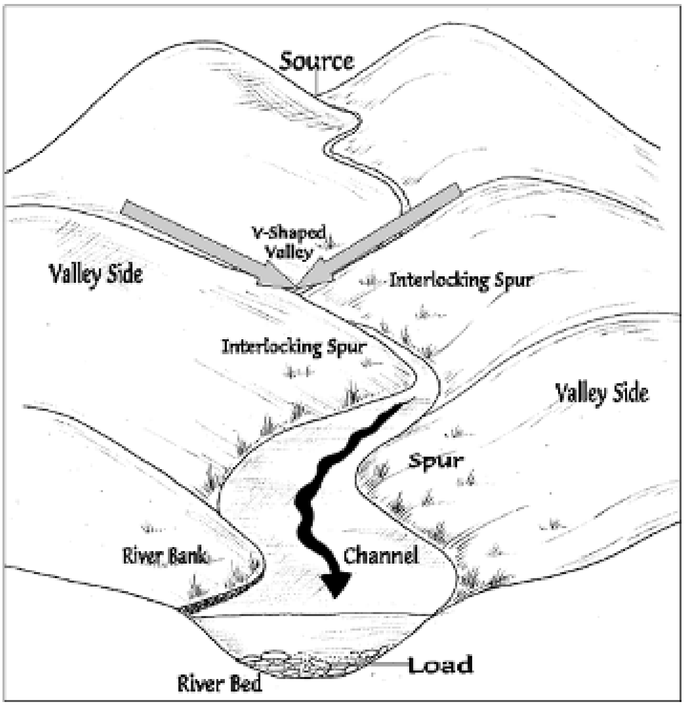



*Source: https://www.tes.com/teaching-resource/ks3-rivers-river-information-poster-activi ty-3411673*

*Figure 9.137 Plunge pool (left) Pot holes (right)*

### 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.




*Source: http://vudeevudeewiki.blogspot.com/2012/01/upper-course-of-river.html*

**Figure 9.138** *Interlocking spurs*

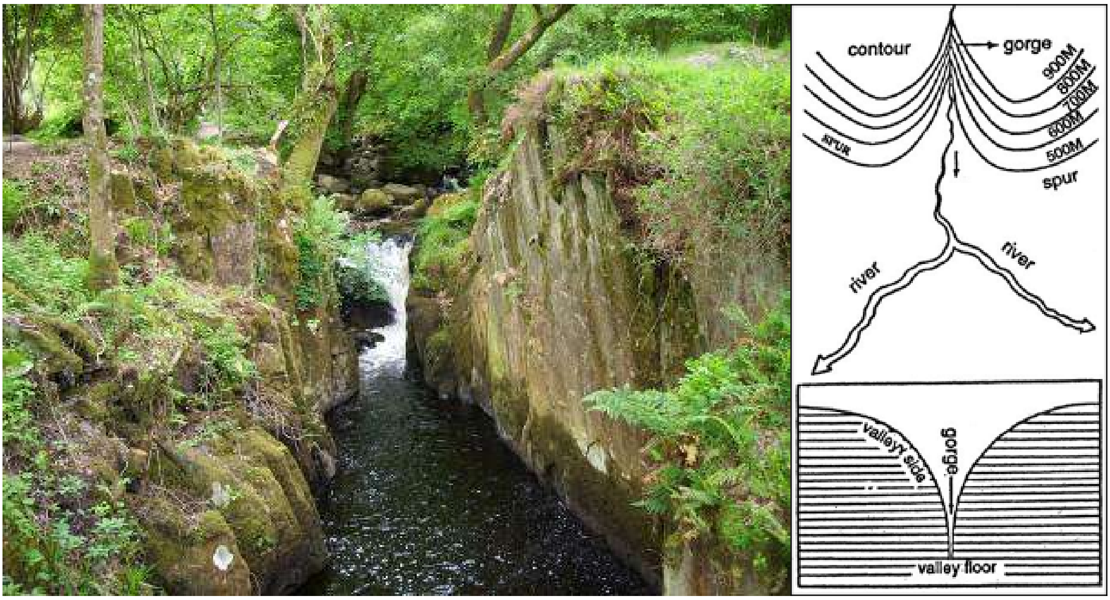
### 9.2.2. Formation of landforms in mature stage

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



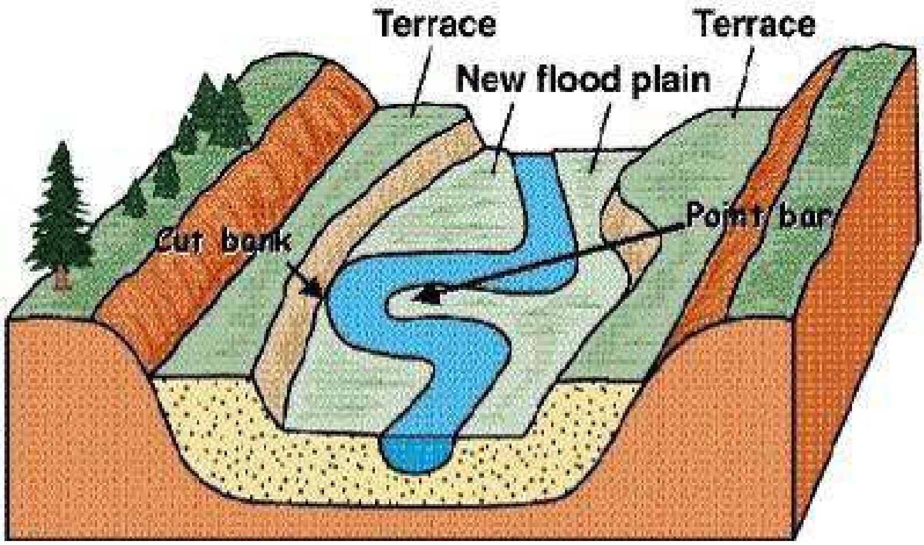

*Source: https://www.internetgeography.net/topics/landforms-in-the-upper-course-of-a-river/*
*Figure 9.139: A river valley with gorges and Canyons*

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".

*Source: https://clasticdetritus.com/2013/03/22/friday-field-photo-181-fault-scarps-on-badwater-fan/ Figure 9. 140: 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.



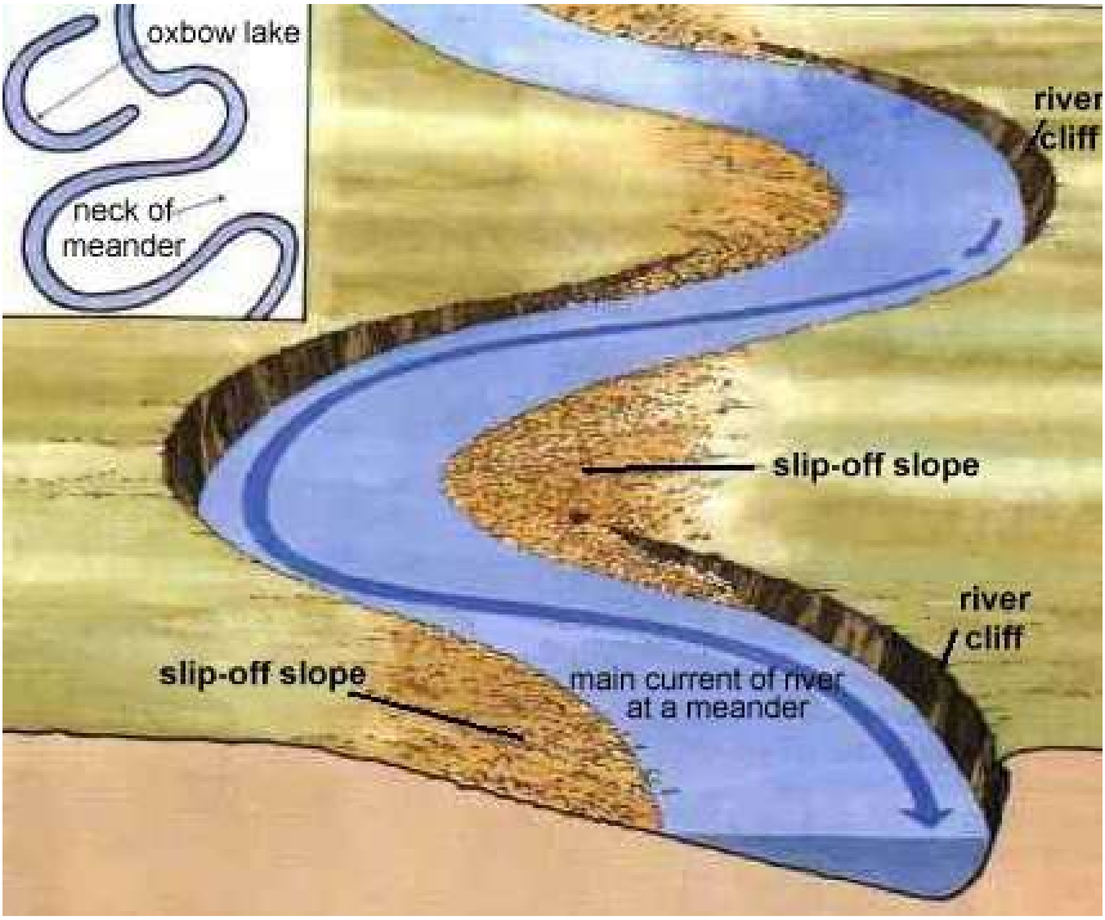

*Source: http://msnickellecgel111.blogspot.com/2016/04/what-characterizes-different-soil_12.html*

*Figure 9.141: A river benches and terraces*

### 9.2.3. Formation of landforms in old stage

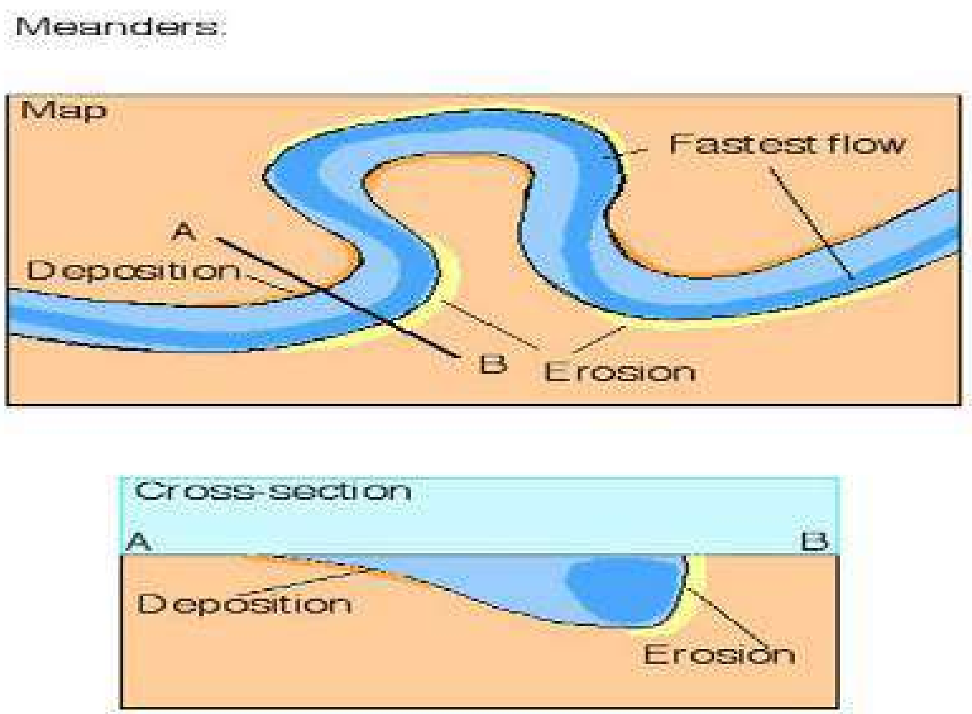
The lower or old stage of river is the last stage where a river nears its destination. This stage is characterized by large deposits along the river's bed and channel. The large deposition is a result of increased lateral erosion, very slow movement of water and very wide river channel. In this stage 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.




*Source: https://www.geoforcxc.com/water/river-features/rive-cliff-and-slip-off-slope/*

*Figure 9.142: River meanders and its features*




*Source: http://www.gly.uga.edu/railsback/1121Lxr28.html*

*Figure 9.143: 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.

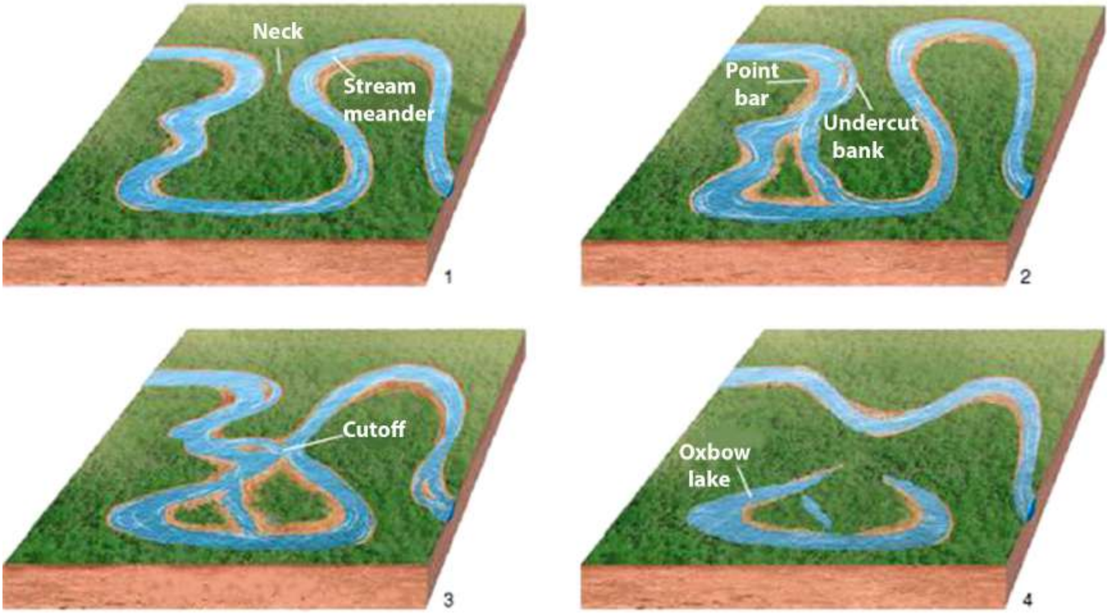
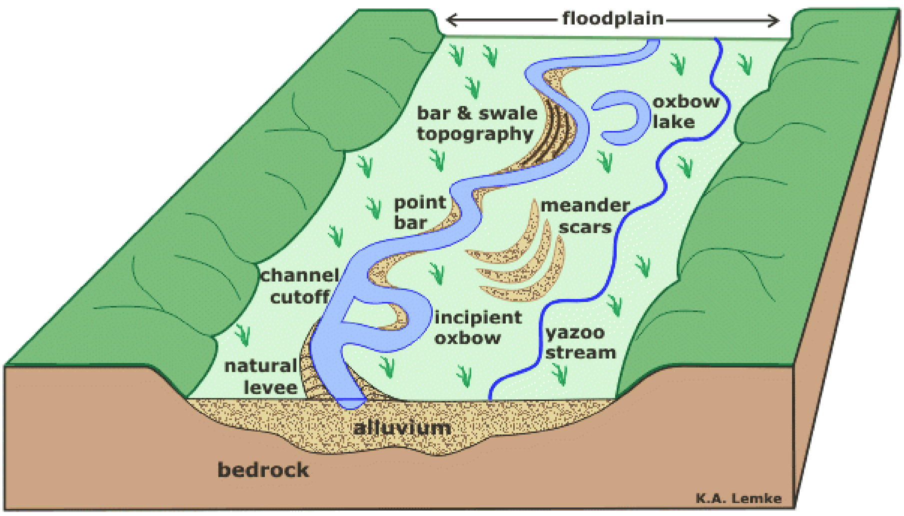


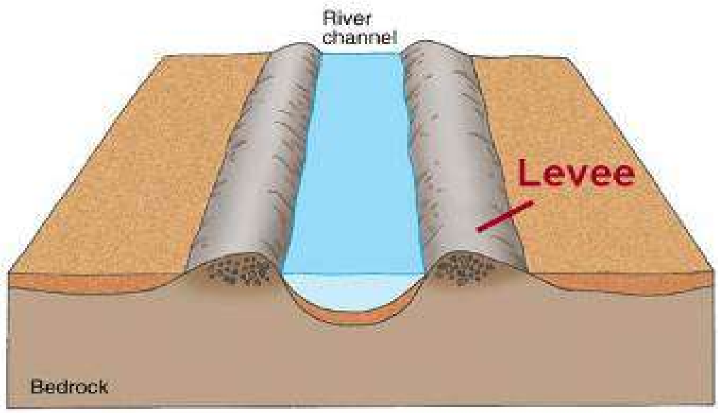

*Figure 9.144: Development of a river meander and an oxbow lake simplified in four stages*

***iii. A 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.




*Source: http://thebritishgeographer.weebly.com/river-landforms.html*
*Figure 9.145: 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.




*Source: https://sites.google.com/site/vhs2015environmentalscience/ water/advantages-and-disadvantages-of-floodpla in*

*Figure 9.146: 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.

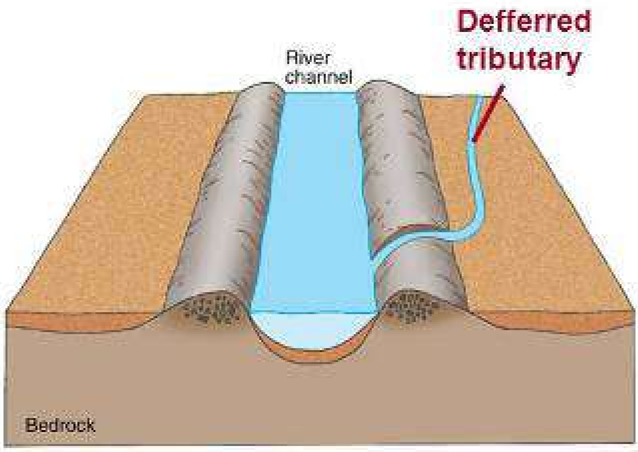
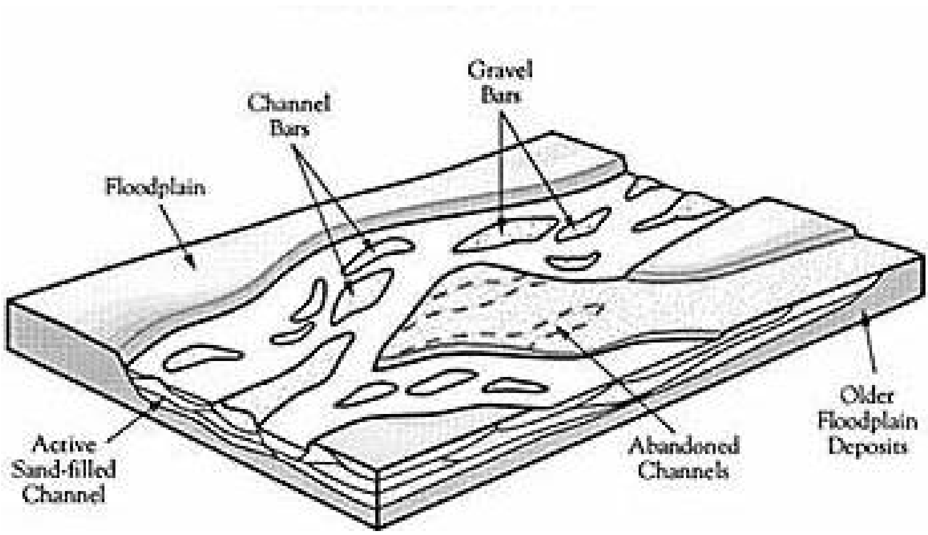



*Figure 9. 147: Deferred tributaries*

***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.




*Source: http://thebritishgeographer.weebly.com/river-landforms.html*

*Figure 9.148: 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 push all its 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 forms a triangular shaped mouth of a river. This is called *delta*. The growth of a delta. The river split up into several separate channels in much the same way as river braids. Deltas are classified into two 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.

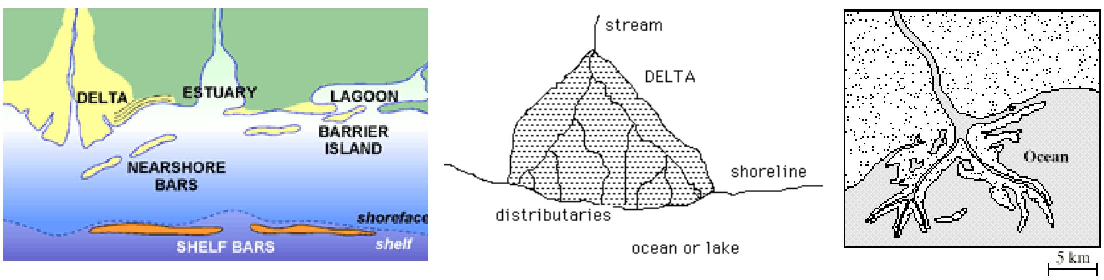



*Figure 9. 149: Estuarine deltas (left), Arcuate deltas (center), Bird-foot deltas (right).*

## Application activity 9.2

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.

## 9.3. River capture and river rejuvenation

## Learning activity 9.3

Make a research and establish the effects of the river capture and River rejuvenation.

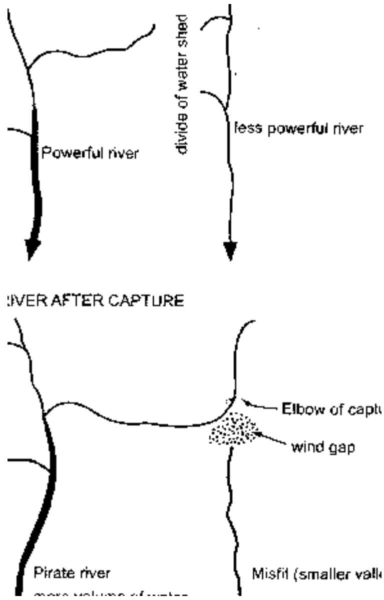
### 9.3.1. River capture

**iii. 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.

**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.




*Source: http://www.kcse-online.info/geog/4.html*

*Figure 9.150: River capture process*

### iv. 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

### v. 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).

## 9.3.2. River rejuvenation

### i. 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:

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

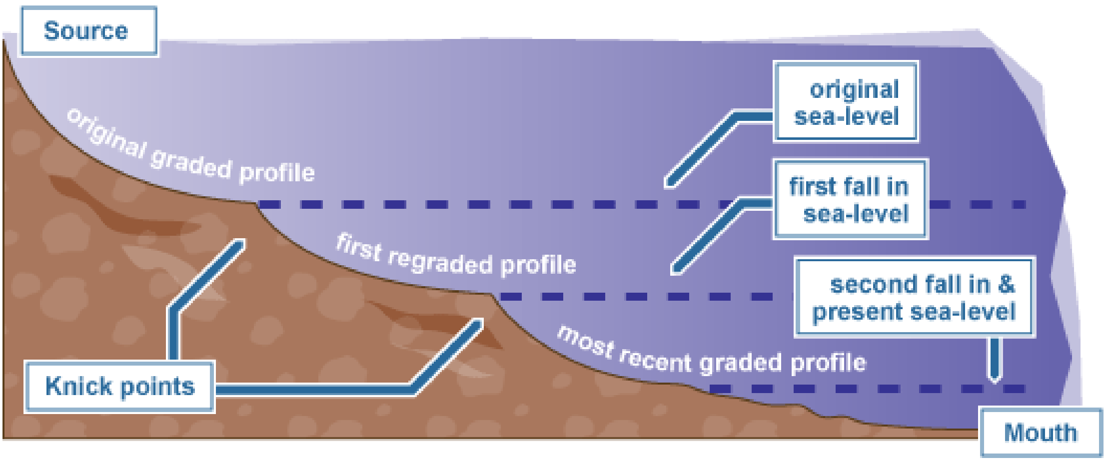
b. Eustatic rejuvenation: This occurs because of changes in sea level due to diastrophic events (subsidence of sea floor or rise of coastal land) and glaciations causing fall in sea level.

c. 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.

### ii. 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




Source: http://slideplayer.com/slide Figure 9.151: Rejuvenation of a river)

### iii. Effects of river rejuvenation on the landscape

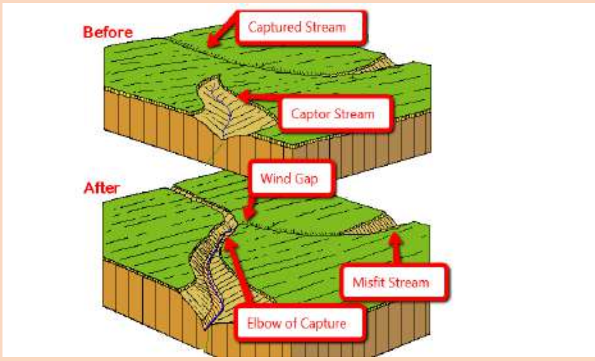
River rejuvenation produces several features as follows:

- **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.

Application Activity 9.3:

1. Observe the following picture and answer the questions that follow.




   i. Explain the factors that favour river capture.

   ii. Describe the effects of river capture on the above figure.

2. Visit your local area, and identify a typical example of a rejuvenated river and explain its causes.

*Source: http://sageography.myschoolstuff.co.za/wiki/grade-12-caps/geomorphology/fluvial-proces-rive*

## 9.4. Drainage in the world

Learning activity 9.4:

Use internet and other geographical resources and describe the types of drainage patterns.

### 9.4.1 Drainage pattern in the world

A drainage pattern is the way in which a river and its tributaries arrange themselves within their tributaries and distributaries. Most patterns evolve over a lengthy period of time and usually become adjusted to the structure of the basin. The development of the drainage patterns is influenced by:

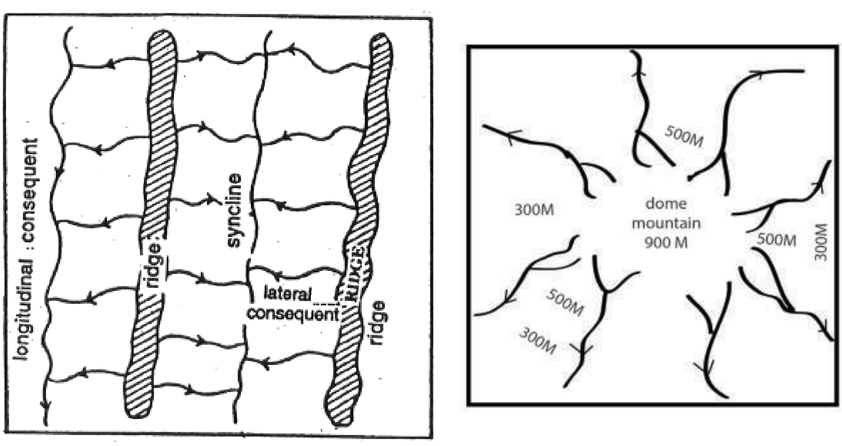
- The gradient of the slope
- The nature of the bedrock. This is in terms of how resistant the rock is.
- The structure of the basement rock.

### 9.4.1. Types of drainage Patterns

There is no widely accepted classification of drainage, because most drainage patterns are descriptive. Drainage patterns are however grouped into patterns independent of structure, and those dependent on structure. There are also some patterns apparently unrelated to structure:

i. Patterns dependent of structure

- **Trellised drainage** or **rectangular drainage pattern** are well adjusted to the geological structures. In areas of alternating resistant and less resistant rock, tributaries will form and join the main river at right-angles. Sometimes each individual segment is of approximately equal length. The main river, is also called a **consequent river** because it is a consequence of the initial uplift or slope and flows in the same direction as the dip of the rocks. The tributaries which develop, mainly by headward erosion along areas of weaker rocks, are called ***subsequent streams*** because they form at a later date than the consequents. Such patterns are developed in the area of simple folds characterized by parallel anticlinal ridges alternated by parallel synclinal valleys.
- **Radial drainage pattern**: This is a system where rivers/streams flow in a circular way, outwards a central body. It develops in areas where the rocks have been lifted up into a dome structure. Streams which diverge from a central higher point flow in all directions. Dome structures, volcanic cones, residual hills, small tablelands, mesas and buttes, and isolated uplands can favour the development of ideal radial pattern.

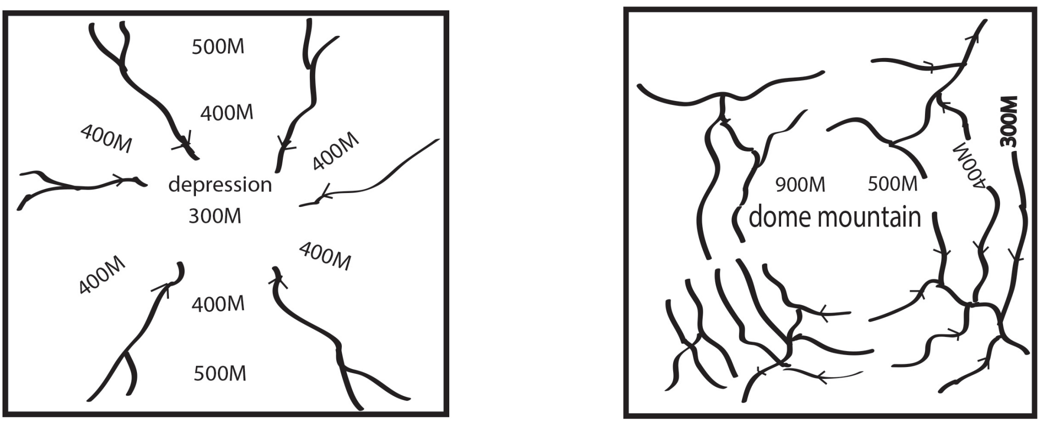



*Source: http://infervour.com/drainage-patterns/*

*Figure 9.152: Trellised pattern (left) Radial drainage pattern (right)*

- **Centripetal drainage pattern** or inland drainage pattern: This is the opposite to the radial drainage pattern because it is characterized by the streams which flow and converge at a point which is generally a depression or a basin. This pattern is formed by a series of streams which after emerging from surrounding uplands converge in a central low land which may be a depression, or a basin or Crater Lake. The best examples are found on Lake Victoria with rivers like R Nyando, River Akagera, River Mara and River Katonga

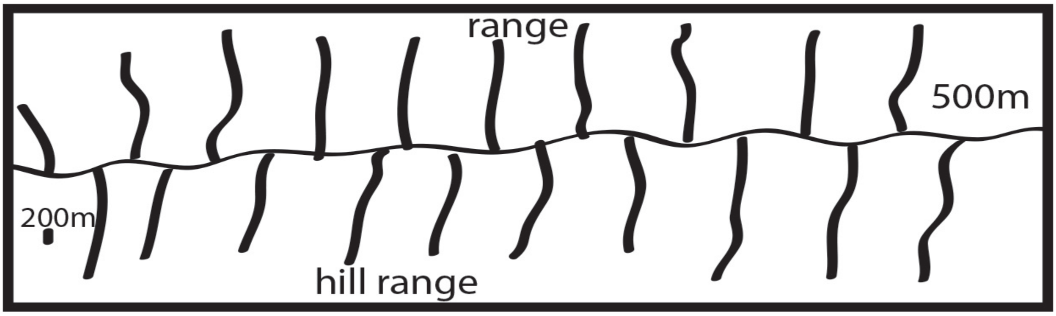
- **Annular drainage pattern**: This is also known as "circular pattern", is formed when the tributaries of the master consequent streams are developed in the form of a circle. Such pattern is developed over a mature and dissected dome mountain characterized by a series of alternating bands of hard and soft rock beds.




*Source: http://infervour.com/drainage-patterns/*

*Figure 9.153: Centripetal drainage pattern (left) / Annular drainage pattern (right)*

- **Herringbone drainage pattern**: This is also called rib pattern (like the rib bones of human beings) is developed in mountainous areas where broad valleys are flanked by parallel ridges having steep hillside slopes. The longitudinal consequent streams, as master streams, are developed in the longitudinal parallel valleys while tributaries, as lateral consequents, after originating from the hill slopes of the bordering parallel ridges join the longitudinal consequents almost at right angles.



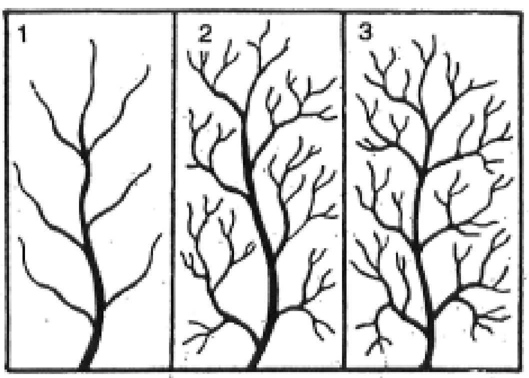

*Source: http://infervour.com/drainage-patterns/*
*Figure 9.154: Herringbone drainage pattern*

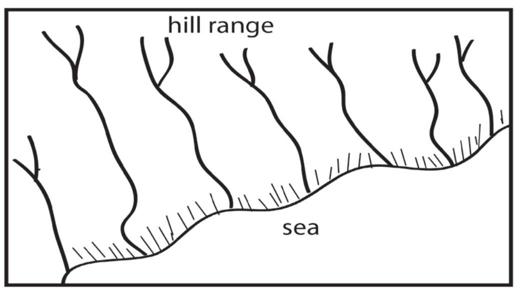
**ii. Patterns independent of structure**

- **Dendritic drainage pattern:** This derives its name from the Greek word Dendron, meaning a tree, this is a tree-like pattern in which the many tributaries (branches) converge upon the main river (trunk). It is a common pattern which develops in basins having one rock type with no variation in structure.

- **Parallel drainage pattern:** This occurs on newly uplifted land or other uniformly sloping surfaces which allow rivers and tributaries to flow downhill more or less parallel with each other (e. g. rivers flowing south-eastwards from the Aberdare Mountains in Kenya).

Dendritic drainage patterns Parallel drainage pattern

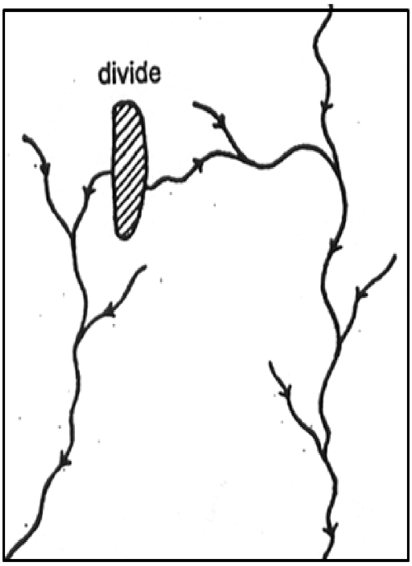


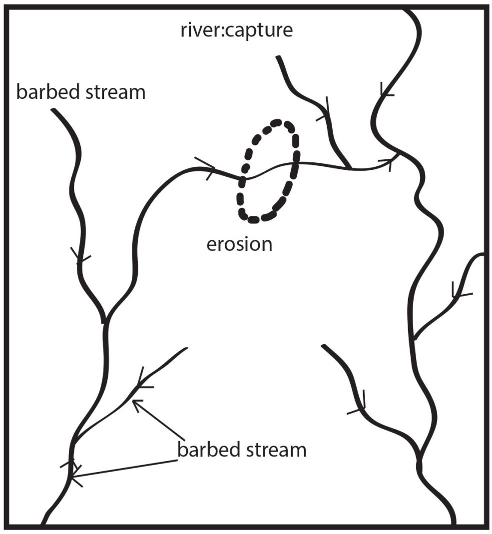




*Source: http://infervour.com/drainage-patterns/*
*Figure 9.155: Dendritic drainage pattern (left), Parallel drainage pattern (right)*

### iii. Patterns apparently unrelated to structure

- **Barbed drainage pattern**: This is also called hooked drainage pattern, is a rare kind of drainage pattern formed when the tributaries flow in the opposite direction to their master streams. The tributaries join their master streams in hook-shaped bends. Such a pattern is generally developed due to river capture.

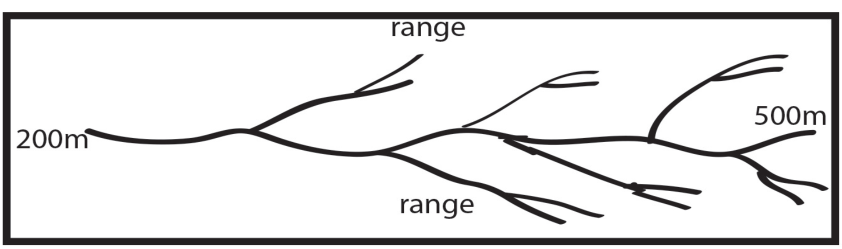



*Source: http://infervour.com/drainage-patterns/*

*Figure 9. 156: Barbed drainage pattern*

- **Pinnate drainage pattern:** This is developed in a narrow valley banked by steep ranges. The tributaries originating from the steep sides of parallel ridges join the longitudinal master consequent occupying the valley at acute angles.




*Source: http://infervour.com/drainage-patterns/*

*Figure 9.157: Pinnate drainage pattern*

### 9.4.2. Superimposed and antecedent drainage

**i. 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.

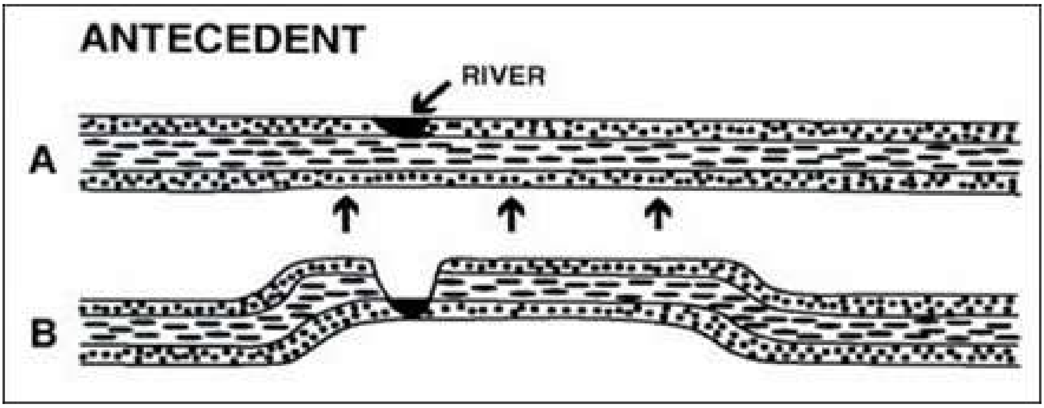



*Figure 9. 158: An antecedent drainage*

**ii. 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.

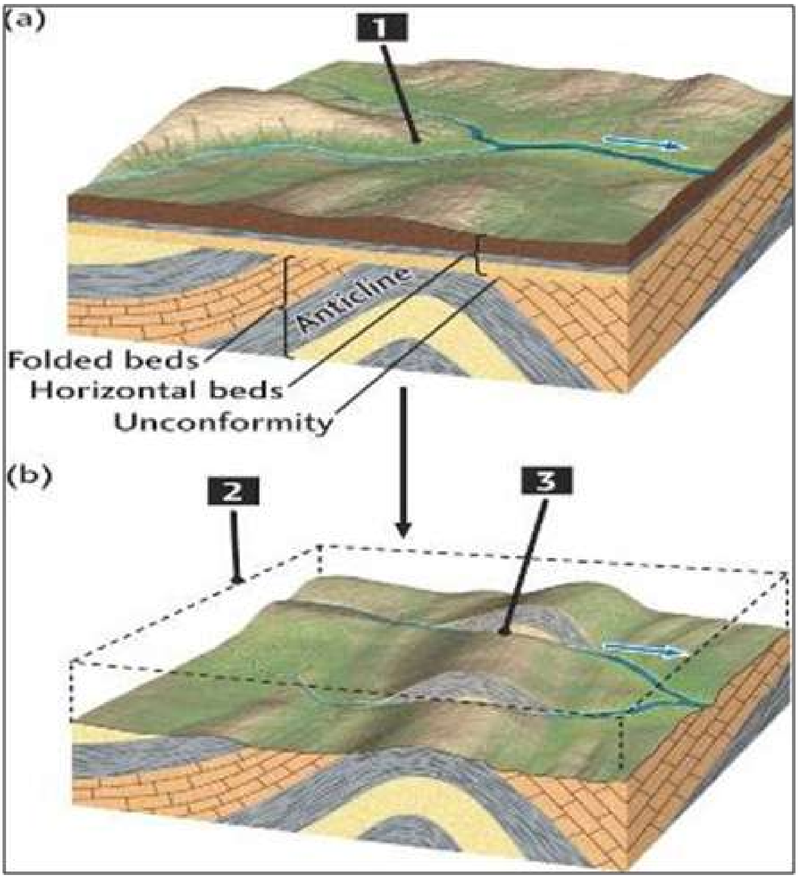



*Figure 9. 159: A superimposed drainage*

## 9.5. Impact of rivers

### Application activity 9.4

1. Visit any nearby river and identify its pattern of drainage and explain how this pattern was developed.
2. Describe the formation of antecedent and superimposed drainage.

### Learning activity 9.5

Describe the developmental activities that are done along any river valley in your locality or in the world.

### 9.5.1 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.

The rivers and riverine landforms influence human beings positively:

- 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

The rivers and riverine landforms influence human beings negatively:

***Negative effects***

- 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 harbour dangerous animals such as crocodiles and hippopotamuses. These at times attack human beings and destroy crops.

### 9.5.2. Case studies of rivers: Major rivers of the world

The following are the major rivers of the world.

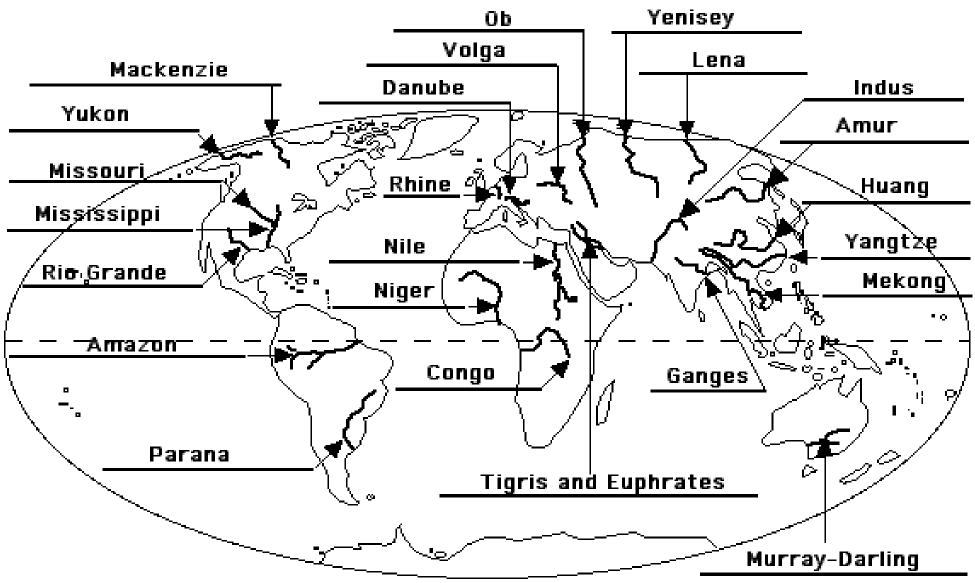



*Figure 9. 160: Figure 32: showing major rivers of the world*

i. ***Amazon River*** is the largest river in the world. It is found in South America. It is 6,400 km long. It has a drainage basin of 7,050,000 square km. It also carries more water than any other river in the world. It can reach a width of 200 km. The Amazon River flows across North Brazil.

ii. ***The Nile*** is the longest river in the world. It is 6,853 km long. Its drainage basin covers 3,400,000 million square km. The source of River Nile is Lake Victoria. It flows into the Mediterranean Sea. The river passes through Uganda, South Sudan, Sudan and Egypt.

iii. ***Ganges River***: it is a trans-boundary river o Asia which flows through the nations of India and Bangladesh. The 2,525 km (1,569 mi) river rises in the western Himalayas in the Indian State of Uttarakhand, and flows south and east through the Gangetic of North India into Bangladesh, where it empties into the Bay of Bengal. It is the third largest river in the world by discharge. The Ganges is the most sacred river to Hindus. It is also a lifeline to millions of Indians who live along its course and depend on it for their daily needs. It is worshipped as the goddess Ganga in Hinduism. The Ganges was ranked as the fifth most polluted river of the world in 2007. Pollution threatens not only humans, but also more than 140 fish species, 90 amphibian species and the endangered Ganges river dolphin.

iv. ***Congo River*** is the second longest river in Africa. It is 4,700 km long. It has a basin of 4,000,000 square km. It is made up of two tributaries. These are Lualaba and Luapula. It flows through northern and western Democratic Republic of Congo (DRC) into the Atlantic Ocean.

v. ***The Niger River*** is the third longest river in Africa. It is 4,180 km long. The river begins in Guinea and runs east through Benin, Guinea, Mali, Niger, and Nigeria. Its main tributary is the Benue River.

vi. ***The Mississippi River*** is found in North America. It is 3,734 km long. Its basin is 2,981,076 square km. The source of the river is Lake Itasca. It passes through mid-United States to the Gulf of Mexico.

vii. ***Missouri River*** is the longest river in North America. It is 4,130 km long. The Missouri is the longest tributary of the Mississippi. The source of the Missouri is the meeting point of Rivers Jefferson and Madison. It joins Mississippi River at St. Louis.

viii. ***The Danube River*** begins in the Black Forest in Germany. It flows eastwards for a distance of some 2,850 km, passing through four Central and Eastern European capitals. It empties into the Black Sea through the Danube Delta in Romania and Ukraine.

ix. ***Rhine River*** is 1,320 km long. It is the second longest river in Central and Western Europe. It begins in the Swiss Alps. The Rhine flows through six countries. These are Switzerland, Liechtenstein, Austria, Germany, France and the Netherlands. It empties into the North Sea at Rotterdam.

x. ***Volga River*** is the longest river in Europe. It is 3,700 km long. It is located in Central and Eastern European Russia. The source of River Volga is the Valdai Hills to the northwest of Moscow. It empties into the Caspian Sea.

xi. ***Huang He/Hwang Ho/Yellow River*** is the third longest river in Asia. It is 4,830 km long. Its source is the twin lakes Gyaring and Ngoring in the Kunlun Mountains. to the northwest of Qinghai province.

xii. ***Chang*** *or* ***Yangtze Mandarin Chang Jiang*** is the longest river in China. It is 6,245 km long. It rises in the Tibetan highlands to the southwest of Qinghai Province. Western China and flowing generally Eastern through central China into the East the river passes through one of the world's most populated regions. It has for many years been used as a trade and transportation route.

### 9.5.2 Case Study of the Nile River in Egypt

Extract from: UK ESSAYS. (March, 2015). The importance of the Nile River. Environmental science essay.

**The Importance of the Nile River:**

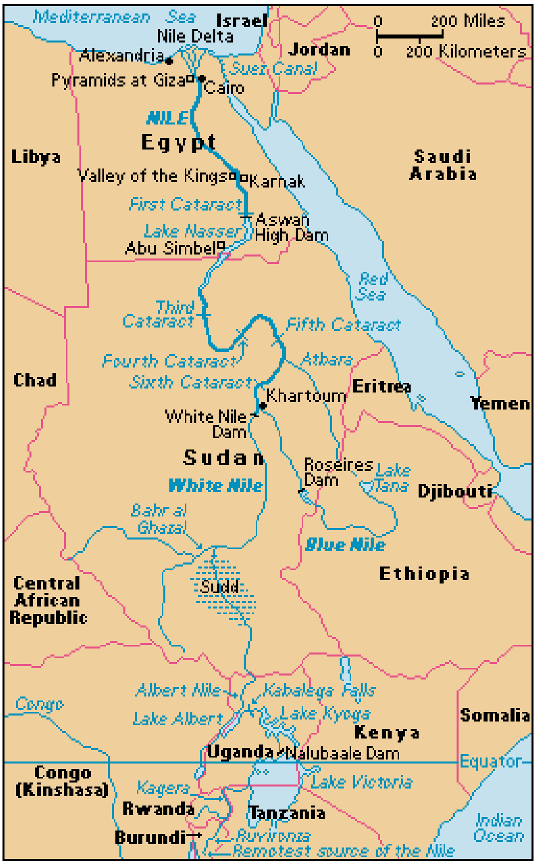



*Figure 9. 161: A Map of the River Nile*

Egypt would be almost all barren deserts without the Nile. The Nile is one of the most important things that Egypt can't live without. No one can deny that the Nile was so important to the pharaohs in their daily life. The pharaohs were so smart, they used the Nile so well to help them in their life. The pharaohs used the Nile for agriculture. The pharaoh got all the rich peasants to do the farm work on the rich lands. Most of the ancient villagers were farmers. Egyptians grew several crops such as wheat, barley, vegetables, figs, melons, pomegranates and vines. The most important crop at this time was grain. The pharaohs used grain to make bread, porridge and beer. The Grain was the first crop they grew after flooding season. Once grain was harvested, they grew vegetables such as onions, cabbages, beans, cucumbers and lettuce. Farmers planted fruit, trees along paths, to give shade as well as fruit. The Egyptians grew their crops along the banks of the River Nile on the rich black soil which was considered one of the best soils for agriculture in the world. This rich soil was left behind after the yearly floods. This soil was ideal to grow healthy crops. Egyptian farmers divided their year into three seasons, based on the cycles of the Nile:

Farming was not done during the flooding season as all the fields were flooded. Instead, many farmers worked for the pharaoh, building pyramids or temples. Some of the time was spent mending their tools and looking for animals. The Growing Season which starts in October, the flood waters recedes, leaving behind a layer of black soil.

Shemu which starts in March and ends in May and called also The Harvesting Season. The fully grown crops had to be harvested and removed before the Nile is flooded again. It was also the time to repair the canals to be ready for the next flood. Every June in the year, the Nile flooded. This was known "the flooding season". During this time the farmers mend tools or make new ones. People would go fishing for extra food or money. To lift the water from the Nile they used a shaduf. A shaduf is a large pole balanced on a crossbeam, a rope and bucket on one end and a heavy counter weight at the other end. By pulling the rope it lowered the bucket into the Nile River. The farmers then raised the bucket of water by pulling down on the weight. He then swings the pole around and emptied the bucket onto the field. Nowadays Egyptian are sticking to the Nile from ancient Egyptians to modern Egypt which prove how living beside the Nile is important and living beside the Nile make life easier.

*Why the Nile River Flooded?*

Rains in Africa, especially rains coming from the Ethiopian Highlands, and melting snow caused the Nile River to flood. The Ancient Egyptians used something called Nilometer to record how high the Nile was during the year.

The flood still continues every year. The annual flood carries dead and decaying plants in its muddy solution. The muddy water is called silt, and silt creates excellent farm soil. Since 1970, the Aswan Dam has controlled the annual flood of the Nile River by holding back water, the Aswan Dam created the world's largest man-made lake: Lake Nasser. The water from Lake Nasser provided new fishing areas and provides much needed water for agriculture.

Since the Nile was so important in old Egyptian history, so it's for sure that the Nile importance increased now much more .One of the most important thing that Egypt gets benefit due to the Nile is the High Dam. The high dam is located in Aswan. It was completed in 1970. It cost one billion dollar; its capacity is 5.97 trillion cubic feet. It was built to control the flood and to obtain from it hydroelectric power and it is also used in irrigation.

The Aswan High Dam captures water flood during rain seasons and releases the water during times of drought. The dam also generates enormous amounts of electric power more than 10 billion kilowatt every year. That's enough electricity to power one million color televisions for 20 years continuously. Unfortunately, the dam has also several negative side effects. In order to build the dam, Egyptian peasants had to move. To make matters worse, the rich silt that normally fertilized the dry desert land during annual floods is now at the bottom of Lake Nasser which lead to that the Farmers have been forced to use about one million tons of artificial fertilizer as a substitute for natural nutrients that once fertilized the arid floodplain. A lot of research proved that Egyptians prefer living along the Nile River because it's much easier for their life rather than living in the desert or away from the Nile River. One of the most important things is using the Nile as main source for water. Water is one of the most important things for the human body because the human body consists of 60% of water which is a very big percentage .The health of the human body cannot work properly without the proper hydrations of the body .we have to drink half of our body weight in ounce every day. The water is very important for every organ inside our body. The brain consist 85% of water, the bones consist of 35% of water, blood consist of 83% of water and the liver consist of 90% of water. This proves how much the water is so important.

There are a lot of economical projects that were made based on the Nile River. The first project that we are going to talk about is the high dam. As we said before, the high dam costs 1 billion dollar and can contain 5.97 trillion cubic feet of water. The high dam provide Egypt from south to north with high amount of electricity to run up their machine such that television, computer, lamps and their appliances. A lot of countries have problem for obtaining high amount of electricity like that in that easy way. This proves how this project which was based on the Nile is so essential now for the Egyptian and can't live without it.

The second project that we are going to talk about is the Nasser Lake. The Nasser Lake is one of the biggest and best artificial lakes that were made with the water of the Nile River.

Tourists come all over the world to see this beautiful lake which was handmade by Egyptians on the Nile river water. The lake extends for 350 miles which is about 560 kilometers and is about 6 mile which is about 10 kilometer wide. Tourists come there to see the impressive variety of animals. There people can find variety of mammals, reptiles and birds.

Tourist also visits this wonderful lake for fishing trip because this lake contains about 32 different fish species which is a large number.

The Third Project is Tuskha Project .This Project is capable of converting all the desert lands in Egypt into agricultural land. The Nile played a very important role in tourism, all tourists come all over the world to see how the Nile is great and they take a cruise from north Egypt to south Egypt and visit all the beauty which is on the Nile. The Nile can be used for a very important activity which is transportation. Egypt has a very big problem which is traffic jam. This is why the government should begin to plan how to use the Nile as a very good way for transportation. The Nile can be used in transporting people from one city to another. The government can also use the Nile in trading which will be very effective and will be a very good solution for the traffic jam because most of the traffic jam is because the trucks and the big buses, so the government should put this solution in the plan because it will help in developing Egypt to the good in the future.

In Egypt, No one can live without the Nile River because no one can live without water this is why Nile is like the main artery of Egypt. The Nile is considered the only weapons that protect Egypt from the upcoming water war that will destroy a lot of countries. The Nile should be used to make project to increase Egypt economy such as the Aswan high dam, the Nasser Lake and the toshka project.

### Application activity 9.5:

Referring to any river in Rwanda like Mukungwa, Nyabarongo, Akanyaru, Base or Akagera rivers, describe the relationship between human activities and the surrounding river.

## 9.6. Lakes, Seas and Oceans

### Learning activity 9.6.

Use internet and other geographical resources to research on:

i. Types of lakes and their mode of formation,
ii. Name 10 largest seas and five largest oceans in the world.

### 9.6.1 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)

### 9.6.2 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.

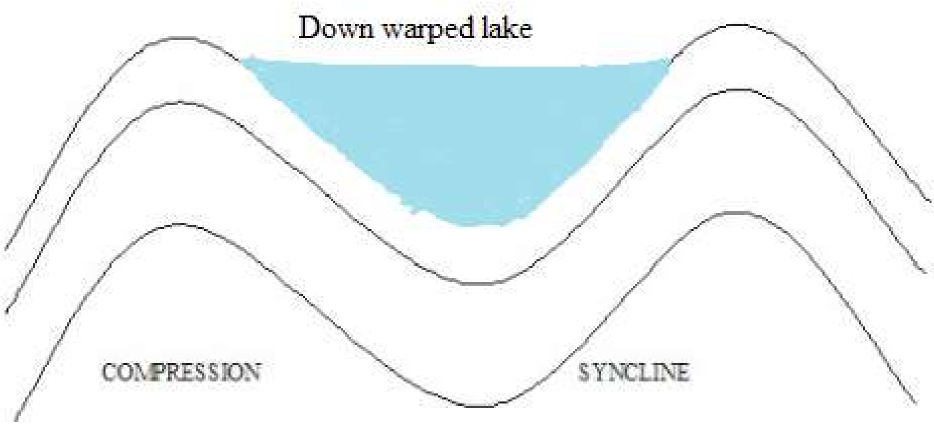



*Figure 9. 162: A section through a folded landscape showing a down warped lake*

- ***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.

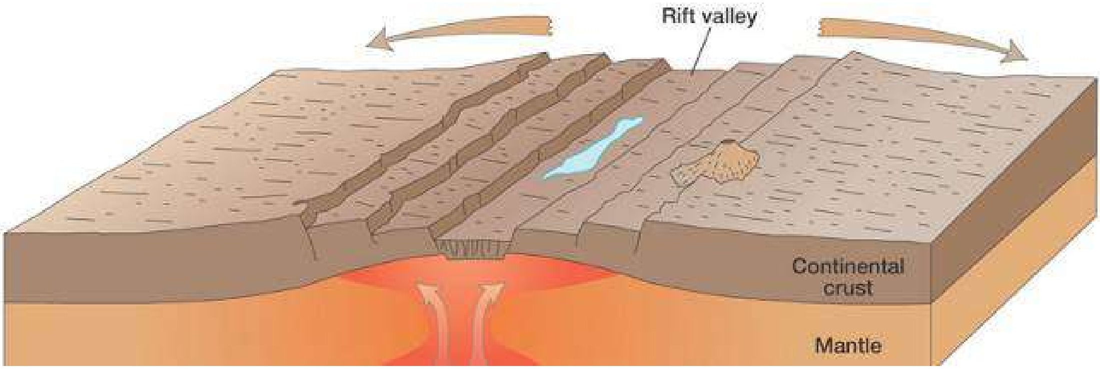



Figure 9.163: A rift valley lake

## b. Lakes produced by glacial erosion and glacial deposition

- ***Cirque/Tarn Lake****:* This 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, often called a tarn, sometimes feeds a mountain river. Tarns occur on the sides of Mount Kenya like Teleki Tarn and on Mt Rwenzori for example Stanley Lake.

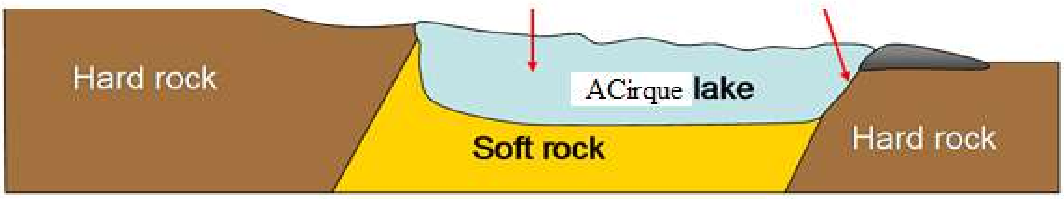



Figure 9. 164: A cross section through a cirque lake

- **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.

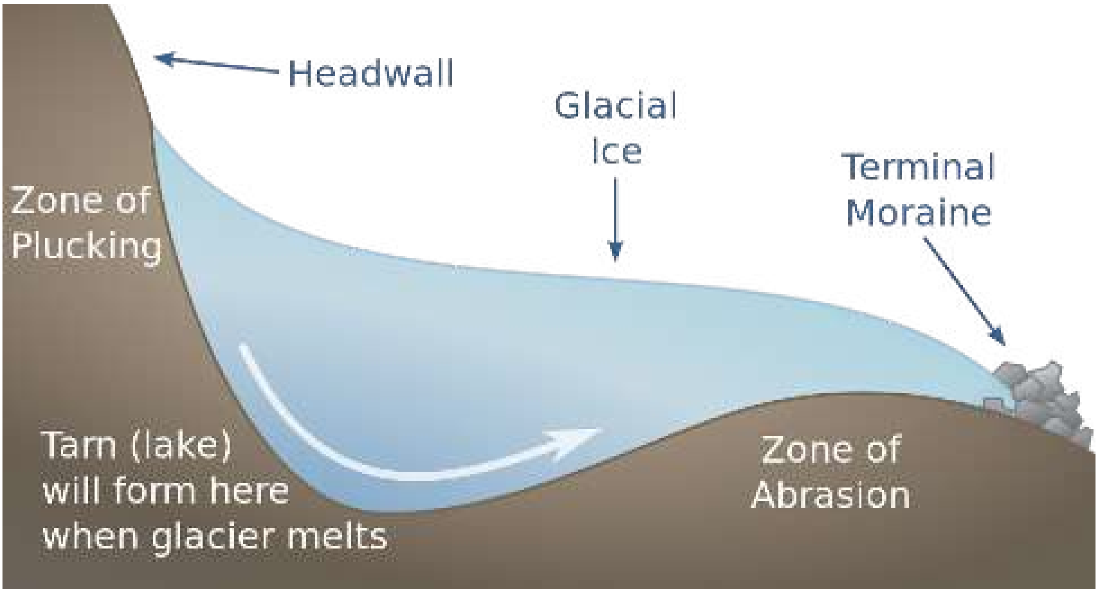


*Figure 9. 165: A section through a glaciated trough during frozen season*

- ***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.

*Figure 9. 166: 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.

*Figure 9. 167: 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.

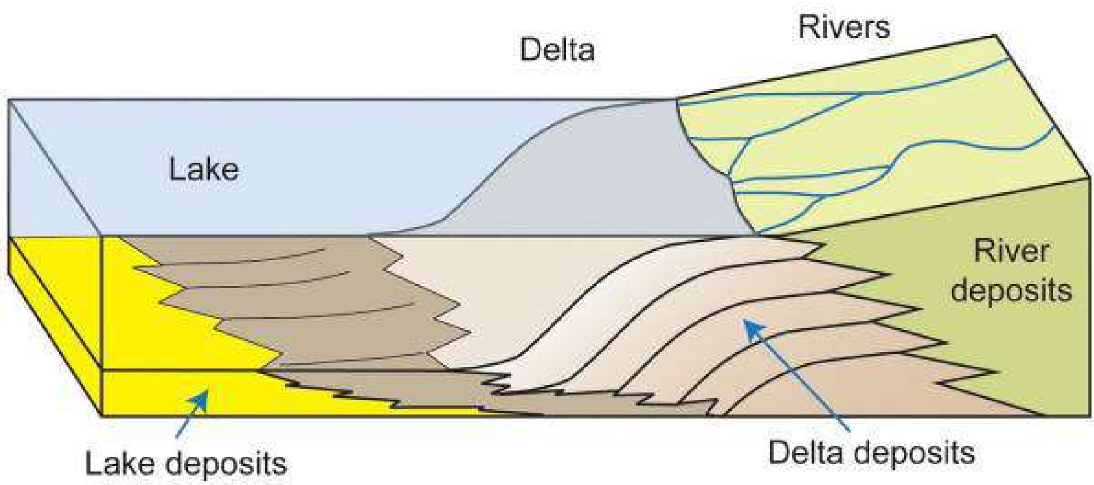



*Figure 9. 168: Delta Lake*

e. **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.

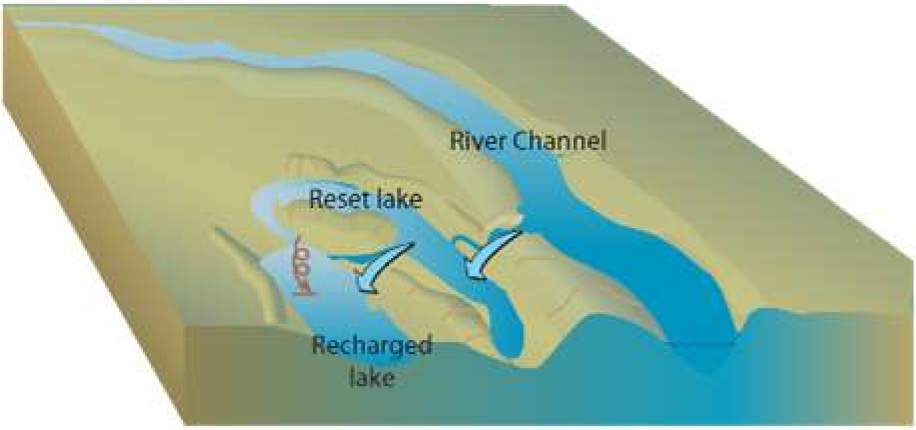



*Figure 9. 169: Flood plain Lake*

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

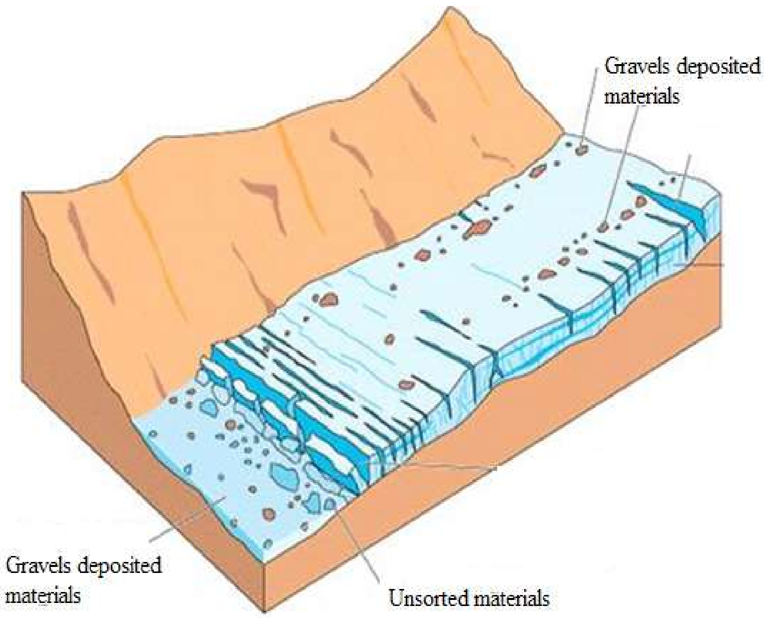



*Figure 9. 170: Boulder Clay Lake*

g. **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.

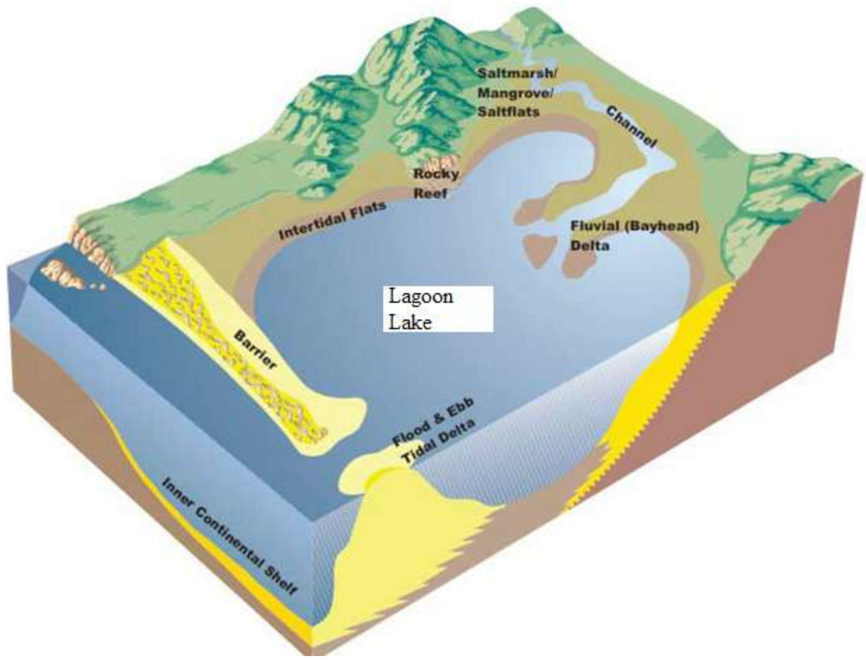



***Figure 9. 171:*** *Lagoon lakes*

### h. Lakes produced by volcanicity

- **Crater and Caldera Lakes:** Calderas often contain lakes. There are several caldera lakes in Africa. Examples are 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.

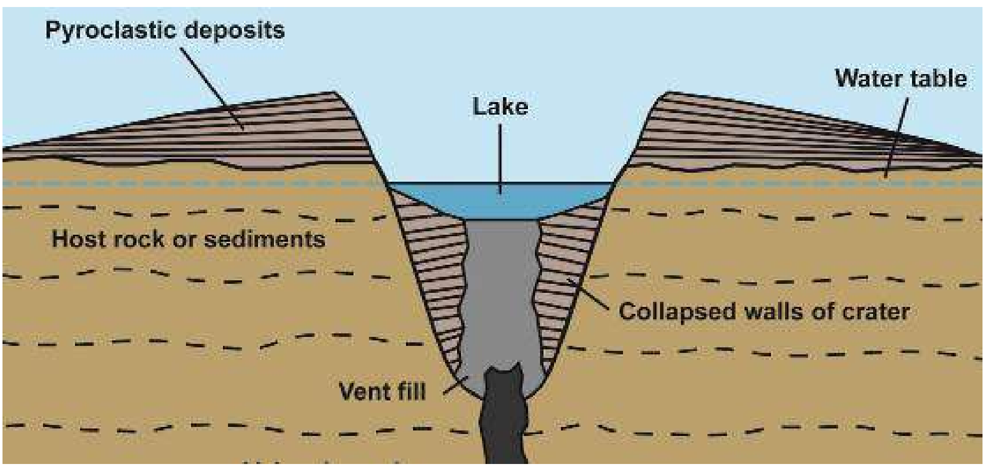



*Figure 9. 172: A crater lake*

- **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.

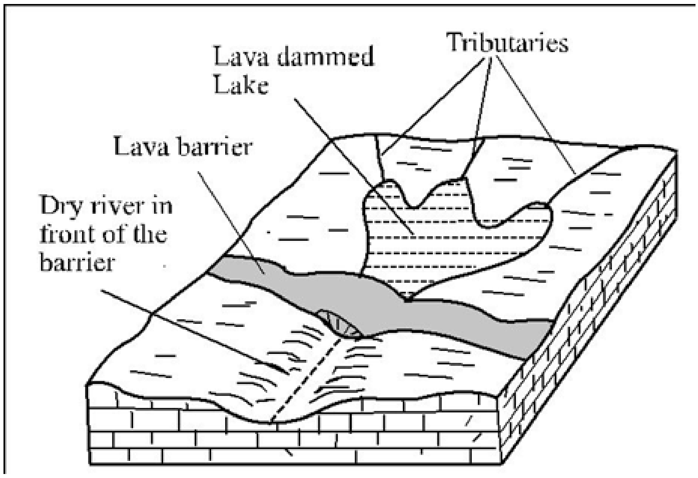



*Figure 173: A Lava dammed lake*

i. **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 and Rwanyakizinga along valley of river Akagera.

### 9.6.3. 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.

### 9.6.4 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.


*Figure 9. 174: A map showing Seas and Oceans of the world*

**b. The 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

### 9.6.5. Importance of seas and oceans

Oceans and seas are very important either to human beings or to climate and the adjacent areas. The following are the importance of oceans and seas:

- ***Source of fish:*** Oceans and seas form habitats for fish. This has promoted the development of fishing and related industries.
- ***Tourism:*** Lakes provide beautiful sceneries which attract tourists. This earns a country foreign exchange.
- ***Cheap transport:*** Ocean and seas are used by ships in transporting goods and

passengers.

- ***Source of useful water:*** Oceans and seas provide water for domestic, industrial uses.
- Source of drinking water for animals like cattle, sheep, goats, etc.
- ***Regulating river flow:*** Some seas help in controlling floods by regulating the flow of rivers.
- ***Modification of climate:*** Oceans and seas are important factors controlling the climate in a given area because they provide the moisture. The oceans and seas also moderate the climate of a given area.
- ***Ends/sources of rivers:*** Some seas and oceans form sources/ends of rivers.

Application activity 9.6

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

## 9.7 Marine Relief

Learning activity 9.7.

Use internet and geographical resources and answer the following questions:

i. Explain the types of Marine relief.
ii. Identify the location of Great Barrier Reef in Australia.

### 9.7.1 Marine Relief

Ocean basins are characterized by five relief zones: continental shelves, continental slopes, deep-sea plains, oceanic trenches and oceanic ridges.

i. **Continental shelf (platform):** This is a continental marginal area submerged under oceanic water with average water depth and gently sloping towards the sea or ocean. The width of continental shelves largely depends on the nature of relief of the coastal land.
ii. **Continental slope:** This is a zone of steep slope extending from the continental shelf to the deep-sea plains.
iii. **Deep sea plains (Abyssal Plains):** A deep sea plain is a *flat and rolling submarine plain* in the ocean/sea basin. These deep-seated plains are found in the depth from 3000m to 6000m.
iv. **Oceanic trenches (deeps):** Oceanic trenches are depressions of the sea

floor, relatively narrow in width, but very long. They are the deepest parts of the ocean floor. Very deep but less extensive depressions are called *deeps* while long and narrow linear depressions with steep side slopes are called *trenches*. For example, the Mariana trench in western Pacific Ocean is the deepest in the world.

**v. Ocean ridges:** The submarine ridges with steep side-slopes sometimes reach the sea level and even project above the water surface and appear as islands. For example, the Mid-Atlantic ridge in the Atlantic ocean.

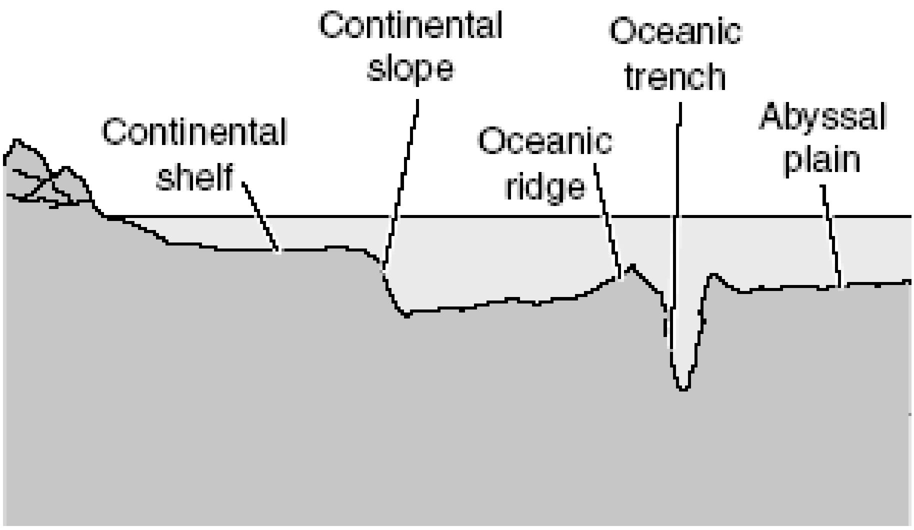



*Figure 9. 175: Marine relief*

### 9.7.2 A case study of the Great Barrier Reef

The Great Barrier Reef is the world's largest coral reef system composed of over 2,900 individual reefs and 900 islands stretching for over 2,300 kilometres (1,400 mi) over an area of approximately 344,400 square kilometres. The reef is located in the Coral Sea, off the coast of Queensland in Australia.

The Great Barrier Reef can be seen from outer space and is the world's biggest single structure made by living organisms. This reef structure is composed of and built by billions of tiny organisms, known as coral polyps. It supports a wide diversity of life and was selected as a world Heritage site in 1981. The Queensland National Trust named it a state icon of Queensland.

A large part of the reef is protected by the Great Barrier Reef Marine Park, which helps to limit the impact of human use, such as fishing and tourism. Other environmental pressures on the reef and its ecosystem include run off, climate change accompanied by mass coral bleaching, and cyclic population outbreaks of the crown-of-thorns starfish.

The Great Barrier Reef has long been known to and used by the Aboriginal Australian and Torres Strait Islander peoples and is an important part of local groups' cultures and spirituality. The reef is a very popular destination for tourists, especially in the Whitsunday Islands and Cairns regions.

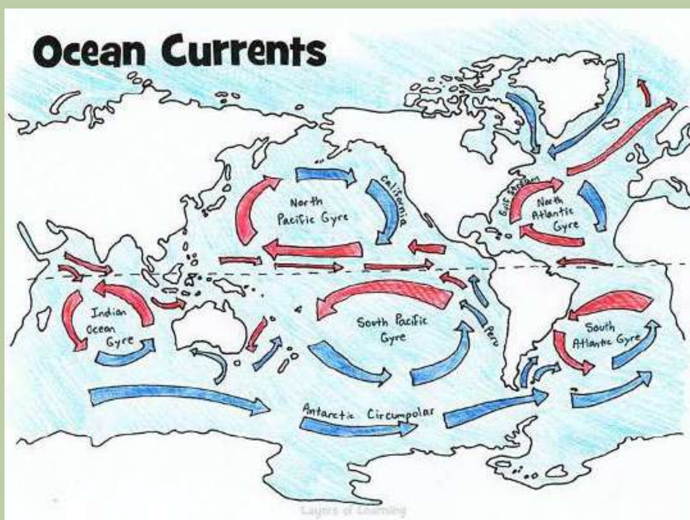
## Application activity 9.7

1. Describe the contribution of marine relief to the aquatic life.
2. Discuss the economic importance of the Great Barrier Reef to the people living in Australia.

## 9.8. Ocean currents

## Learning activity 9.8

Observe the map provided below and identify the major types of Ocean currents in their respective locations.




### 9.8.1 Definition, types and location of major ocean currents

**Definition**

**Ocean currents** are slow and steady movements of a mass of oceanic water in a definite direction. It is more or less similar to water streams (rivers) flowing on the earth's surface. Ocean currents are the most powerful of all dynamics of oceanic waters because they pass over thousands of kilometers. Ocean currents are categorized according to their areas of origin and temperature. They are warm ocean currents and cold ocean currents. They are divided, on the basis of velocity, dimension and direction into drifts, currents and streams.

**Types and location of major ocean currents**

Ocean currents are classified into ***surface*** or ***horizontal currents*** and ***vertical ocean currents***. Surface currents move water horizontally parallel to the earth's surface. ***Surface currents*** are powered by wind. Friction between wind and water causes the water to move, driving ocean water in huge circular patterns all around the world.

Surface ocean currents include ***warm currents*** also called equatorial currents. Trade winds drive the ocean surface waters westward in a concentrated channel along the equator. As these surface currents approach the western margins of the oceans, the water actually piles up against the eastern shores of the continents. This phenomenon is the **western intensification.**

The piled-up ocean water then goes where it can, spilling northward and southward in strong currents, flowing in tight channels along the eastern shorelines. As these currents move towards the west, they are deflected by continents and move either direction northward and southward along the eastern coasts of continents. For instance, in the Northern Hemisphere, the ***Gulf Stream*** and the ***Kuroshio*** (a current east of Japan) move forcefully northward as a result of western intensification.

***Cold ocean currents***, also called ***cool ocean current***s, move toward the East. Being colder with higher density, they flow to replace warmer and lesser dense equatorial surface currents moved westward which are actually being deflected left and right by continents at their eastern coasts. These currents are deflected by western margins of continents and converge at the equatorial zone.

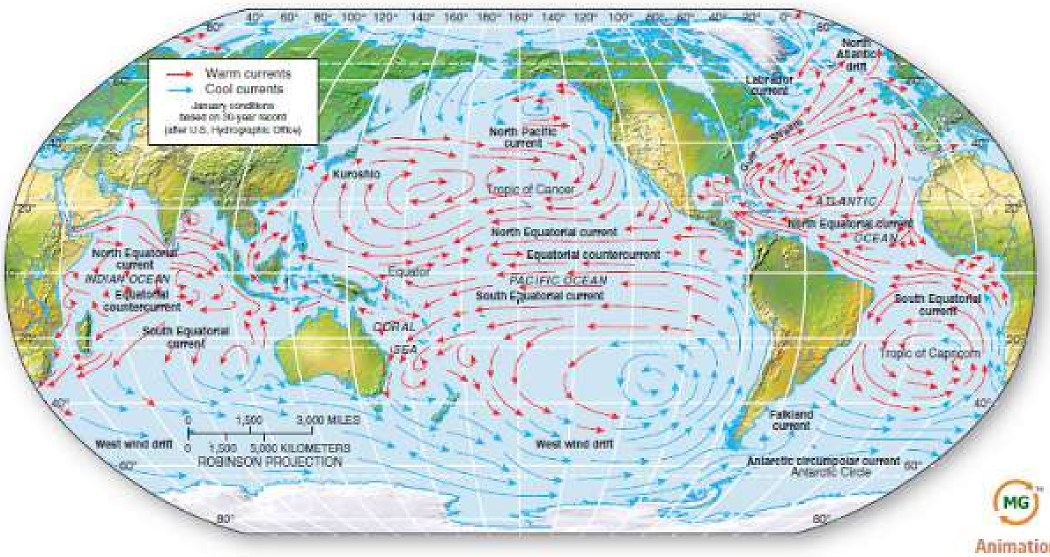



*Figure 9. 176: Warm and cold surface ocean currents*

Ocean currents are located both on the western and the eastern coasts of continents. Several ocean currents have different names according to their areas of origin or temperature. Major ocean currents of the world and their names are presented on the map provided below.

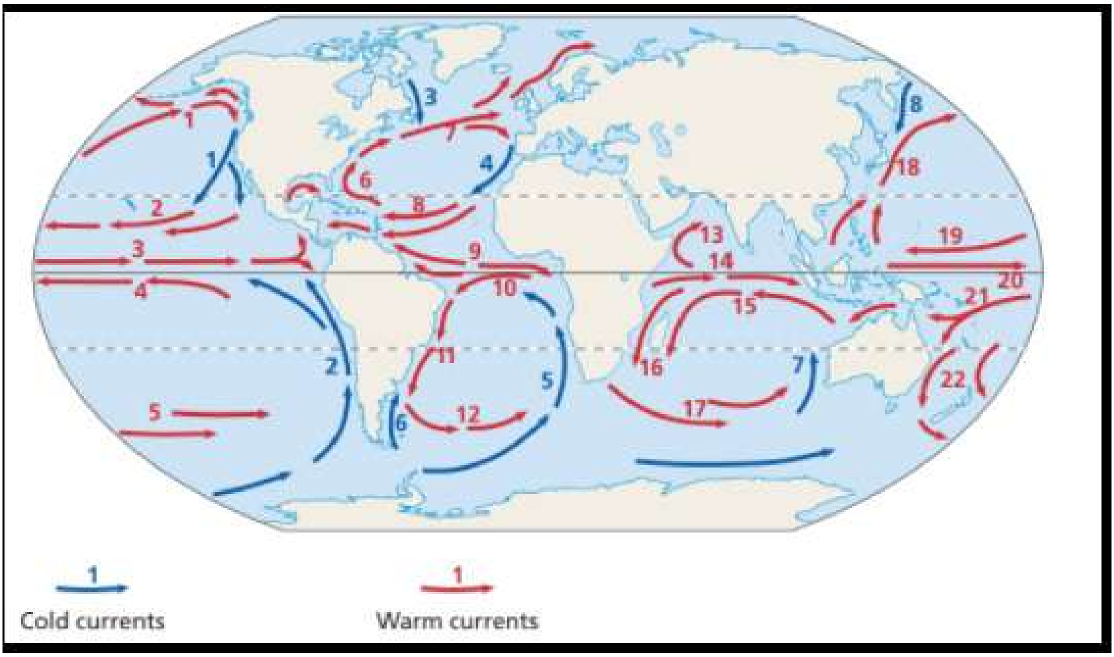



*Figure 177: The major surface ocean currents and their location*

**Cold ocean currents**

1. Californian Current
2. Humboldt current
3. Labrador current
4. Canaries current
5. Banguela current
6. Falkland current
7. West Australian current
8. Okhotsk current

**Warm ocean currents**

1. North pacific drift
2. North Equatorial current
3. Equatorial counter current
4. South Equatorial current
5. West wind drift
6. Gulf stream
7. North Atlantic drift
8. North Equatorial current
9. Equatorial counter current
10. South Equatorial current
11. Brazil current
12. West wind drift
13. Monsoon current
14. Equatorial counter current
15. South equatorial current
16. Mozambique current
17. West wind drift
18. Japan current
19. North equatorial current
20. Equatorial counter current
21. South Equatorial current
22. East Australian Current

***Vertical ocean currents*** include ***upwelling*** and ***downwelling flows***

Where surface water is swept away from a coast, either by surface divergence (induced by the Coriolis force) or by offshore winds, an upwelling current occurs. **Upwelling** is a circulation in the ocean that brings deep, cold water to the ocean surface. In upwelling, wind blowing offshore carries water away from the land. When surface water is pushed away, cold water from deep in the ocean rises to replace the vacating water. This cool water, generally, is nutrient-rich. Regions where this occurs are known as good fishing areas. Such cold upwelling currents exist off the Pacific coasts of North and South America and the subtropical and mid-latitude west coast of Africa. These areas are some of Earth's prime fishing regions.

In other regions with an accumulation of water - such as at the western end of an equatorial current, or in the Labrador Sea, or along the margins of Antarctica - the excess water gravitates downward in a **downwelling current**. These are the deep currents that flow vertically and along the ocean floor and travel the full extent of the ocean basins, carrying heat energy and salinity.

### 9.8.2 Causes and characteristics of ocean currents

#### a. Causes of ocean currents

Surface ocean currents, like surface winds, are influenced by the Coriolis Effect. The Coriolis effects deflects currents north of the equator, such as the Gulf Stream, to the right. Currents south of the equator are deflected to the left. The continents also influence ocean currents. Currents moving towards the west in the Pacific are deflected by Asia and Australia. The current deflected by Coriolis Effect move eastward until North and South America deflects them.

There are several factors or causes of ocean currents. These are:

- The factors relating to the earth's nature and its rotation such as gravitational force and deflective force by earth's rotation.
- Oceanic factors like pressure, gradient, temperature variations and salinity differences.
- Ex-oceanic factors like atmospheric pressure and winds, evaporation and precipitation.
- Current modifying factors like direction and shape of coastlines, relief of the ocean basins, seasonal variations and rotation of the earth.

#### b. Characteristics of ocean currents

- Ocean currents are classified as either warm or cold depending on their origin and temperature.
- Ocean currents which flow from the Equator towards the poles are warm, while those flowing from the poles towards the Equator are cold.
- In the Northern Hemisphere, Ocean currents move clockwise, while in the Southern Hemisphere, their movement is anticlockwise.
- Warm ocean currents occur mainly on the eastern margins of continents, while cold ocean currents occur on the western margins of continents.

### 9.8.3 Influence of ocean currents on the climate and the adjacent lands

Ocean currents have both positive and negative influences on climate and the adjacent lands. These influences are:

- **Modification in the coastal climate and inlands**: Ocean currents while flowing along the coasts modify their weather conditions in a number of ways. The most effective impacts of ocean currents are seen on the temperature of affected coastal lands. The effects are both positive (beneficial) and negative (injurious) to flora and fauna.
- **Ocean currents help in maintaining the temperature balance** of ocean water as the warm currents transport warm waters of the tropical zones to the colder areas of the temperate and polar zones and cold currents bring cold waters of high latitudes to the areas of low latitudes.
- **Cold ocean currents**, on the other hand, lower down the temperature considerably of the affected areas and thus cause snowfall. The winds blowing over warm currents pick up moisture and help in increasing the amount of precipitation in the affected coastal areas.
- **Effects on fishing:** Ocean currents act as distributing agents of nutrients, oxygen and other elements necessary for the existence and survival of fishes. Ocean currents transport planktons from one area to another area. These planktons are useful food for fishes.
- **Effects on trade and navigation:** Ocean currents were used to determine major ocean routes for the navigation of commercial ships in ancient times. Today's power-motored ships do not rely the ocean currents and prevailing winds for guidance. The occurrence of fog due to convergence of warm and cold currents poses serious threats to navigation. Larger icebergs brought by cold currents damage ships.

#### Application activity 9.8

1. Explain why some ocean currents are warm whereas others are cold.
2. Describe the effects of ocean currents to the climate of East Africa.

### 9.9. Ocean tides: Definition, types, causes and the effects

#### Learning activity 9.9

Do research using internet and geographical resources to describe the causes and effects of tides

### 9.9.1 Definition and types of tides

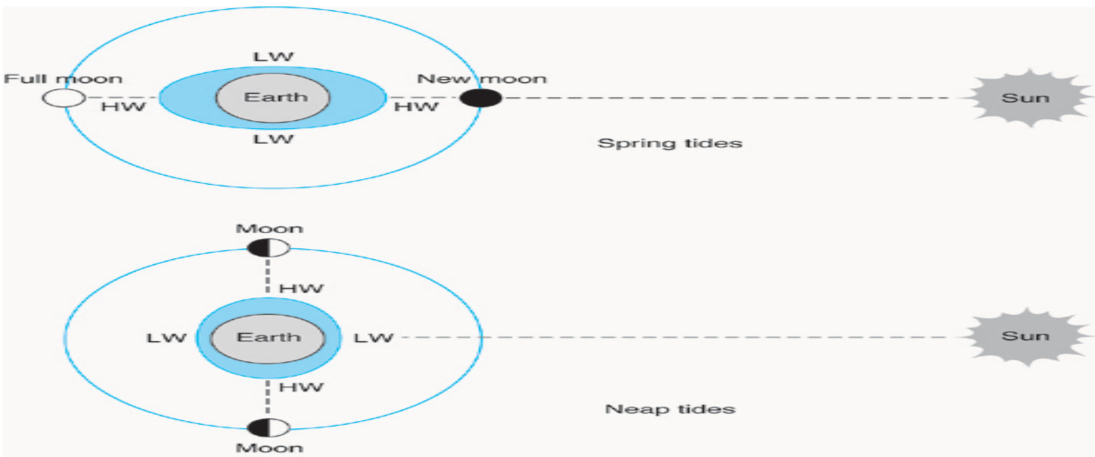
A **tide** is a pattern of twice-daily oscillations in sea level, (rise) and (fall), produced by astronomical relations among the Sun, the Moon, and the Earth; experienced in varying degrees around the world.

The *rise of seawater* and its movement towards the coast is called ***flood*** and the resultant high water level is known as high tide water. The *fall of seawater* and its movement towards the sea is called ***ebb*** and the resultant low water level is called low tidal water. The difference between high tide water and low tide water is called tidal range. The sea waves generated by tides are called *tidal waves.* The highest tidal waves are commonly referred to as, "*Tsunami*" off the coast of Japan.

The major types of tides are briefly described below:

**i. Spring tides**

They are generated by the increase in gravitational attraction, which produces the highest high tides, the lowest low tides, and the maximum tidal range. They take place when the sun, the moon and the earth are almost aligned. The height of such spring tides is 20% more than the normal tides. Such tides occur twice every month (during full moon and new moon) and their timing is fixed.




(LW: low tide, HW: high tide)

*Figure 178: Spring season*

ii. Neap tides

They are midway between the Spring tides. Neap tides occur when the sun, the earth and the moon form a right angle with the earth at the apex. In this arrangement, the Moon and Sun cause separate tidal bulges, affecting the water nearest to each of them. In addition, the left-behind water resulting from the pull of the body on the opposite side augments each bulge

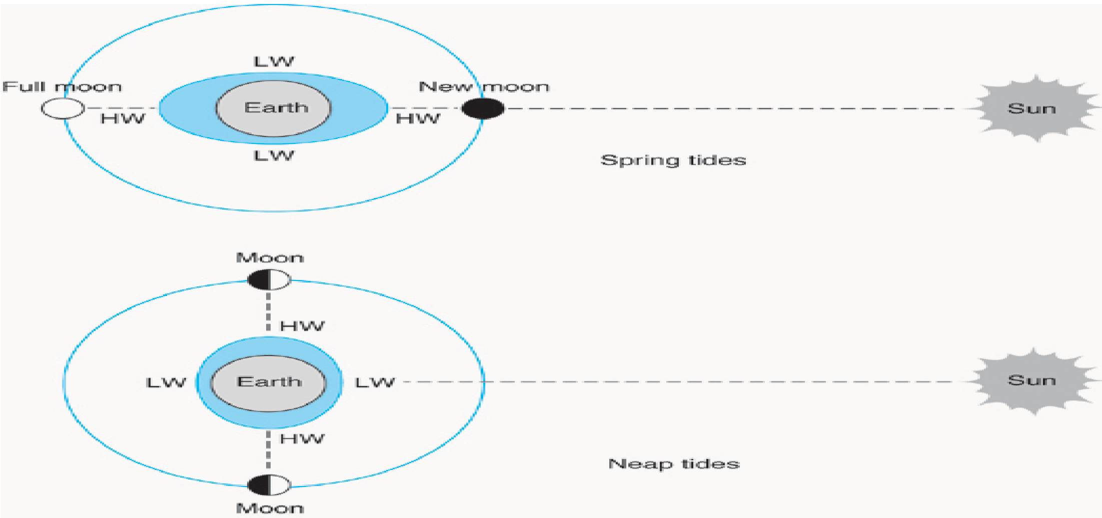



*Figure 9. 179: Neap tides*

### iii. Tropical and equatorial tides

The position of the earth, the moon and the earth in straight line is called **Syzygy.** When the sun, the moon and the earth are in sequential order in straight line, in other words when the sun and the moon are in one side of the earth, the position is called **conjunction** (the situation of solar eclipse). When the position of the earth is in between the sun and the moon, this is called opposition. On the other hand, when sun, the earth and the moon are in position of right angle, this position is called **quadrature.** When there is maximum declination of the moon to the north of Equator, the moon's rays fall vertically on the tide centers and hence spring tides are caused. Spring tides are also caused along the Tropic of Capricorn which is opposite to the tropic of Cancer. These types of tides are also called **tropical tides**. When the moon is at vertical position to the Equator (once per month) the tide caused is called **equatorial tide.**

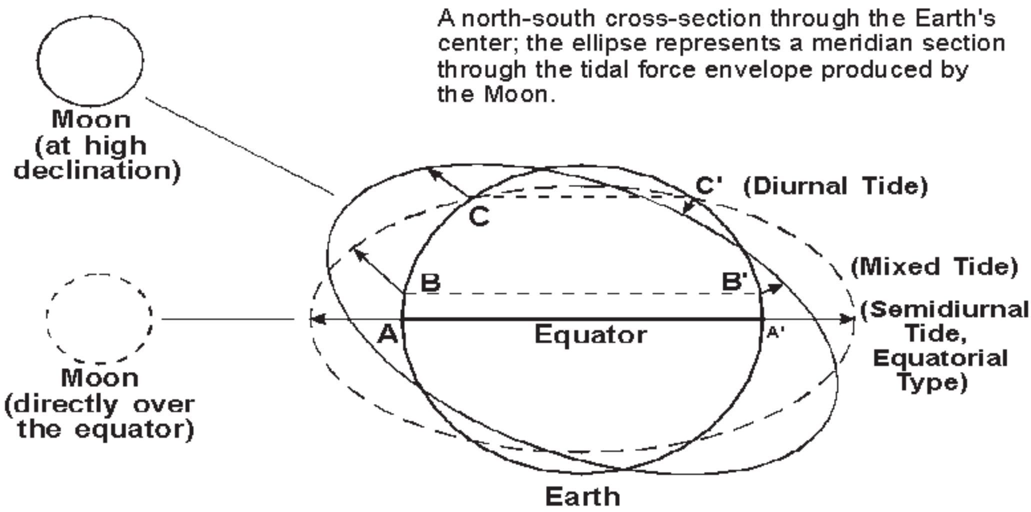



*Figure 9. 180: Tropical and Equatorial tides*

**iv. Perigean Tides**

These are characterized by the high tides which are much higher than normal. They occur when the moon is at its nearest point to the earth and thus its gravitational effect is the greatest.

**v. Apogean Tides**

These are tides with a small tidal range. They occur when the moon is far away from the earth. At this junction its gravitational effect is at the lowest point causing the high tide level to be lower than usual.


*Figure 9.181: Varying distances between the earth and the moon*

**vi. Daily and semi-diurnal tides**

The tides recurring at the interval of 24 hours 52 minutes daily are called diurnal or daily tides while the tides recurring at the interval of 12 hours 26 minutes are called semi-diurnal tides.

### 9.9.2. Causes and effects of tides

The origin of tides in the oceans is primarily concerned with the gravitational forces of the earth and the moon. The earth rotates from west to east and revolves around the sun following an elliptical orbit. Similarly, the moon rotates from west to east and revolves around the earth along an elliptical orbit so that the distance between the moon and the earth changes during different times in every month.

The gravitational force of the moon will be at its maximum at the earth's surface facing the moon, while it will be minimum at the opposite side of the earth. Consequently, the water on the earth's surface facing the moon is attracted and pulled and high tides occur.

There are many effects of tides as explained below.

- The daily rising and falling of the sea level generates tidal waves which can be harnessed to produce electricity. This is done at St. Malo in North West France.
- Tides generate strong and swift ebb and flood currents. The flow in and out of bays through narrow inlets causes erosion.
- Tidal currents carry very fine silt and clay in suspension. These fine sediments settle on the floor of bays and estuaries where they accumulate in layers and gradually fill them up. This may silt up harbours hence hindering water transport.
- High tidal waves may flood coastal settlements leading to destruction of property and loss of life.

**Application activity 9.9**

1. Explain the relationship between tides and winds.
2. Describe the effects of tides on lake shores of Rwanda.

### 9.10. Reasons for protection of global water bodies

**Learning activity 9.10:**

Explain the importance of protecting water bodies?

Water is one of the most essential commodities apart from air but we tend to take it for granted. That is why we don't seem to have enough even though we have more than we needed in our motherland.

The following are the major reasons for protection of global water bodies:

i. ***Economic uses:*** Water is needed by human beings for drinking, washing, cooking, and for sanitation. The recommended basic requirement for domestic purposes is about 50 litres a day. Thus, for a world population of slightly more than 7 billion people, the total volume of freshwater needed for domestic use annually is at least 110 x 109m$^3$.

ii. ***Agricultural use***: The volume of water needed by agriculture to grow the food to keep the population alive also must be added to this total. Agricultural water needs are much greater than human consumption needs, given that 600 and 1,800m$^3$ is needed each year to grow the food for one individual. Industry also uses large volumes of water. Including hydropower, navigation and fishing, over 6,000 km$^3$of water are presently used each year (estimates vary) for activities with economic considerations, of which about 67% is used for irrigated agriculture and less than 3% for domestic purposes.

iii. ***Recreational uses:*** Many freshwater bodies are used for sports activities, boating, sightseeing, swimming, photography and other active or passive recreational pursuits. They are also important for sports and commercial fishing. Unfortunately, due to lack of knowledge about their impacts, introducing fish from other places into a new environment lacking their natural controls (e.g., predators, environmental conditions), has resulted in some cases in the decimation of existing native fish species, while also affecting entire local.

iv. ***Aesthetic values***: Often termed 'inspirational' or 'spiritual' values, these values are impossible to place a price on - indeed, there are some who say these values are priceless! However, although difficult to quantify, such values have long attracted the attention of poets, artists, writers and the religious.

v. ***Cultural values:*** Many lakes and rivers have played a critical role in human history, forming an integral part of our common cultural heritage. Religion and socio-cultural values are part of the human existence. Also a beautiful place for praying (Photo 5), they can facilitate lasting participation in achieving the goal of integrated watershed management for sustainable water use.

vi. ***Educational uses:*** As discrete, biologically-comprehensive and accessible habitats, lakes, rivers and other bodies of inland water also represent unique educational 'tools' for informing and educating the public.

vii. ***Scientific values:*** The biota and ecological processes of freshwater bodies have long attracted attention from a number of scientific disciplines, being the subject of countless investigations. Such investigations are very important, primarily because they tell us how parts of the living world are structured and how they function, as well as what the past was like, and perhaps what the future may be.

***viii. Ecological values***: As integral parts of the global hydrologic cycle, pathways for the circulation of essential elements, and repositories for a significant fraction of the world's biodiversity, freshwaters have an important ecological role in sustaining the planet's life-support systems. These so-called 'ecosystem services', like many other non-recognized-economic values, are difficult to value economically, although studies are underway to develop tools for assessing these services. One estimate is that the annual value of ecosystem services provided by wetlands, lakes and rivers in the world are worth about US$ 6.6 trillion dollars.

## Application activity 9.10

1. Discuss the ways you use to protect water at your school.
2. Visit a river or lake shore in your local environment and identify what the people around have done to protect 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

# UNIT 10

# POWER AND ENERGY PRODUCTION IN THE WORLD

# UNIT 10: POWER AND ENERGY PRODUCTION IN THE WORLD

## Key unit competence:

By the end of this unit, I should be able to evaluate the success of sustainable development projects in power and energy production in different parts of the world.

### Introductory activity

1. Observe pictures provided below and answer the following questions:

i. Identify the types of power and energy shown above.
ii. Which ones are renewable among them?
iii. Explain how each type of power and energy works.
iv. Indicate the types of power and energy used in Rwanda within those shown on the pictures above.

2. Describe the problems that some countries face in power and energy production.
3. Name the leading producing country of each type of power and energy sources worldwide.
4. How can power and energy contribute to the sustainable development of our planet?

## 10.1. Sources and forms of energy used in the world

### Learning activity 10.1

1. Make a short tour in the school and the surrounding environment and answer the following questions:
   i. Identify the activities that require power and energy at your school.
   ii. Describe the forms of power and energy needed for each activity identified above.
2. Discuss the sources of power and energy exploited and not exploited in Rwanda.

### 10.1.1 Classification of energy resources

There are two main categories of energy resources:

- **Non-renewable resources:** These are resources of energy without the capacity of replenishing themselves after being used. When used they get exhausted and cannot be re-used. They include minerals, natural gas, oil and coal.
- **Renewable resources:** They are inexhaustible. These are resources of energy with the capacity of replenishing themselves after being used. They include water, wind, solar, plants (biomass) and animals (biogas).

### 10.1.2. Non-renewable energy sources

Non-renewable energy resources are available in limited supplies. This is usually due to the long time it takes for them to be replenished. They include nuclear energy and fossil fuels energy resources like coal, oil and natural gas.

#### a. Nuclear energy (Uranium)

Nuclear energy is energy obtained from uranium through a chain reaction. When it was realized that when the nucleus of an atom is bombarded by electron it disintegrates and releases enormous quantity of energy, two thoughts came in the mind of rational man:

- to build an atomic weapon, and;
- to generate electricity.

Thus, mankind has developed the art of both. The release of energy by this process is known as fission. Based on this process scientists build reactors in which controlled fission went on to produce energy (heat) and this heat generated electricity.

Generation of electricity involves a lot of technical know-how and so far, only highly developed countries have been able to master it. Thus, the USA, Canada, the UK, France, Japan, Germany are the largest producers of electricity by nuclear fission. Nuclear energy contributes about 9% of all energy produced in USA, though it produces 50% of all electricity generated by nuclear energy worldwide. France derives about 75% of its electricity from nuclear energy, 18.5% in Britain, 15% in Japan and 7% in German. Among the developing countries India is the leader producing 3% of her total requirements from nuclear power plants.

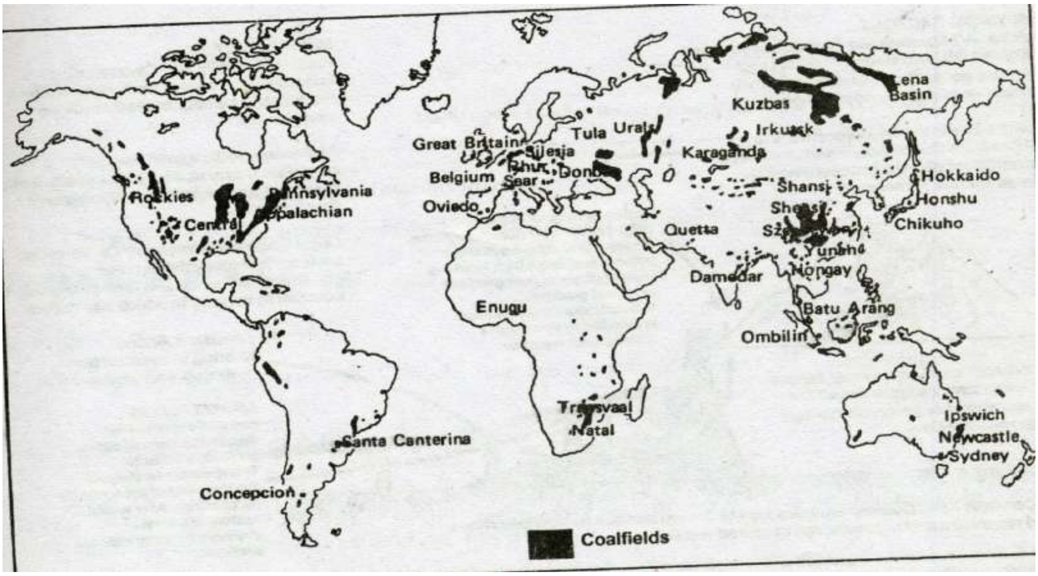
### b. Coal

Coal is a sedimentary deposit formed by the slow action of heat and pressure on plant remain buried in the long past. It is a mechanical mixture of carbon, hydrogen, nitrogen, sulphur, etc. It is the content of carbon which determines the quality of coal.

i. Types of coal

The amount of fixed carbon and hydrocarbons forms the basis of classification of coal into various types. The following kinds of coal are generally recognized:

- **Anthracite:** It is a hard and dense coal which is relatively free from iron compounds and moisture. It is made by 95 % of carbon.
- **Bituminous:** It is unusually black and highly lustrous. The moisture content is relatively low. The fixed carbon content ranges from about 50 to over 80% and that volatile matter from 40 to 15%.
- **Lignite:** It is also known as brown coal. The higher grades vary from dark brown to almost black. It is characterized by high moisture content, generally about 40%. The fixed carbon content is also 40%. The structure is fibrous, and sometimes woody.
- **Peat:** It occurs in bogs, especially in areas of cool temperate climates. This is young coal which consists of partly decomposed vegetation.




***Source:*** *Jens Nordmann,et al. Harrison at http://www.pgdp.net*

**Figure 10.182***: Major Coal fields in the World*

ii. Uses of coal

The coal can be used:

- in thermal generators to produce thermal electricity.
- as a domestic fuel for heating and indirectly in the form of a gas and electricity.
- in iron smelting e.g. through use of metallurgical coke in blast furnaces.
- to provide a number of raw materials for the chemical industries like coal gas, coal tar, benzele and sulphate of ammonia.

### c. Petroleum (oil)

Petroleum is an inflammable mixture of oil hydrocarbons with very complex properties. Petroleum literally means 'rock oil.' It exists underground in solid, liquid and gaseous form. Accumulations of petroleum are found in underground fields, pools or reservoirs of sedimentary rock formations.

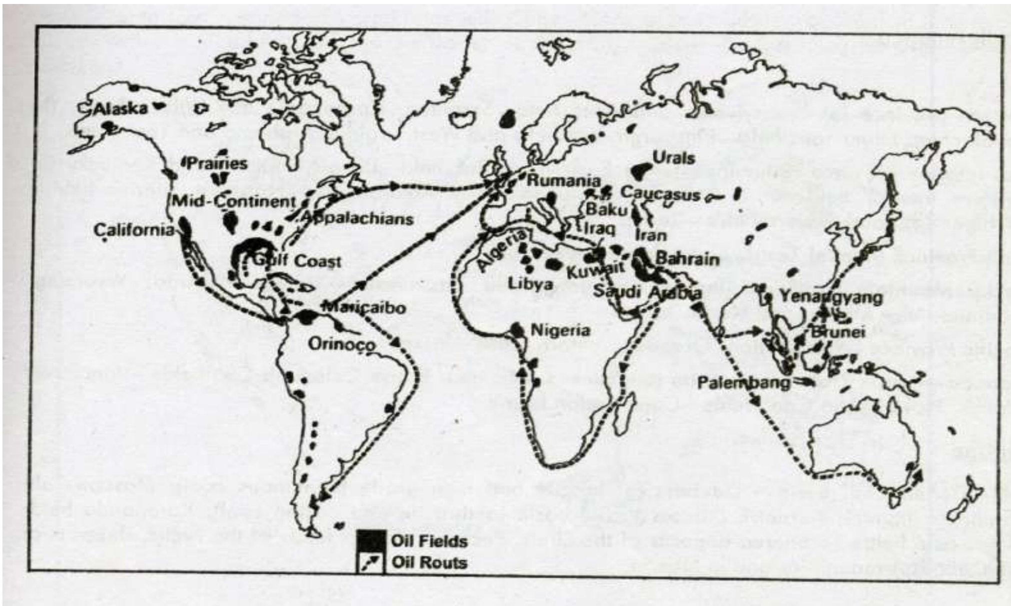
i. Three grades of crude oil according to gasoline yields

- Paraffin - base oil has high percentage of methane (highest yields)
- Mixed-base oil has high percentage of naphthene (intermediate yields)
- Asphalt - base oil has heavier hydrocarbons (lowest yield)

ii. Uses of petroleum

Petroleum can be used:

- for heating homes and hearths;
- as industrial power to drive/move engines and for heating furnaces and producing thermal electricity;
- as transport power for driving railways, motorcars, ships and aeroplanes;
- as lubricants of machines especially high-speed machines;
- as a raw material in various petro-chemicals industries, such as synthetic rubber, synthetic fibres, fertilizers, medicines.




*Source: © 1996 The Washington Post Co*

*Figure 10.183: Major oil regions of the world*

### d. Natural gas

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium.

The world's proven reserves of natural gas are estimated at about 700 trillion cubic feet. The USA (40%), the Middle East (23%), and the former USSR (11%). Most of the rest is in northern Canada, Europe and Venezuela. Much smaller amounts are widely scattered in several countries including Mexico, South American countries, Pakistan, china, Indonesia and Australia. Nigeria is the first petroleum producing country in Africa.

Natural gas may occur with or without petroleum. Where gas occurs in association with oil, it is generally found in increasing amounts at the greater depths that needs to be drilled.

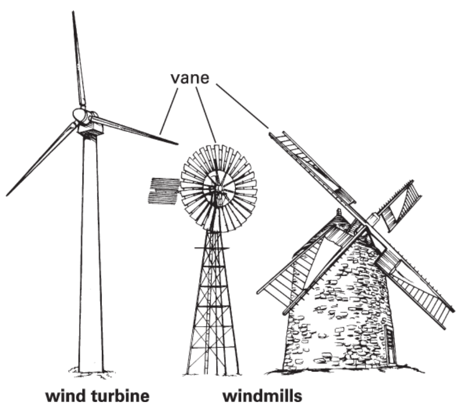
Natural gas (Methane) as a fuel may be used for cooking, heating and even to generate electricity. It has the advantage that it can be pumped through pipes from wells to consumption sites. It is also a "clean fuel". This means that it causes less air pollution. Natural gas can be shipped in liquid form, called liquefied natural gas.

### 10.1.3. Renewable energy sources

Renewable energy is the energy that is generated from the resources that are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating or cooling, transportation and rural energy services.

#### a. Wind energy

Wind power is an indirect form of solar energy that can be used to produce electricity. Wind is an almost unlimited, free, renewable, clean and safe source of energy. It has a moderate net useful energy yield and is based on fairly well developed technology. As we can see it from the figure below, the process of the production of energy from the wind is the following: usually a propeller blade is mounted on a tower. The blade is connected onto an electric generator. As wind blows, the blade spins and turns the generator which produces electricity by converting the kinetic energy of the wind into electric energy. A suitable site for a wind turbine depends on the local wind conditions.

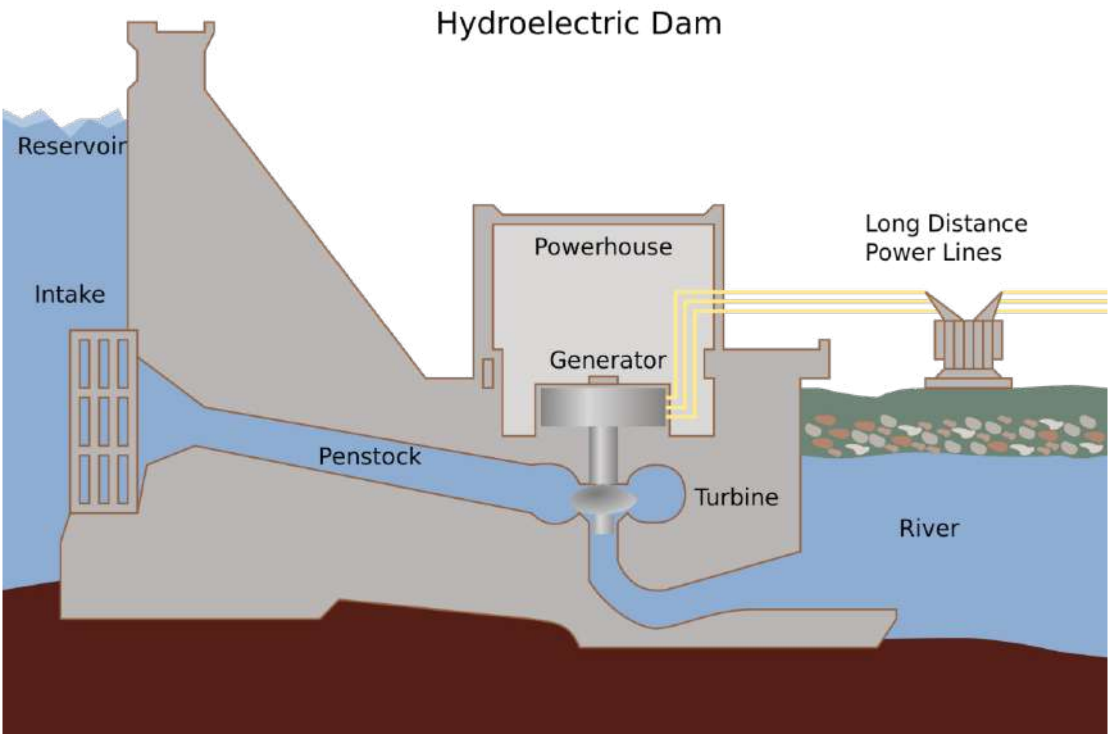



*Source: Windmill (© 2018 State of Colorado)*

*Figure 10.184: Windmill*

**b. Water energy**

This is the energy produced from running water. Usually, a dam is constructed along a river to store water. The water is then made to fall over a steep gradient. It then passes through a turbine hence spinning the blades of the turbine. Rotation of the blades causes the turbine to turn an electric generator that produces electricity.




*Source: https://commons.wikimedia.org/wiki/File:Hydroelectric_dam.png*

*Figure 10.185: Hydro-electric power station set up*

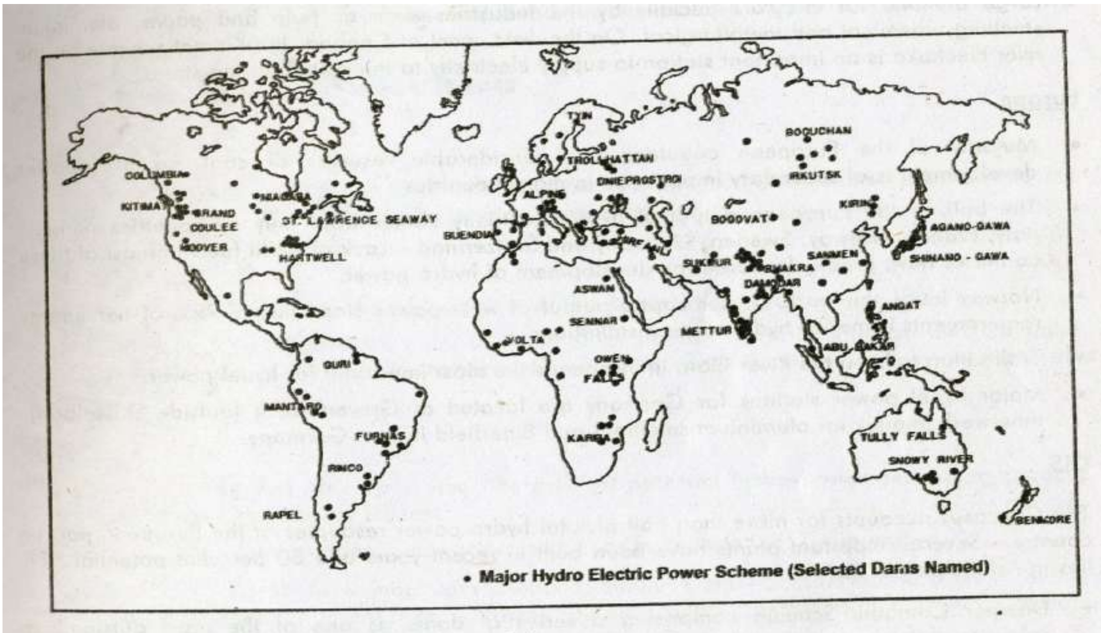
Hydro-electrical power energy requires the following physical and economic conditions:

**i. Physical conditions**

- A seismological less sensitive area.
- High quantity of water supplied by fairly heavy rainfall distributed throughout the year.
- Great altitude with steep slope to enhance water velocity.
- Existence of rapids and falls favour the development of power by increasing the velocity of stream.
- Narrow steep-sided valley to facilitate dam construction.
- A hard rock for firm foundation.
- Existence of lakes or space for water reservoir.
- The absence of coal, petroleum, etc., expedites the development of waterpower.

### ii. Economic Conditions

- Market: Large demand for hydroelectric power;
- Huge capital outlay;
- Technological knowledge and skill and
- Transport facility.




*Source: Zarfl et al (2014) (https://freshwaterblog.net/2014/12/01/how-will-the-hydropower-boom-affect-global-river-ecosystems)*

*Figure 10.186: Major hydroelectric power schemes*

### c. Solar energy

Breeder reactors, fusion reactors and solar energy are the only energy alternatives that could support high energy generation indefinitely. However, breeders have potentially serious environmental and economic problems and nuclear fusion is so complex, it can never be economically feasible. In contrast solar energy is abundant, clean, safe and virtually inexhaustible free fuel.

If the direct sunlight falling on the earth in only 3 days is concentrated and converted to useable form of energy, it would equal all of the energy in the earth's known reserves of coal, oil and natural gas.

The figure below shows the process of solar energy production. A greenhouse uses panels of transparent glass to trap solar energy. Another way of tapping solar energy is by use of solar cells. This transforms sunlight directly into electricity.

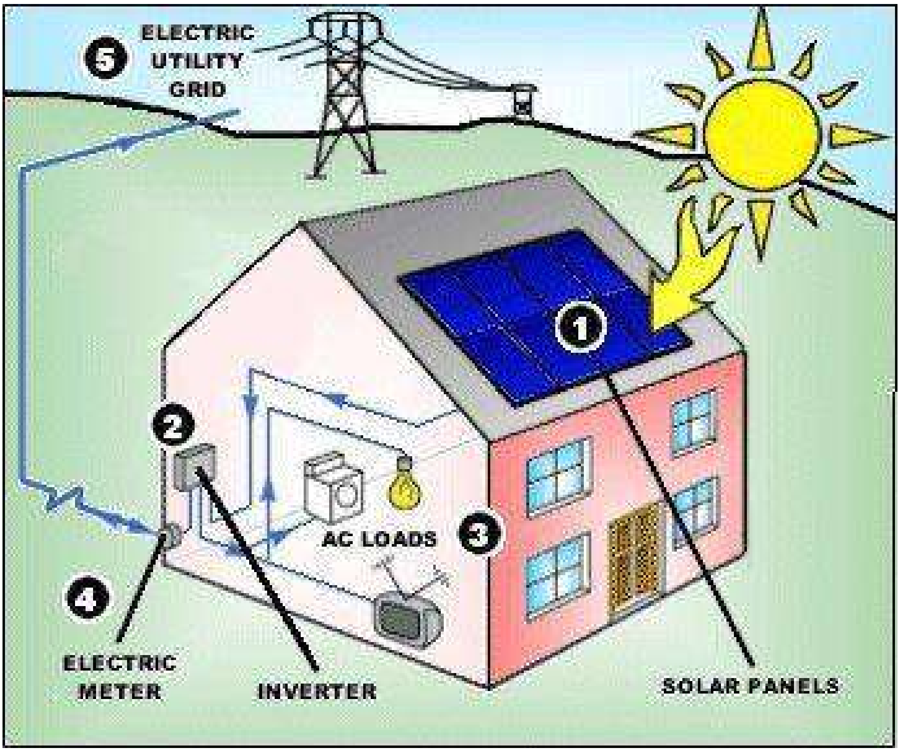
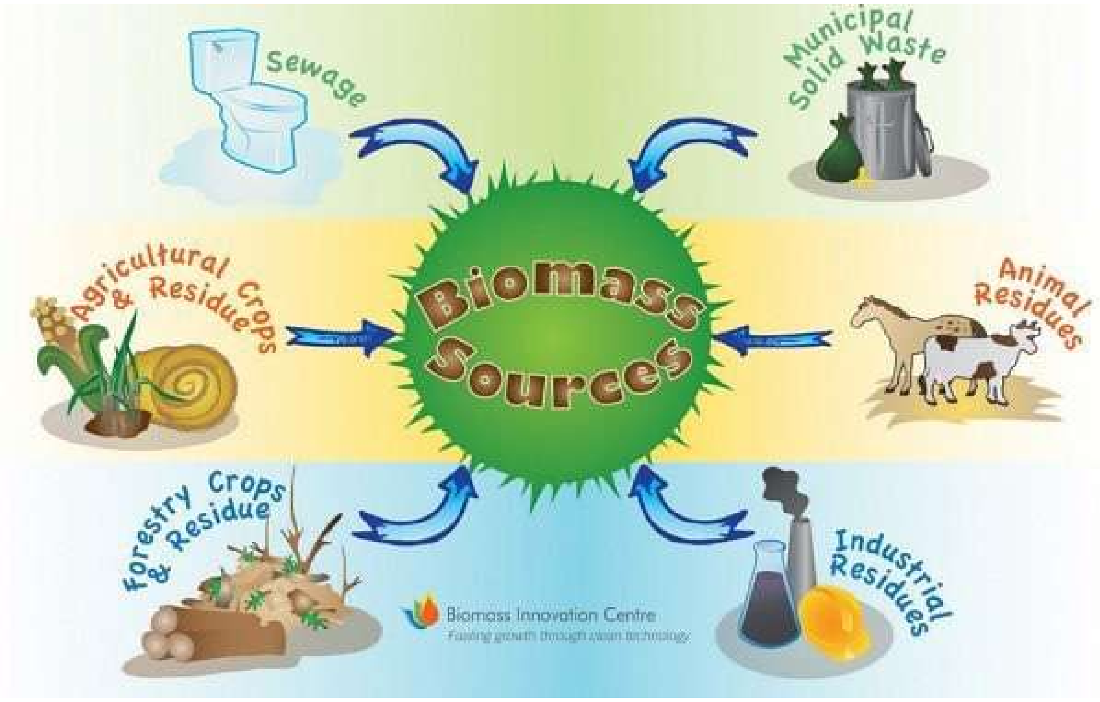



*Figure 10.187: Solar panel*

**d. Biomass**

Many people consider the wind and the sun as the main forms of renewable energy. However, biomass (plant material and animal waste) is the oldest source of renewable energy, used since our ancestors learned the secret of fire.

Biomass is a renewable energy source for the two reasons: first the energy in it comes from the sun, second, biomass can re-grow over a relatively short period of time compared with the hundreds of millions of years that it took for fossil fuels to form. The generation of energy starts through the process of photosynthesis. Through this process, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates—complex compounds composed of carbon, hydrogen, and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the energy they captured from the sun.
Bio-mass energy includes: wood fuel, Bio-gas and Gasohol.




Source: (data:image/jpeg;base64,/9j/) found in March 27, 2018

Figure 10.188: Biomass sources.

i. Wood fuel: This is a very important source of energy in third world countries. The wood obtained from forests is either used directly or converted to charcoal.

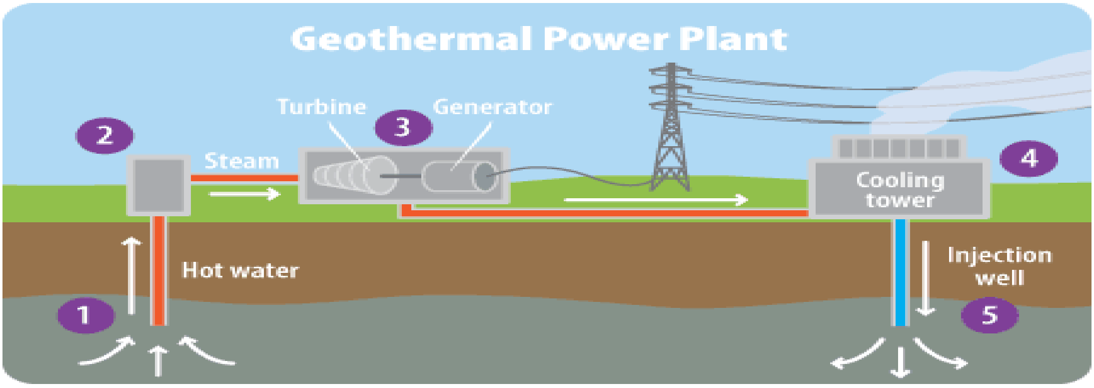
ii. Waste products (Bio-gas)**:** This is a flammable gas produced by micro-organisms, when organic matter is fermented under specific temperatures, moisture content and acidity. It is mainly composed of methane which burns with a blue flame.

iii. Gasohol: Plant material may be converted to alcohol which is a fuel. Wood, wood wastes and garbage can be heated to produce methanol. Most plants containing starch and sugar like sugarcane and cassava can be converted to ethanol. Corn, corn stalks, manure and sewerage can be fermented and distilled to give ethanol. Both methanol and ethanol are directly burned as a fuel.

### e. Geothermal

Geothermal energy is produced when rocks lying deep below the earth's surface are heated to high temperatures by energy from the decay of the radioactive elements in the earth and from magma. Geothermal energy can be considered as renewable source of energy if deep underground heat flows can be tapped.

Geothermal energy can either be used for heating water, directly and space heating needs in agriculture and for domestic purposes or it can be converted into electricity.




*Source: (https://www3.epa.gov/climatechange//kids/images/4-1-5-geopower.gif)*
*Figure 10.189: Generation of geothermal energy*

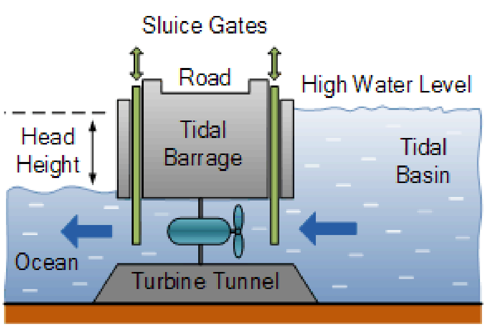
### f. Tidal energy

Tidal energy or tidal power is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity. Although not yet widely used, tidal energy has potential for future electricity generation.

As the tide rises and falls water flows into and out of bays and estuaries. If the bays and the estuaries can be closed by a dam the energy in the tidal flow can be extracted four times a day and used to spin a turbine to produce electricity.

Although all coastal areas are subject to some tidal changes, only those few areas with a large enough tidal range of some four to five meters are potential sites for tidal power plants. These sites are located for most part on both sides of North Atlantic, the English Channel and the Arctic coast of the C.I.S. a few developing countries such as Argentina and India also have some tidal power potential.

There are presently two tidal power projects: one in Commonwealth of Independent States (C.I.S) and the other in France.





*Source: Alternative Energy Tutorials © 2010 – 2018*
*Figure 10.190: Tidal Energy Syms*

Application activity10.1

i. Describe the sources of power and energy exploited in Rwanda.
ii. Indicate the main hydro-electric power stations in Rwanda.
iii. Suggest other alternative sources of power and energy that can be used in the world.
iv. What types of energy sources promote environmental sustainability?

## 10.2. Factors and importance of power and energy production in the world

Learning activity 10. 2

1. Describe the areas of power and energy production in Rwanda and showing the reasons of their geographical location.
2. What are the challenges that Rwandans would be facing if those areas identified above were not there?

### 10.2.1 Factors favouring power and energy production in the world

The following are the major factors influencing power and energy production in the world:

- Availability of market is a pre-requisite for the power and energy production. For example, densely populated areas, industrially and commercially advanced, have a great demand for electricity.
- Availability of capital to invest in power and energy production. Production of energy/power, setting up power houses, and transmitting electricity through wires to the areas of consumption require a lot of capital in terms of money.
- A high degree of technical knowledge and skills.
- The amount of energy to be produced depends on the potentiality of power and energy generator. For example, the amount of hydro-electrical power to be produced depends on the quantity of water and velocity of stream. The latter, in turn, depends upon the gradient of the stream.
- The natural environment of the area where the power and energy will be produced and transported such as the topography (e.g. nature of terrain and slope), climate (e.g. amount of rainfall, sunshine), hydrology (e.g. quantity and quality of water), vegetation (e.g. amount of biomass) affect the production of power and energy.

### 10.2.2. Importance of power and energy in the development of the world

Power plays a role in the development of a country in different ways such as:

- **Earns foreign exchange**: Energy can be exported in neighboring country and in that way, it is contributing to the earning of foreign exchange. The economies of many countries are depending on the production of petroleum which is the most used worldwide source of energy. For example, the DRC earns $40 million annually through exports of electricity from Inga dam plant.
- **Development of industrial sector:** The engine that moves the industrial sector is energy and without it the whole sector would ground to a standstill. Most industries use petroleum and its by-products to run the machines. Electricity is also used to run machines while wood fuel is used in various processing industries such as tea processing.
- **Development of transport sector:** Petroleum is used in road transport, water transport and air transport meaning that it is the basic element in transport.
- **Creation of employment opportunities:** The generation of electricity is offering employment to a good number of people.
- **Development of Agricultural sector:** Solar energy is used to dry grains and other produce such as tobacco, cocoa and coffee. Petroleum and its products are used to run water pumps and other agricultural machinery. Wind power is used in dry regions to pump water for irrigation.
- **Improvement of welfare of people in general:** Various forms of energy is used for various purposes such as cooking, lighting and heating. In the rural areas, the main sources of energy are firewood, charcoal and liquid petroleum. In Urban sector, charcoal, kerosene, liquid petroleum, gas and electricity are used.

Application activity 10.2

1. Describe requirements for Rwanda to fully exploit its available power and energy resources.
2. Visit your local industrial areas and identify the role of power and energy in an industry.

## 10.3. Problems and possible solutions for power and energy

### Learning activity10.3

Visit a power station in your environment and do the following:

i. Identify the problems of power production
ii. Suggest the possible solutions to the identified problems.

### 10.3.1 Problems hindering the development of power and energy in the world

The energy crisis is still experienced in different parts of the world. This is due to the following reasons:

- Coal has some inherent problems. Petroleum is not going to last long. Hydroelectricity has its own limits and nuclear energy has some political problems for it to be socially accepted worldwide because of the risks of its catastrophes.
- Overdependence on oil and its products. Many countries rely on petroleum and petroleum products in industrial, transport and agricultural sectors. It therefore becomes quite difficult to switch to other sources when there is a problem with the supply of oil.
- Economic and political embargoes fixed by the rich countries. For example, in 1973 the oil producing countries in the Middle East imposed oil embargo on USA because of its interference in the Israel and Palestine war.
- Increase in oil prices imposed by the Oil Producing and Exporting Countries (OPEC).
- Depletion of wood fuel due to overexploitation of forests.
- Exhaustion and deepening of coal mines. Coal is a non-renewable source of energy. Its continuous use leads to the deepening of the mines hence its exhaustion. Consequently, the cost of extraction increases leading to high prices of coal in the world market.
- Environmental pollution: Some sources of energy like coal and petroleum are sources of Carbon dioxide which is emitted in atmosphere. The increase of carbon dioxide in atmosphere leads to ozone layer depletion and climate change with their consequences.

### 10.3.2 Possible solutions for power and energy in the world

As the energy is used at a very high rate and people will continue to do so in the future, there is no doubt that it will be exhausted one day. Since our energy resources are limited, certainly there is a need to do something about it like:

- **Move towards renewable resources:** The best possible solution is to reduce the world's dependence on non-renewable resources and to improve overall conservation efforts. Much of the industrial age was created using fossil fuels, but there is also known technology that uses other types of renewable energies – such as steam, solar and wind. The major concern is not so much that we will run out of gas or oil, but that the use of coal is going to continue to pollute the atmosphere and destroy other natural resources.
- **Buy Energy Efficient products:** Replace traditional bulbs with fluorescent tube lights CFL's and light emitting diode (LED's). They use less watts of electricity and last longer. If millions of people across the globe use LED's and CFL's for residential and commercial purposes, the demand for energy can go down and an energy crisis can be averted.
- **Energy Simulation:** Energy simulation software can be used by big corporates and corporations to redesign building unit and reduce running business energy cost. Engineers, architects and designers could use this design to come with most energy efficient building and reduce carbon footprint.
- Government may come in and improve on public transport efficiency so as to reduce the need to use personal vehicles to reduce the use of petroleum.
- On the domestic front, energy conservation can be achieved by making electrical appliances like refrigerators, television, electric cookers more energy efficient. This can be supplemented by switching of electricity gadgets when not in use.
- Educating the public about the importance, the conservation and the sustainable use of energy resources.

### Application activity 10.3

This is an extract of an interview with Wilson Karegeya, a firm's director for commercial services, Rwanda Energy Group held with iPAD Rwanda Power & Infrastructure Investment Forum in Kigali.

This interview was conducted two months before splitting EWSA into WASAC and REG. Read it carefully and answer the questions related to it.

**Let's start with an update on the reform of the energy and water organisations in Rwanda.**

Rwanda Energy Group today was still EWSA two months ago. EWSA was the Energy, Water and Sanitation Authority, a government parastatal, which they thought splitting the organisation would ensure more efficiency, better and quick service delivery. So it was split two months ago,

forming two corporations: one for water, the Water and Sanitation Corporation, headed by a Managing Director. It was a department in EWSA and is now a standalone company and still 100% owned by government. There is also the Rwanda Energy Group (REG), which will specifically deal with energy projects. REG also has two subsidiaries, the Energy Development Corporation Ltd and the Utility Corporation. The Energy Development Corporation will mainly

**What do you hope to achieve in the next 12 months?**

We have now embarked on asset separation; EWSA had a lot of assets that need to be shared between the water company and the electricity company. There are issues of accounts and fixed assets like land and buildings that need to be split and shared. That is what the new companies are doing right now. We are being assisted by Price Waterhouse and some other specialised companies to make sure the reform is done well for better service delivery.

And we expect, of course, more specialisation for these companies. The water company will now specialise in making sure that they deliver clean water to the population. They will be less distracted because they will be mainly focused on providing clean water. And the electricity company will now not be overstretched, looking into water and electricity but looking specifically into electricity projects, so I expect more focus for these companies that will lead to better service delivery.

**The energy projects that you will invest in, can you highlight specific challenges and how**

you will overcome them? One challenge is that we were used to government investments where government invests in energy projects. We have now adopted an approach to involve the private sector more in the generation phase of it: where we identify projects that need to be developed, advertise them, attract private investors, (IPPs) and negotiate the power purchase agreements with them, once we agree and sign the contract, the project is up and running. Where I see challenges is in the contract management. It is an issue that we are not used to working with IPPs. Although you sign a PPA with an independent power producer, it is more about managing the contract from day one up to the last day of the contract. So that is a challenge there but we hope to overcome it by training our staff to make sure they know how to deal with IPPs, know what to expect and when and what the IPP has to deliver. That is very important.

**In terms of generation capacity in Rwanda, what is currently available and how much are you projecting?**

Currently we are at 110 megawatts capacity and we expect to generate up to 563 megawatts by 2017. That is the target we have. There are on-going projects that will enable us achieve this targeted megawatts and some are nearing completion. We have also taken the direction of utilising the regional interconnectors to be able to share power with the neighbouring countries. We are currently negotiating a PPA with Kenya aiming at purchasing power from Kenya through Uganda.

**Power generation goes hand in hand with other infrastructure development such as roads,rail etc. what are the plans there?**

In the transmission sector we have also started using private developers. We recently advertised a tender to attract investors to come and do the transmission lines and improve the networks as we expand the capacity. Of course, there is a need to improve the network, so we are doing that concurrently. What is a day like in Rwanda in terms of electricity supply? Until recently there weren't many power outages in Rwanda. But now industry is growing and the demand for energy is growing and we are striving every day to increase the capacity to serve all our customers, be it investors, industrial or domestic. Of course, you get investors who come to us saying —I want 5 megawatts, I want 15 megawatts, I want up to 10 megawatts‖, so you have to work hard to make sure you use all the resources available to provide such electricity.

A recent example is a new cement factory that has asked for up 15 megawatts, and we have a total capacity of 110 megawatts for the whole country. So you can imagine how hard we have to work. The good news is that we have secured the power the factory requires.

**Who looks at tariffs and the regulation around tariffs?**

It is RURA (the Rwanda Utility Regulatory Agency). But if we are attracting investors for projects above 5MW, we negotiate a tariff. For projects below 5 megawatts, there is a feed in tariff set by RURA. For big projects, Rwanda Energy Group negotiates with the developer and agrees a tariff at which it will supply electricity.

**What is the situation with residential access to power?**

For now, the residential users are connected and satisfied. The challenge we are facing is the new industries that are emerging. Otherwise the domestic customers had no issues so far. Perhaps they might have to start competing for the insufficient power that we have – to share this among the commercial and domestic clients that we have. But we are working very hard to bridge the demand gap that is growing day by day.

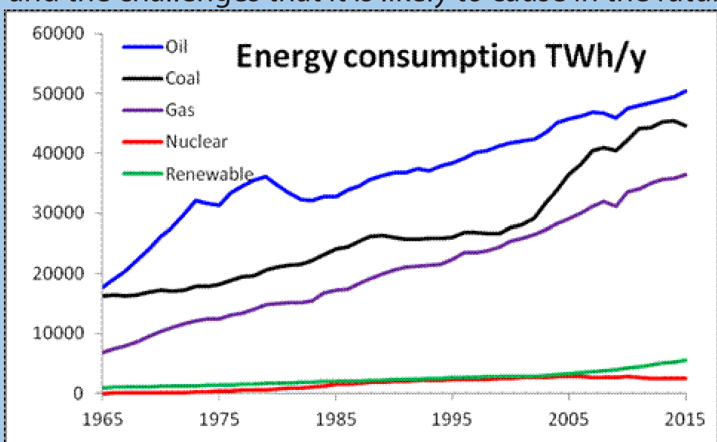
**What do you see happening in the East African region in the next five years?**

My personal view is that if the current trend of cooperation among the East African member States continues, I see success. When I look at the engagement between member countries, sharing power, that is success. When I see the opening of borders for trade, that is success, and opening of borders for human capital, that is success. If this trend is maintained I see a powerful East African Community.

*Extracted from: ESRI AFRICA: AFRICA'S POWER JOURNAL, Published on September 10, 2014*

## End unit assessment

1. Assess your district infrastructures and suggest the potential power and energy sources to be exploited
2. If you were the chairperson of African Union propose appropriate strategies for sustainable power and energy development in Africa.
3. Account for the status of power and energy production in the world.
4. Basing on relevant examples or case studies, explain how energy resources contribute to the development of some countries. What about Rwanda in that regard?
5. Analyze the figure below and discuss the trend of the use of energy in the world and the challenges that it is likely to cause in the future.



# UNIT 11

## INDUSTRIALIZATION IN THE WORLD

# UNIT 11: INDUSTRIALIZATION IN THE WORLD

## Key unit competence:

By the end of this unit, I should be able to evaluate the success of sustainable development projects in the industry in different parts of the world.

### Introductory activity:

Mr. Gatete is a farmer, he grows crops like coffee, cotton, bananas and fruits and rears cows and goats. He sells both crops and animal products to Amahoro Cooperative Society which transforms these products into Juice, Packed milk, Cheese, Clothes etc.

1. According to you, in which category of industry does Mr. Gatete belong to?
2. Explain the factors on which Amahoro Cooperative Society base on to establish the factory which transforms Gatete's products and the problems that may be associated with the factory.
3. Make research on internet and find out five examples of more industrialized countries in the world and describe the factors for their industrial development.

## 11.1. Definition, classification of industries, factors influencing location of industries and major industrial regions of the world

### Learning activity 11.1

Use experience from your local environment and answer the following questions:

1. Identify the categories of industries observed.
2. Describe the factors that influenced their location.

### 11.1.1. Definition of industry

**An industry** is an establishment that involves production of goods and offering of services. It also refers to the processing of raw materials into finished goods.

**Industrialization** refers to the concentration or to the development of industries in an area, country or region.

### 11.1.2. Classification of industries

There are three categories of industries which are closely interrelated.

- **Primary** / Extractive industries

These are industries which produce raw materials. They are concerned with the extraction of natural resources. They involve agriculture, forestry, mining and fishing.

- **Secondary** / Manufacturing industries

These are industries that transform raw materials into finished products suitable for consumption. They include food, beverages, chemical products, etc.

They are subdivided into two categories:

- Heavy industries: Such as engineering, metal goods, chemical, ship building industries, etc.
- Light industries: Such as food processing, plastics, textiles, electrical equipment, cosmetics and toilet articles etc.

- **The tertiary** / Service industries

These are industries involved in the provision of services. The tertiary industries do not produce goods but provide backup services to the industrial sector. The services provided include transport and communication, trade and commerce, financial insurance, printing and publishing, education, health, banking, etc.

### 11.1.3. Factors influencing the location of industries and industrial development

There are several factors, including physical, economic, political; historical that influence the location of an industry. A brief description of these factors is shown below:

- Efficient labor: An adequate or skilled labor force is essential in the initiation and continuance of an industry. It gives the company a maximum output with lowest possible costs.
- Power and energy: Any industrial establishment must be located in the areas with enough fuel or other sources of energy.
- Land: The location of any industry requires extensive land for set up and future extension.
- Government policy**:** Government's policy of encouraging industries is also an important factor. This can be done through tax reduction, giving land and energy to investors to establish industries in the areas. This is done for economic and political reasons e.g. job creation and regional balance.

- Raw materials: Raw materials in their different forms are important in the location of industries. Therefore, the availability, the value, size, quantity, quality, weight and proximity of the raw materials are essential requirements for industrial location.
- Transport and communication: Modern industries require constant supplies of raw materials, often in great bulk from various sources. Finished goods have to be distributed to many places also. Thus the availability of a good network of transport facilities is another important factor in the location of industries.
- Market: There is a very strong justification for industries to be located near the markets which consume their finished products. Some types of industries are more likely to be located near markets than others; e.g. perishable goods, fragile goods, bulky goods etc.
- Capital: No industry can be developed unless it has financial support. The finance may be provided by private investors, large companies, or by the government. Capital is required in every phase of industrial development. Money is required for the purchase of the land , construction of factories, purchase of machines, acquisition of the required raw materials, transportation of both raw materials and finished goods and for the payment of wages, marketing, advertisement, etc.
- Water supply: Certain industries, especially iron and steel, aluminum smelting, thermal power generation, pulping of timber, synthetic fibre manufacture and chemicals, consume enormous quantities of water either in processing the raw materials or for cooling purposes.
- Industrial inertia: This is when an industry remains in its original location even if the initial advantage that led to its location is no longer available. This is due to three main factors:
    - The presence of a good transportation network of roads, railways, canals and so on. An industry moving to a new site might face transportation difficulties.
    - Influence of skilled labor and experienced workers built up in that area.
    - The cost of building and equipping a factory is extremely high. Industrial establishments do not readily undertake a complete move with the new building and tooling-up costs that this entails.
- Sites: Some industrial plants have to be sited on leveled ground instead of hilly regions. Others require vast acreage of land and the cheapness of the available land is a primary consideration.
- Climate: Climatic factors sometimes have to be taken into account especially in countries with extremes of climate. Costs of heating, air conditioning factories or offices may be prohibitive. Hot climate may create problems of storage. Climatic factors such as severe winters or annual floods may affect transportation adversely.

- Political stability: encourages long term investment necessary for industrial development. This is why countries with little political instability like Western Europe are advanced in industrial development than developing countries of Africa and Asia.

#### 11.1.4. Major world industrial regions

There are major industrial areas in both developed and developing countries. Japan, USA, and Russia are the example of industrialized countries in developed countries, Egypt, South Africa, China and South Korea in developing countries.

**Application activity 11.1:**

1. Describe the categories of industries common in Rwanda.
2. Visit the industries located in your area and describe the factors that led to their location..

### 11.2. Importance of industries and problems affecting industrial development

**Learning activity 11.2**

According to you, why is it important for a country to have industries?

#### 11.2.1. Importance of industries

Industries have the following advantages:

- Industries provide self-sufficiency in essential goods rather than the need for imports and dependency on foreign aid. In other words, it causes import substitution and export promotion, which encourages development.
- Self-sufficiency gives greater political and economic strength. It makes a country more independent of foreign political or economic domination.
- It creates employment. It employs both skilled and unskilled labor.
- Industrialization earns the country foreign exchange. If the products are manufactured for export, the value of the commodities is increased and so the revenue obtained from their sale also increases.
- Industrialization raises living standards of the population as they contribute to increase their income.

- It contributes to the diversification of the economy and reduces reliance on agricultural products which may fluctuate in prices.
- Industrial growth is cumulative and can stimulate growth in other sectors of the economy.
- It provides infrastructure particularly electricity, transport and communication.
- Industries also improve social amenities like schools and hospitals.
- It contributes to the development of research and technology and the regular training of skilled man power.

### 11.2.2. Problems affecting industrial development

There are several problems that affect many industries. Below are the main and common ones:

- Inaccessibility to the distant world markets which results into low demand for the manufactured goods especially in landlocked countries.
- Lack of real capital investment. Many countries have a problem of inadequate funds to set up industries.
- Shortage of unskilled, semi-skilled and skilled labor. Inadequate managerial and entrepreneurship skills have also affected industrial growth.
- Lack of adequate supporting infrastructure. This is critical for the development of industrial activity.
- Developed countries face the twin challenges of reduced demand and increased unemployment levels in older industries as well as finding new market for their industrial output.
- Competition for markets has led to blocks of countries grouping to reduce trade barriers and to increase integration of supply and demand. Such trade agreements allow individual countries to take advantage of agglomeration economies and cheap labor among themselves. However, for countries outside the trading block, they act as barriers to trade and tariffs.
- The infrastructural facilities in the developing countries are not at the level necessary to produce and support industrialization.
- The shortage of valuable minerals in some countries, such as iron ore which form a basis for the establishment of industries. These countries have to import raw materials at high costs.
- In developing countries, poverty lead to a low demand for industrial goods resulting into a limited market, thus affecting the process of industrialization.

Application activity11.2:

Explain why the industries in developed countries are highly developed than the ones in developing countries.

## 11.3. Problems resulting from industrial development and ways to mitigate them

Learning activity 11.3

Why is it not advisable to live near industrial areas?

Industrial development has both positive and negative effects on a given country.

- Pollution of the environment: In the areas of heavy industrial concentration, land, air and water are contaminated by industrial wastes.
- Wildlife Extinction: Industrial pollution affects habitats of wildlife and destroys its species; it is hard to recover them in the environment. For instance, major industrial accidents like oil spills, fires, leak of radioactive materials cause great damages.
- Global Warming**:** With the rise in industrial pollution, global warming has been increasing at a steady pace. Smoke and greenhouse gases are being released by industries into the air and this contributes to global warming. Melting of glaciers, existence of floods, tsunamis, hurricanes are some of the effects of global warming.
- The accidents caused by the machines used in industries: The machines used in industries for various purposes may cause the accidents from the misuses by the employees or from other external causes; e.g. Lightening, tsunami, electricity, collapses of mining tunnels, etc.
- Leaching of resources from the environment: Industries do require large amount of raw materials to process into finished products. This requires extraction of minerals from beneath the earth. The extracted minerals can cause the environment destruction in different ways.

Ways to mitigate the problems caused by industries

- Isolation of industries from settlements and sources of water to reduce the effects of pollution.
- Reducing of greenhouse effects through neutralizing industrial fumes before they are disposed into either air or water.

- Efforts should be made to control pollution. These can take the form of industries treating their wastes before disposing them as well as recycling some of those waste products and the use of biodegradable materials.
- Promotion of training skilled manpower and use of appropriate technology to reduce accidents in industries.
- Creation of special areas/ zones where industrial wastes are channeled or poured.

**Application activity 11.3:**

Examine the ways of reducing problems caused by industries in developing countries.

## 11.4. Case studies on major industrial regions in the world

**Learning activity 11.4**

Make research and identify the major world industrial regions.

### 11.4.1. Developed countries

#### a. Industrialization in USA

**i.** Factors for the high level of industrialization in USA

USA is the world's leading industrial nation. About four-fifth of the industrial output of North America is contributed by the United States alone. The factors, which helped in the industrial development of USA, are:

- A wide range of raw materials such as agricultural raw materials and mineral raw materials.
- The population of USA was made up of immigrant from many advanced European countries especially from U.K, France, Germany, Holland and others. These immigrants brought with them the experience skills and technical knowhow of their mother countries. This encouraged rapid industrial development.
- USA is located on the opposite side of Atlantic from Europe. This has stimulated trade and growing world markets. It has also led to industrial expansion.
- USA has extended water transport from St. Lawrence Seaway to the heart of

the continent via the Great Lakes. This has stimulated industrial development by providing cheap means of transport for raw materials and finished goods.

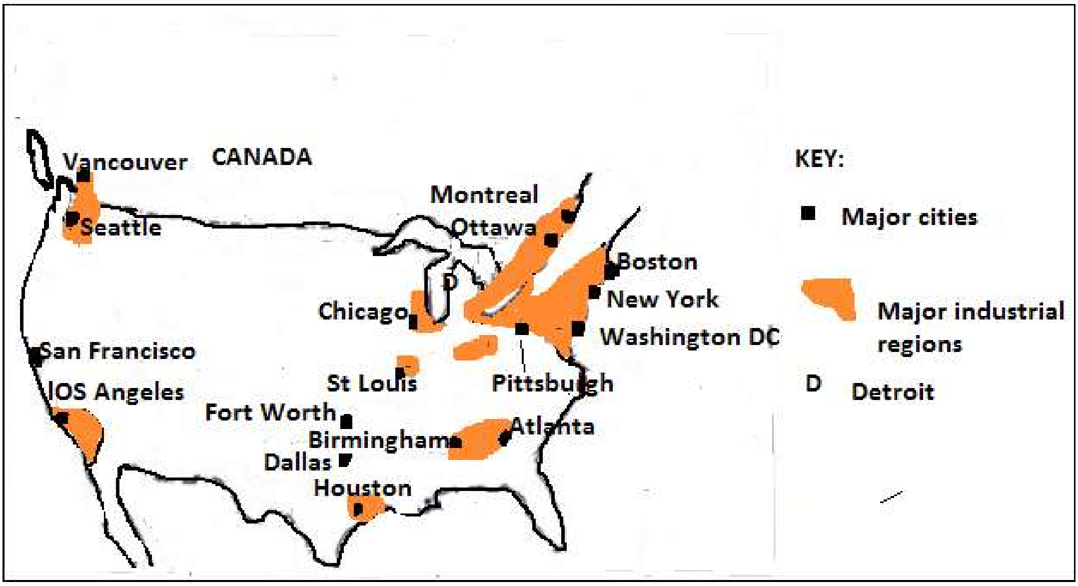
- USA has a high level of technology. This has been maintained by adequate educational and training facilities and a technological system. This system attracts skilled scientists and technologists. This brain gain helps to give the USA a lead in scientific modern industries such as electronics computers and so on.
- USA has abundant petroleum, natural gas, local and hydro-electric power. The availability of various sources of power in economic quantities has stimulated the development of large manufacturing industries.
- Availability of capital generated from international trade (from exports) encouraged industrialization.
- The government of USA also encourages rapid industrialization. It encourages export promotion.
- There is internal competition among the industries and this has stimulated industrial development.
- Availability of extensive land for industrial development.

**ii.** Industrial regions of USA

There are six industrial regions in USA:

1. Southern New England: It is centered in Boston with two types of industries; shipbuilding and textile,
2. Mid-Atlantic States: This region includes cities of New York, Philadelphia and Baltimore. The industries here include iron and steel, engineering, printing, electrical goods, foot wear and consumer goods.
3. Pittsburgh – Lake Erie region: this is the core of heavy industries, engineering, glass, pottery, chemicals, synthetic, rubber, tyre making, generating hydroelectric power from Niagara Falls, flour milling etc.
4. Detroit industrial region: this is the greatest automobile manufacturing region of the USA. Other industries include electrical wires, glass, batteries, paints, alloyed steel etc…
5. South Appalachian region: It is centered in Birmingham. Industries include steel making, Hydro Electric Power generation, cotton textiles, metal works, machinery manufacture etc.
6. Eastern Texas: It has major cities like Dallas, Fort Worth and Houston. This region is the major USA source of oil and gas.

Major industrial regions of USA




**b. Industrial development in Japan**

i. Factors for high level of industrialization in Japan

Japan is the most highly industrialized country of Asia and ranks among the main industrial nations of the world. Despite its shortage of industrial raw materials, Japan has been able to develop her industries because of the following reasons:

- Development of hydro – electric power resources to provide enough power to support rapid industrial development because of little quantity of coal.
- Efficient use of its limited raw materials such as copper, manganese, iron ore, sulphur and timber.

- The coastline and many large ports facilitate the importation of large quantities of raw materials from all over the world. This is because of the geographical location of Japan.
- The population that provides a large supply of labor and the development of industries since it has small land for agriculture.
- The government that encourages industrial development. It has formulated a technically based education system. This has improved the country's technological development
- A high and expanding market potential. It is located near Asian countries

which are mainly agricultural dependent. These provide market for Japanese goods

- Aid from USA: after the Second World War, Japanese industrial establishments were destroyed. It got financial assistance from rich countries specifically the USA. These loans were used to replace and rebuild the ruined industries
- Advanced technology: Japan adapted latest techniques from Western industries and have been able to improve upon them
- Improved transport network: water transport, modern ports were build, roads and railways were improved.

ii. The Major industrial regions of Japan

Japan is the most industrialized country in Asia and ranks among the industrial nations of the world. There are four main industrial zones in Japan:

- **The Keihin Region:** This is the most industrial region in Japan located on the Kwanto plain to the East of HONSHU. It is formed by the conurbation of three important towns; Tokyo, Kawasaki, and Yokohama. This region has 20 % of the Japan's population and account for 33 % of the country's output. The major industries found in this region are Chemicals, machinery, textiles, food processing, furniture. Each town in the region specializes in a particular item. Tokyo is noted for electrical engineering (especially Television sets, refrigerators, washing machines and computers.) Yokohama has precision engineering, shipbuilding, oil refining, petrochemical products and port industries. Kawasaki is renowned for marine engineering, cement works and glassworks. The manufacture of iron and steel products is centered on Chiba.

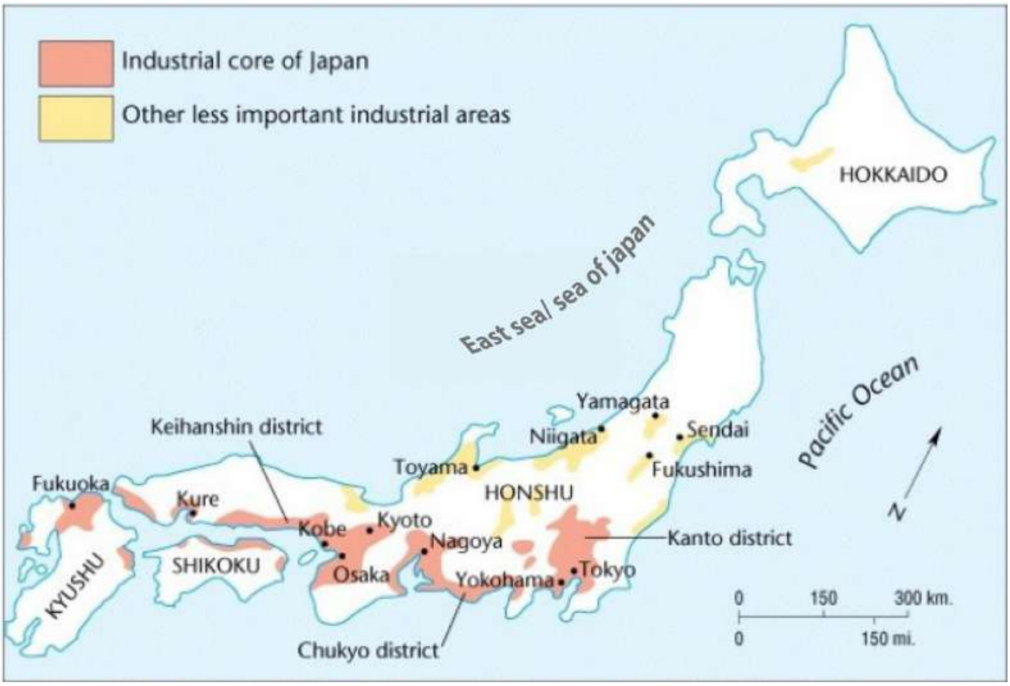
- **The Hanshin Region:** this stretches across a great industrial conurbation of three major cities formed by Osaka, Kobe and Kyoto. It accounts for about 20 % of Japan's industrial output. It is important for the manufacture of textile, iron, and steel products, handcrafts, and shipbuilding. Osaka is the greatest textile industry. Plastics, footwear and textiles machines are also made. Kobe concentrates on shipbuilding, oil refining, and petrochemical industries. Kyoto is important for the manufacture of crafts, toys, and oriental (Asiatic) ware.

- **The Ise Bay Region:** this is the third industrial region dominated by NAGOYA industrial Region on the Nobi Plain with a wide range of manufacturing industries including textile mills that process local silk, imported cotton , wood and also synthetic fibres ; engineering industries including all kinds of machinery , automobiles ,locomotives and aircraft . The nearby towns of Tajimi and Seto are noted for musical instruments such as guitars, violins and pianos are mass-produced at Hamamatsu.

- **The Kitakyushu Region:** in the northern Kyushu area, the Chikugo coalfield and good accessibility gave rise to a conurbation, called Kitakyushu. This one, embraces several towns, including Yawata, Kokura and Moji. The industrial area extends southwards to Fukuoka and Nagasaki. It makes steel, ships, machine parts, chemicals and textiles.

Apart from the above four major industrial regions, there are several scattered industrial towns. Iron and steel are made at Muroran, oil refining is important at Akita and Niigata, engineering at Hiroshima, shipbuilding at Kure, and textiles at Okoyama, Hakodate and Sapporo in Hokkaido are also industrially developed.

**Major industrial regions of Japan**




*Source: https://www.google.com/industryinjapan&source*

## c. Industrialization in Russia

i. Factors for high level of industrialization in Russia

- Presence of a variety of minerals such as Iron, copper, gold, diamond, coal etc.
- Improved transport network of railways, aircrafts and developed road network.
- Existence of agricultural raw materials such as cotton for textiles, milk for dairies, hides and skins for leather and footwear industries.

- Availability of capital from financial institutions to promote industrial development.
- Improved research to develop cheap and highly efficient methods of production. This has led to technology and industrial development.
- Government policy of promoting self-sufficiency in most of the manufactured goods consumed in the country.
- Attraction of foreign investors from Europe, Japan and USA has greatly contributed to industrial development.
- Presence of a large population which provide a large domestic market and cheap labor force.
- Skilled labor in form of electrical, mechanical, chemical engineers, laboratory assistance.

ii. Industrial regions of RUSSIA

The Russian industries are concentrated in the four major areas:

1. The Moscow – Gorki region: this region has diverse industries including heavy engineering, steel industries, railways, equipment, automobiles, aircraft and food processing.
2. The Ukraine industrial region: This region has developed during the period of USSR (Union of Soviet Socialist Republics) the main industries are iron and steel, making machinery, chemicals, etc.
3. The Urals industrial region: engineering (heavy) and metallurgical industries dominate all other activities,
4. The Kuzbas region: This area has large thermal plants, extensive coal deposits, engineering, hydro-electric power plants, metallurgical plants, chemicals including petrochemicals.

## Major industrial regions of Russia


### 11.4.2. Developing countries

#### a. Industrial development in China

Industrial development in China began after the beginning of Communist rule in 1949, and now China is an art industrial power of Asia and of the world. There has been a complete transformation of the industrial system during the last 60 years.

Under the new system and policy, China is developing its industrial system in a planned manner. Rapid development has made China a leading producer of iron and steel, textiles, and cheap consumer goods such as toys, household goods and light metal goods.

i. Factors for industrial development in China

- Large quantities of natural resources: They constitute the raw materials for industries such as coal, copper, zinc, lead, and manganese. This has given rise to industries dealing in copper processing, steel products, electrical equipment etc.
- Deposits of coal and petroleum**:** They act as a source of energy for the industries. Coal is the single most important energy source.
- Large population**:** With over 1.3 billion people, China has large domestic market for its industrial goods. Chinese manufactured goods have a ready market even in other countries like USA, Japan, UK, and the European union.

- Location of China: On the Asian main land and the most populated continent provides the market for manufactured goods, the promotion of trade and procurement of raw materials.
- Government policies: Communist system has great influence on the development of industries where each commune was encouraged to have its own industries.
- Education: Chinese system provides the basic skills on practical knowledge required in industries and workshops.
- Cheap labor force: With a large population, China has a big labor force which is cheap, skilled and unskilled. China has a largest labor force in the whole world.
- Transport and communication systems: Aircraft is developed to communicate with the entire world and railway transport is improved for acquisition of raw materials and distribution of manufactured goods. Also the country has navigable inland water ways but has been improved by construction of canals.

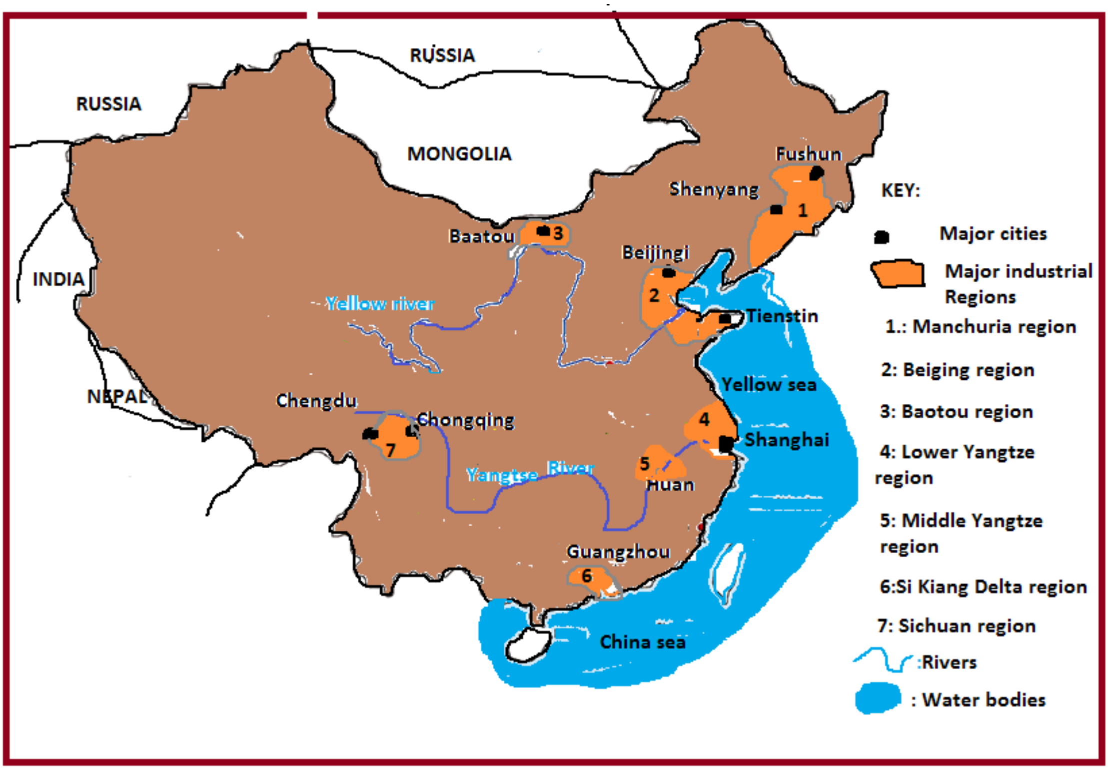
ii. Industrial regions of China

- Manchurian Industrial Region: This is the most important industrial area of China with centers at Anshan (steel industry), Penki (steel industry), Fushun (coal, lubricating oil, and chemicals), Mukden or Shenyang (machinery and tools) and Dairen (mills and shipyards). All of them are nearby coal and iron ore deposits. Anshan, Fushun and Shenyang form a triangle, within which there are numerous large plants.
- Tientsin and Beijing Region: This is a second industrial area located at the northern end of the North China Plain, near the Kailan coal reserves, with Tientsin, Peking or Beijing and Tangshan as its main centers. The presence of coal-fields in Shansi and Hopei has contributed to the rise of the metallurgical and engineering industries here.
- Lower Yangtze Industrial Region**:** This is China's oldest industrial region. It existed since the middle of 19th century. Shanghai is the main industrial town and port of this industrial region. The main goods produced are cotton, silk, textile, food, leather, radio, television sets, utensils, leather, etc. There are also shipyards, oil refineries, flour mills, steel plants, metal works and a great variety of light industrial products.
- The Middle Yangtze Industrial Region**:** It is located on the middle Yangtze plain around the former tree towns of Hankow-Hanyang-Wuhan. There iron and steel works there that are based on Peninsiang coal and Tayeh iron ore. Shipbuilding, metallurgical and heavy industries, railway equipment and chemicals are important items of production.

- Sichuan (Szechwan) Industrial Region: Sichuan (Szechwan) province above the Chang Jian (Yangtze Kiang) gorge has many important industries around Chongqing (Chungking) and Chengdu (Chengtu).The rich deposits of coal, iron, Ferro-alloys and abundant agricultural raw materials have all encouraged industrial development. Iron and steel, textiles, paper and pulp, machinery, cement, and chemicals are made here.
- Si Kiang Delta Region: **T**he port of Canton is the main industrial centre at the mouth of the Xi Jiang (Si Kiang). Canton lacks local raw materials and once was known largely for commerce. Modern industries are centered on silk production; there are silk mills, jute and cotton goods are manufactured, rubber is processed, and there are food-canning and match factories. Iron works and machine factories occupy sites near the docks.

In China, many cities are considered to be the industrial cities. Some towns such as Anning, Kiuchuan (iron and steel); Yumen and Hangzhou or Hangchow (oil refining); Lanzhou or Lanchow (chemicals, textiles, mining equipment) and Kunming (chemicals, machinery,textiles) have industrial development**.**

Major industrial regions of China



### b. Industrial development in South Korea

i. Factors for industrial growth in south Korea

- Highly skilled labor force: The education system provides basic skills required in industries and workshops. There is highly trained labor force in managerial and marketing which help the country to compete with other countries.
- High technology: In industries, microelectronics and computers which keep in touch with scientific advancement.
- Government support**:** Policies aiming at export-oriented industries, rather than to supply the local market.
- Agricultural development: The country is self-sufficient in rice growing with large schemes of irrigated land this has made the rural economy more efficient.
- Many business people: Companies or businessmen from Europe, USA, Japan who had the capital and skills to build industries have been attracted by low wage rates in South Korea.
- Infrastructural development: Well developed transport and communication network which makes the exportation of goods very easy.
- Research: This is highly emphasized especially in electronic industry, so as to improve all the existing products and develop new products to meet the market demands.

ii. Major industrial regions of South Korea

- The major industrial regions of South Korea are: Seoul, Yeosu, Chongju, Gwangju, Masan (Changwon), Ulsan, Pohang, Taejon, Busan, Yongdimpo.

- The major industries found in these regions are Iron and steel, petrochemicals, ship building, agricultural equipment, machinery, electronics, textiles and light industries.

**Major industrial regions of South Korea**


*Source: https://www.google.com/industryinkorea&source*

### c. Industrial development in Egypt

In the 1920's, the Egyptian economy was characterized an agricultural economy. Three quarters of the Egyptian exports was raw cotton. As a result, industrial output was mainly cotton spinning and weaving, followed by preserved food, cigarettes, soap and handicrafts

i. Factors for industrial development in Egypt

- Availability of raw materials: Egypt has agricultural raw materials to feed the industries like cotton for textile and sugar for agro-based industries.
- Availability of minerals: Egypt has various mineral resources such as oil, Iron, Zinc, Copper, Lead, phosphate that lead to the development of industries.
- Availability of power and energy: Egypt has the cheapest source of fuel (HEP) due to Aswan High Dam which allowed the connection of most Egyptian villages to use electricity.
- Internal market: Egypt as one of the most densely populated countries in Africa, its population is the ready market for manufactured goods.
- Availability of water**:** Despite that Egypt is a desert country; it has high strategies to use available water from the Nile River. Water is used as a raw material in food processing, construction, cooling machines and other industrial activities.
- Improved transport: Water, canals, roads, and railway, provide the cheapest water transport cost of raw materials and finished goods.
- Relief: The gentle relief of Egypt enables the construction of industries and transport routes which facilitate the development of industries.
- Government policy**:** The government is currently adopting an industrial policy that entails large-scale privatization of state owned enterprises as well as the gradual removal of subsidies and price controls in the remaining public sector companies.

ii. Major industrial regions of Egypt

**1. Cairo:**

It is the industrial centre of Egypt with textile industries, food processing, motor vehicle assembling and chemical industries. There are also Iron and steel industries located at Hulwan near Cairo city.

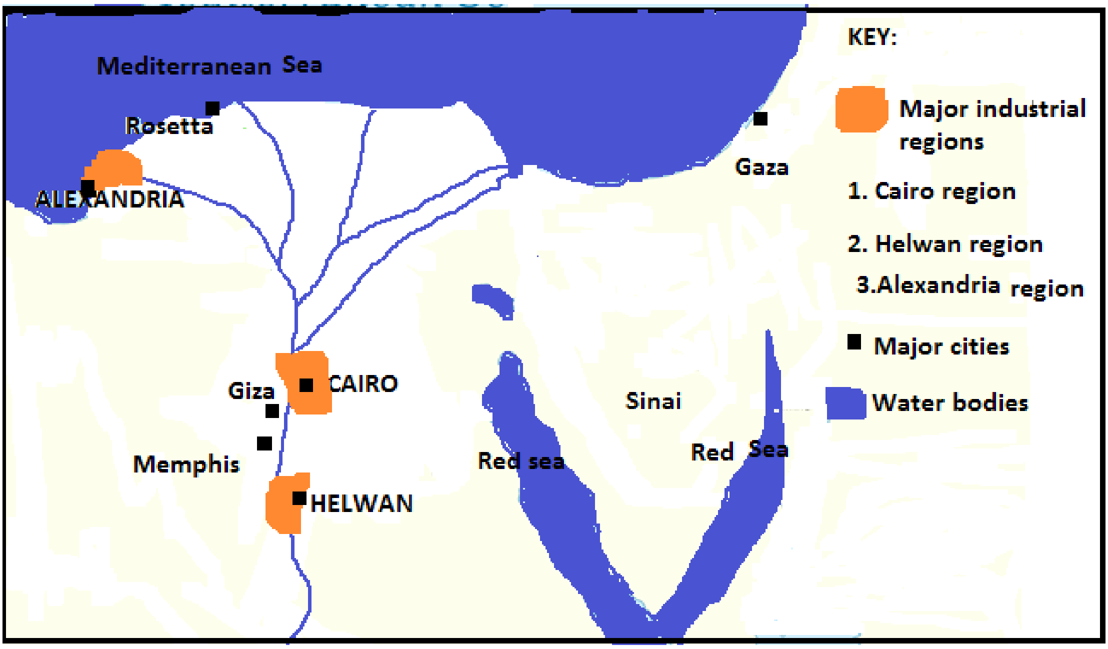
**2. Alexandria:**

It is the main industrial centre in Egypt as well as the country's largest sea port. It has agricultural, textile and chemical industries etc.

**3. Helwan industrial area:**

It is found on the bank of river Nile with several industries mainly the agricultural industries, sugar, gases and steel industries.

**Major industrial regions of Egypt**




### d. Industrial development in South Africa

South Africa is the most industrialized country in Africa. Today South Africa exports a large amount from manufacturing sector. Two thirds of South Africa's national outputs are derived from manufacturing industries.

i. Factors for industrial development in South Africa

- Large quantity of mineral resources: South Africa is endowed with a wide range of mineral resources which constitute raw materials for industries. The exploitation of minerals has stimulated industrial development.
- Presence of energy: The most important of this is coal. There are also numerous rivers, which produce hydro-electric power. Such rivers include orange, the Transvaal River and others.
- Climate: Ranging from the temperate climate, Mediterranean, desert and tropical climate. The variety of climate contributes to a wide range of agricultural products, which form the raw materials for many industries.
- Forest resources: contribute to the development of sawmills, furniture making and manufacture of paper industries.
- Fish resources: South Africa has one of the most developed fishing industries on the Africa continent. This has given rise to fish canning, freezing, fishmeal and fertilizers industries.
- Labour: Abundant labor supply.

- Market: Large market for its finished manufactured products.
- Capital: Enough capital to invest in Industries.
- Transport and communication: Good transport and communication networks.
- Government policy: Encouragement from the government.
- Land: Availability of land for industrial location and extension.

ii. Major industrial regions of South Africa

**1.** Johannesburg: The main industries found here are textile industries, chemical industries, paper and printing, engineering, electrical equipment, saw milling etc.

**2.** Springs: The major industries in this town include manufacturing of mining machinery, electric goods, printing machinery, sheet glass, paper and food canning industries.

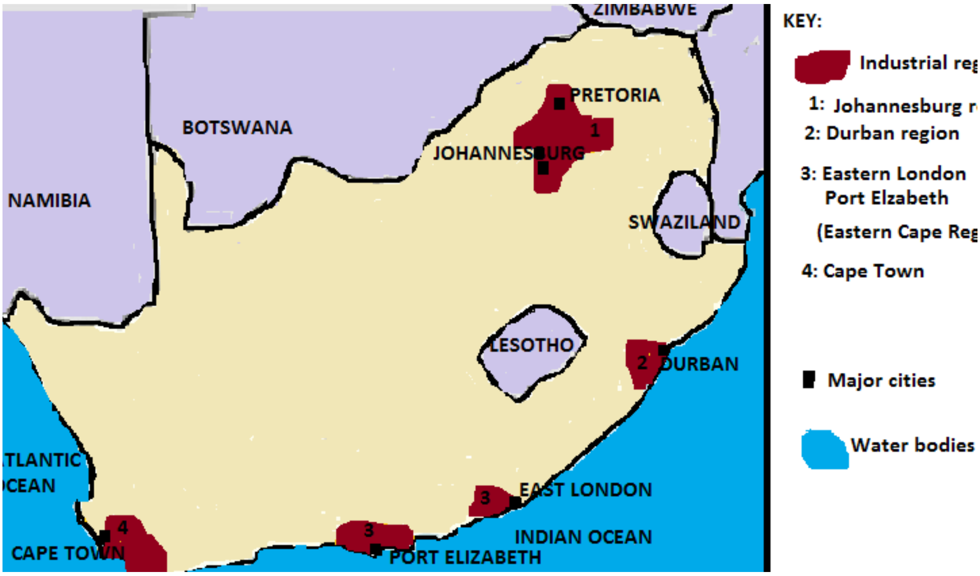
3. Durban: Industries in this region include ship repairing, oil refining, soap manufacture, textile, light engineering etc.

4. Cape Town: It has food processing, textile, chemical, paper and printing etc.

5. Pretoria: industrial establishment include glass, cement, metal working, manufacturing railway wagons etc.

6. Eastern Cape Industrial Zone**:** Is formed by East London and Port Elizabeth. It is the important port for international trade. It produces building material, soft drinks, furniture, clothes, local agricultural products etc.

Major industrial regions of South Africa




## Application activity 11.4

1. Compare the factors that have led to the development of industries in Japan with those of South Africa
2. Analyse the economic importance of industrialization in these countries:

   a. USA

   b. Egypt

   c. Russia

## End unit assessment

Make a field trip in any industrialized area around your area and answer the following questions:

1. Discuss the physical and human factors influencing location of industries in an area.
2. Describe how industrialization contributes to sustainable development.
3. Analyse the ways of improving the level of industrialization in developing countries.

# UNIT 12

# TRANSPORT AND COMMUNICATION IN THE WORLD

# UNIT 12: TRANSPORT AND COMMUNICATION IN THE WORLD

## KEY UNIT COMPETENCE:

By the end of this unit, I should be able to analyse the impact of transport and communication projects on the sustainable development of different countries in the world.

### Introductory activity:

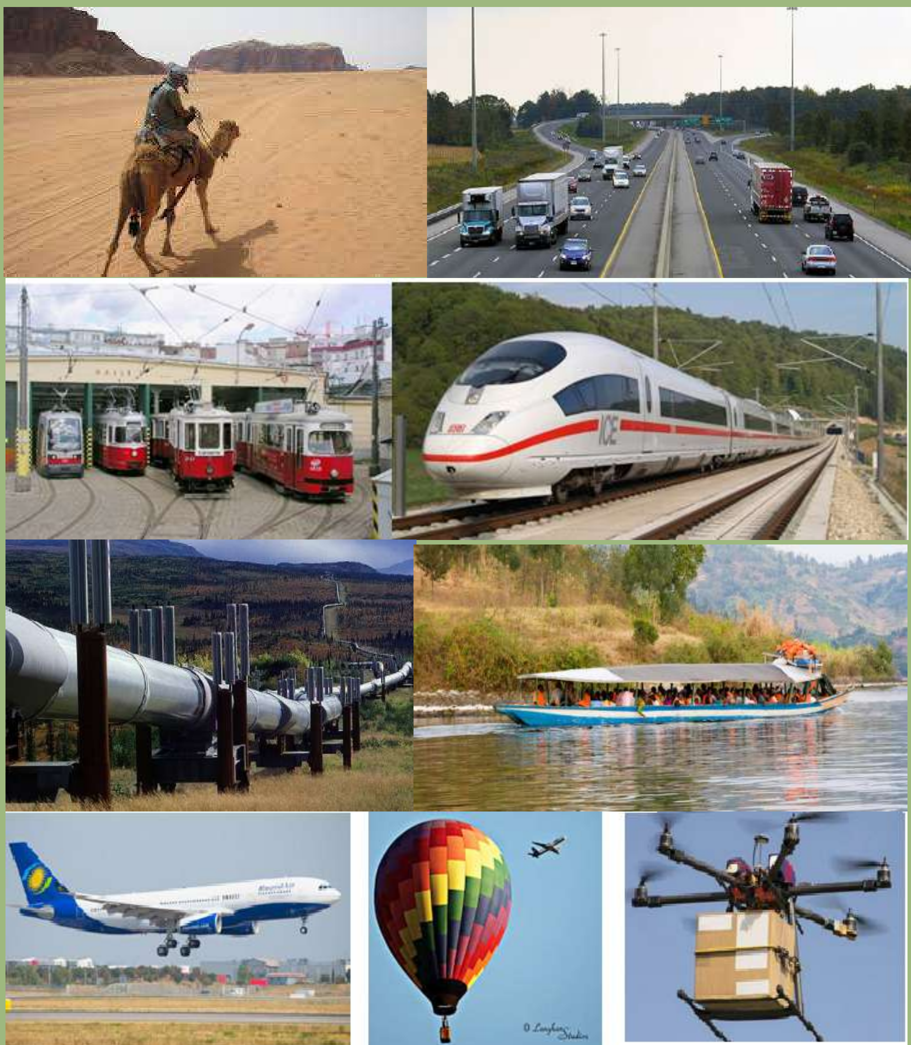
Read the passage below and answer the following questions. In eastern province of Rwanda there is a high production of banana. Mr. Gatabazi imported a lorry to help the people to carry their harvests to the market instead of using their heads. Gatabazi extended his businesses and became a businessman in the city of Kigali. He started to import his products from China. Sometimes he goes there to purchase goods or calls his partners using his mobile phone, then orders his goods, and pays using his BK Visa card, and finally gets his goods without moving from Rwanda to China.

What types of transport mentioned are above?

1. Explain the economic importance of the transport that Gatabazi introduced in that area.
2. Describe the types of transport that he uses to import goods from China.
3. What form of communication that he uses to get his products?
4. Mention other types of communication he can use to order for his goods.

## 12.1. Transport
### 12.1.1. Meaning and types of transport

Learning activity12.1



1. Observe the above photographs and identify the types of transport shown.
2. Which type of transport is common in your area and why?

The term **transport** refers to the movement of passengers and goods from one place to another. All means of transport need places where journeys start and end. These are called **terminals.**

Terminals for land transport are called **Bus station or Train station**. Those for air transport are **Airports** while terminals for water transport are called **ports**. There are two types of ports such as in-land ports and sea Ports. A port needs a productive hinterland, that is an area from which the ports receives goods and passengers and where they are delivered (areas surrounding a port).

### A. Types of transport

There are three main types of transport as described below with their advantages and disadvantages:

- Land transport
- Water transport
- Air transport

### i. Land transport

Land transport is the type of transport that takes place on land. It can be subdivided into: Human portage, Animal transport, Road transport, Railway transport and Pipeline transport.

#### a. Human portage / porterage:

This is when people carry their load on their heads, on their backs or in their hands. It is the most used transport by most people in various parts of the world. It is predominant in developing countries because of limited capital and infrastructure to use modern facilities and inaccessibility of an area. For example, lack of roads to reach remote areas.

*Figure 12.191: Human portage*

**Advantages**

- It helps in inaccessible areas.
- It is cheap compared to other forms of transport.

**Disadvantages:**

- It is very slow compared to other forms of transport.
- It requires a lot of human energy and is time consuming.

**b. Animal transport:**

This form of transport is commonly used in areas where it is not easy to develop other means of transport especially in arid (desert) areas. Animals used include: Camels, cows, Horses, Donkeys etc.

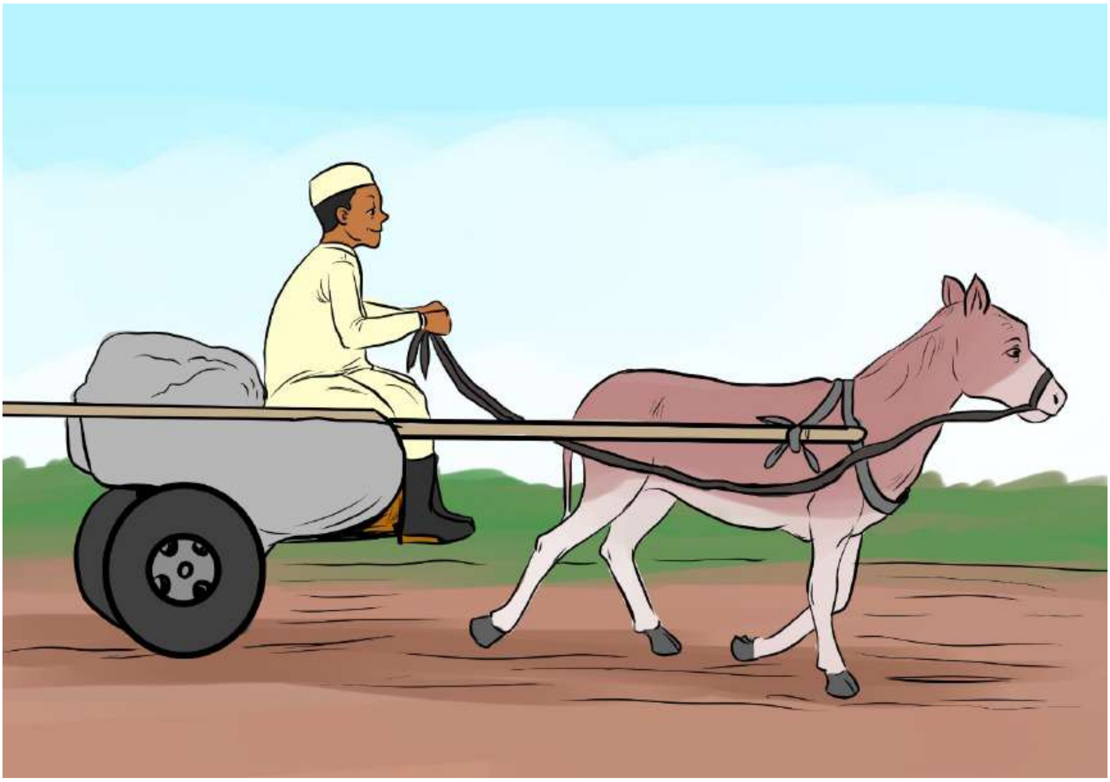


***Figure 12.192**: Animal portage*

**Advantages**

- It is used in wild areas where other means are not possible.
- It is quicker than the human portage.
- It is suitable in areas where human labour is limited

## Disadvantages

- It is slow compared to road transport.
- Some animals cannot move in hilly areas.
- Some animals cannot withstand certain climatic conditions.

### c. Road transport:

This involves the movement of goods and passengers mainly by vehicles, bicycles and motorcycles.

*Source: https://www.google.com/Roadtransport&source*

*Figure12.193: Road transport in California (left) and in Kigali (right)*

## Advantages

- Roads can be constructed in areas which are accessible to other forms of transport.
- Because of being flexible goods can be sold on route or can be delivered any time.
- It is cheaper and faster for short distances.
- In some cases, it does not require large capital, except road construction.
- It is easier for people to own and purchase vehicles, bicycles and motor cycles than airplanes, motors boats and ships.
- It provides door to door services.

## Disadvantages

- Heavy loaded Lorries are too slow.
- Weather conditions affect road transport especially during the rainy season.
- There are expensive to construct and maintain especially in towns.
- Roads are affected by congestion and traffic jams in heavily populated urban areas.

- Unsuitable for heavy and bulky goods compared to water transport
- Vehicles at times run empty because of not having a scheduled timetable.

### d. Railway transport

This involves the carrying of passengers and goods by train or tram along designated routes.

*Source:https://www.google.com/ Trams&source*

*Figure 12.194: Trams (Left) and Train (Right)*

**Advantages**

- It is cheaper for transporting bulky goods.
- It is less affected by weather conditions.
- It uses known routes and known timetable.
- It carries more load and a big number of people.
- It is safe since the chance of accidents or breakdowns are minimal.

**Disadvantages**

- The use of railway lines does not allow trains to reach remote areas.
- It is very expensive for short distances.
- It is not suitable for carrying perishable commodities.
- It is time consuming/ slow.
- It is costly in terms of maintenance. Currently trams are being replaced by buses in modern cities.

### e. Pipeline transport

This involves the movement of liquids and gases through a pipe from one point to another.

*Source: https://www.google.com/search?q=pipelines&source*

*Figure 12.195: Pipeline*

**Advantages:**

- It is cheap and easy to maintain.
- It is relatively fast.
- It can be used to transport large quantities of liquids at a single time.
- It is not affected by weather conditions.
- It does not pollute the environment.
- It is free from traffic congestions.
- It is convenient in transporting highly inflammable commodities such as petroleum.

**Disadvantages:**

- It cannot be used to transport other commodities, apart from gas and liquid only.
- It may be damaged leading to heavy losses.
- It does not provide door to door services.
- It is expensive to construct.

### f. Water transport

This is the movement of goods and passengers on water by use of ships, ferries, canoes and boats. It involves both in-land and marine water ways.

Source:https://www.google.com/search?q=marine&source

***Figure 12.196:*** *Marine transport (left) and boat transport in Lake Kivu (right)*

**Advantages of water transport.**

- It does not require any route construction.
- It is the cheapest for bulky goods.
- Bulky commodities can be transported over a long distance.
- It experiences less traffic congestion compared to road transport.
- It is suitable for carrying fragile goods because there is no shaking.

- Disadvantages of water transport.
- Construction of sea port is too expensive to be afforded by most countries.
- It is used by areas with navigable water bodies i.e. limited in use by landlocked countries.
- It can be affected by sea pirates.
- It is very slow in movement compared to air and road transport.
- Obstacles on rivers such as rapids, waterfalls, floating vegetation, sand bars, aquatic animals, make them un navigable hence affecting movement of water going vessels.
- Canals are affected by seasonal changes.
- Storms and winds sometimes interfere the ship schedule.

### g. Air transport

This is the form of transport that uses flying objects in the air such as airplanes, drones and balloons.

*Figure 12.197: Rwandair (airbus 330-200) (left), balloon (center), and drone (right)*

**Advantages of air transport**

- It is the fastest and most comfortable method of transport.
- It is suitable for transporting perishable commodities.
- It is suitable for carrying urgently needed goods.
- It can go to any place with an airport.
- It is secure, not subjected to robbers.
- It is less affected by relief features.
- It does not need any route construction compared to road and railway transport.
- Its time saving sine it follows a specific time schedule.

**Disadvantages of air transport**

- It causes air and noise pollution.
- It has limited storage space.
- Usually weather conditions such as fog interfere with its schedule.
- It is very expensive in terms of movement costs.
- Long time is taken in air traffic control at airfields. e.g. checking and booking
- It requires large capital in airport construction and aircraft purchase.
- It requires highly skilled man power to operate.
- It is a target for terrorist attacks.

## Application activity 12.1:

1. Explain why land transport is the most used type of transport in Rwanda compared to air and water transport.
2. Describe the challenges associated with road transport.

## 12.1.2. Factors influencing the development of transport and importance of transport

### Learning activity 12.2

1. Rwandair is improving its business worldwide. Explain the importance of that improvement?
2. Make research and analyze the physical and human factors that influence the development of transport in your district.

#### a. Factors influencing the development of transport

The factors affecting transport are physical, political and socio- economic. They are discussed below:

- Relief: Steep slopes make the construction of roads and railway lines expensive. On the other hand, valleys have swamps, that contain water logged soils that are too soft to allow heavy objects like trailers, Lorries and trains to move on them.
- Climate: Too much rainfall results into floods and landslides, hindering transport on the ground. On the other hand, accumulation of fog and clouds reduce visibility hence affecting transport.
- Vegetation: Thick vegetation cover makes construction of road and rail networks difficult because it requires uprooting big trunks of trees. Furthermore, thick vegetation modifies climate through evapo-transpiration hence affecting air transport.
- Capital: The construction of roads, railway lines and airports is expensive. At the same time, a lot of money is required to buy ships, trucks as well as airplanes.
- Political instabilities: Wars lead to massive destruction of transport means and infrastructure such as roads, wagons, airports and ports, making transport extremely difficult.
- International restrictions based on international boundaries: These affect transport in that they restrict amount of freight. The same applies to road transport.
- Economic factor: The structure and nature of transport costs are examined, together with service quality and methods of pricing and charging.
- Government policy: These include political motives for transport facilities; government involvement in capital, monopoly, competition, safety, working conditions and coordination between modes, transport as an employer and social consequences of transport developments.

### A. Importance of transport to the development of countries

Efficient transport is an important factor for economic development on both global and national scales. It can be a boost or a barrier to economic growth. Transports can contribute to economic development in the following ways:

- Transport promotes trade and industrialization through the transportation of necessary raw materials to factory for production of goods and finished goods to consumers
- Transport systems offer employment opportunities to many people.
- Transport promotes urban development as many urban centers have developed where transport network converges.
- Promotion of international relations since transport brings leaders together face-to-face talks.
- Promotion of tourist industry, tourists move by use of means of transport.
- Stimulation of the development of other sectors such as, agriculture, fishing and mining.
- Transport increases revenue through taxes to the government and income to local transporters.

Application activity 12.2:

Visit the nearest taxi park and note what you observe in terms of economic impact of the transport.

## 12.1.3. Problems/challenges affecting transport and strategies of improving transport.

Learning activity 12.3.

Analyse the photograph below taken in Nyabugogo and explain the phenomena that occurred in relation to the problems affecting transport.

### a. Problems/challenges affecting transport

There are major problems affecting transport activities as mentioned below:

- Inadequate capital: Transport requires enough capital investment. That is why it becomes difficult for developing countries that have weak economies to construct and maintain transport facilities such as roads, airports, ports, and railway lines.
- Natural barriers: Hostile environment such as deserts, forests, rugged and mountainous terrain hinders the establishment of transport facilities.
- Political instability: Some countries have undergone periods of political instability. With long periods of fighting in these countries, transport facilities were targeted for destruction while new lines were not established.
- Climate like heavy rainfall and floods make roads muddy and slippery. Bad climate disturb air transport also.

- Mass wasting like landslides and mudflows affect roads in mountain areas and make roads impassable for some times.
- Low technology causes over dependence on imported expertise and technology which are expensive. This is associated with lack of skilled man power to construct infrastructure.
- Presence of water falls and rapids along river courses and their tributaries make water transport difficult.

### b. Ways of improving transport

- Ensuring political stability and avoid wars that destroy transport facilities.
- Containerization of the ports and harbors for effective handling of goods and reduce delays.
- Government policies. Governments have to develop and implement international transport projects like building international highways or railways as the project understudy between Rwanda and Tanzania. Such policies boost transport development.
- Bridges are constructed across rivers to connect different areas across rivers and streams.
- Draining swamps for road construction.
- Improve engineering technology and use of national resources and materials to construct transport infrastructures. There is also need to train skilled manpower.
- To develop air transport for both domestic and international connections in big countries like it is the case in USA, in areas with large impenetrable rainforests like Equatorial forests in DRC or Amazonian forest in South America and large water bodies (oceans).

## Application activity 12.3:

1. Using examples, explain the challenges affecting transport in Rwanda.
2. Suggest different ways Rwanda as a landlocked country can use to improve its international transport.Hui con ta estrari bunimum faut omperfinte popore tus, ses, culegerum se firtius inatui cum nihilic

## 12.1.4. Case studies

**Learning activity 12.4:**

Make research, and find where the following are located on the world map: Tanzam railway, Trans African Highway, Trans- Siberian railway, Rotterdam Europort and St. Lawrence sea way.

### a. Tanzam railway / Tazara railway

Tanzam railway also called Uhuru railway runs from Kapiri-Mposhi in Zambia, northwards to Dar es Salaam on the Indian Ocean in Tanzania. It was opened in 1975.

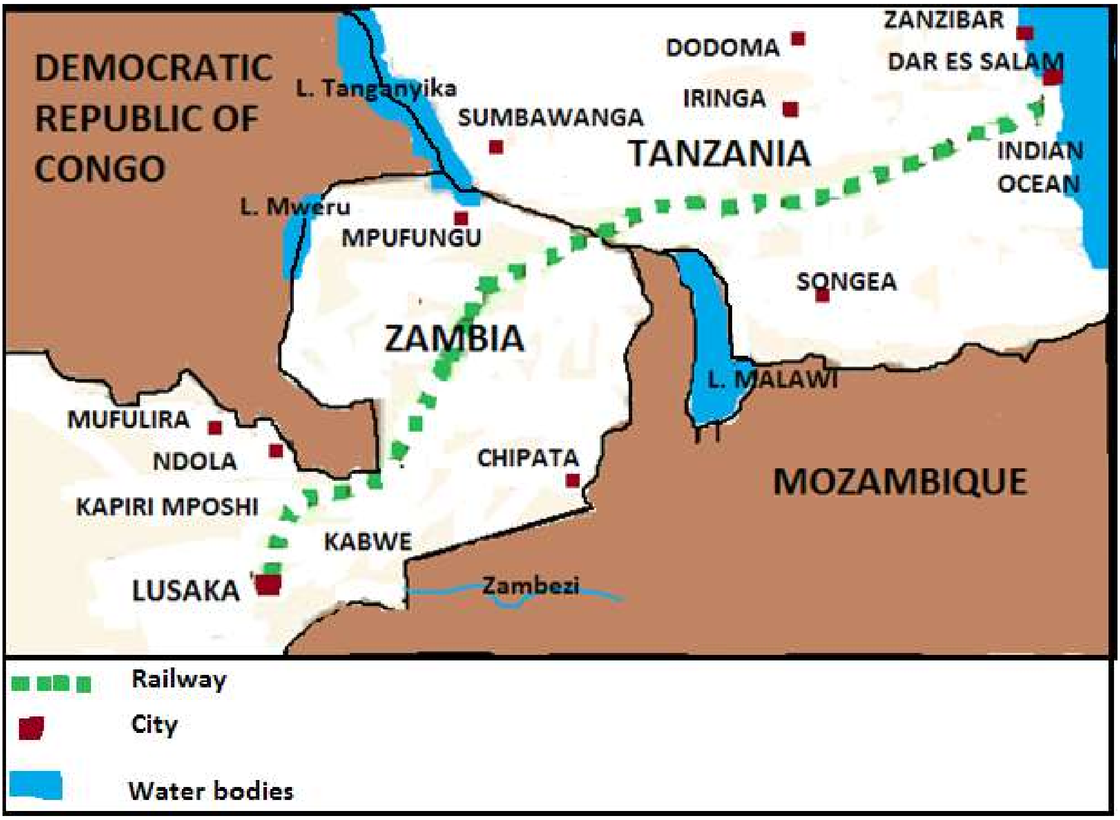



***Figure 12. 198**: Tanzam Railway*

i. Major aims of Tanzam Railway

- To promote Tanzanian and Zambian exports and imports.
- To solve Zambia's problem of being landlocked,
- To create accessibility to the sea for export of copper.
- To open up the southern highlands of Tanzania which were productive but remote.

ii. Benefits of the Tanzam Railway

- Tanzam Railway provides landlocked Zambia with reliable access to the sea and therefore made the flow of trade easier.
- It promotes economic development in remote parts of Tanzania which were not accessible.
- It leads to political and economic development of Tanzania and Zambia.
- Industrial growth has been achieved since both raw materials and finished goods can be easily transported by using railway. Tanzam railway encouraged the development of mineral exploitation in Tanzania and Zambia e.g. coal and Zambian copper.
- It provides employment opportunities for the local people like drivers, technicians, casual laborers and earns income to improve their standard of living.
- It has contributed to the economic growth of the port of Dar-es-Salaam while increasing government revenue.
- It contributes to the development of tourism especially to Tanzanian through port charges.
- It influences the development of other transport systems like feeder roads.
- Railway reduces transport costs incurred by Zambia compared to using the ports of other countries for its trade such as Lobito in Angola.

iii. Shortcomings of Tanzam Railway

- The serious delays on the route because of the long distance covered.
- High cost of maintaining the railway lines due to frequent breakdown. Railway need to be regularly rehabilitated and upgraded.
- It is affected by the weather conditions (heavy rain). Kilombero valley section is always exposed to flooding.
- Zambia faces the problems of high taxes in the payment of port charges at Dar-Es-Salaam.
- There is poor management of railway lines due to corruption and embezzlement. Private sectors can better manage the railway.
- There is a use of old line structure with shortage and inappropriate locomo-

tives and wagons. There is a need to develop systematic programs to replace old locomotives and wagons as well as communication systems.

### b. Trans- African Highway (T.A.H)

This is a highway that starts from Cape Town to Cairo linking the Northern and Southern regions of Africa. It passes through Bulawayo, Harare, Lusaka, Dar-es Salaam, Nairobi, Addis Ababa and Khartoum to reach Cairo. It has deviations to serve other regions adjoining the highway. It also runs from Mombasa through Uganda, DRC and Cameroon to Lagos in Nigeria. The main purpose to build Trans-African Highway was to promote trade between all corners of Africa.


***Figure12.199**: Trans- African Highways*

i. Advantages of the Trans-African Highway:

The Trans-African Highway has too much benefited the African States in / by which it passes in the following ways:

- It has enhanced cooperation among the countries through which it passes.
- The highway spearheaded the formation of economic and political unions such as East African Community (EAC) and Economic Community of West African States (ECOWAS).

- It has increased trade prospects between member States and has also stimulated trade on the continent by facilitating easy movement of people and goods.
- It has enabled the development of the remote parts of African countries.
- It encourages tourism in those countries where it passes and the distribution of human settlement patterns (linear and nucleated types).
- It is important in the transportation of agricultural raw materials.

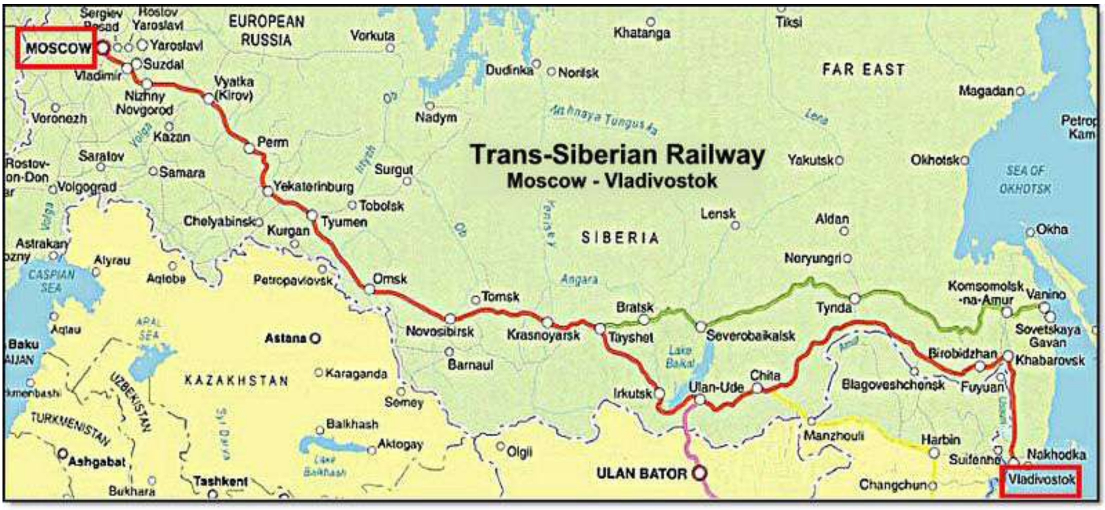
ii. Problems facing Trans-African Highway

The following are the major problems facing trans-African highway:

- Political instability or wars) in some African countries in which the high way pass has limited transportation of goods along this highway, this has affected its effective use.
- Frequent civil conflict affects its performance in various parts of the continents where the high way is passing.
- Some countries charge high tariffs at the border posts which is increasing the cost of transport.
- The volume of trade along the highway has further reduced due to delays caused by numerous border bureaucracies of screening and vetting of goods and passengers across borders.
- Insecurity and loss of goods on transit caused by banditry and smuggling along these highways have made the highways unsafe. This has further reduced their usage.

### c. Trans- Siberian railway in Russia

The Trans-Siberian Railway is a network of railways connecting European Russia from Moscow with the Russian Far East and the East Sea / Sea of Japan. It is the longest railway in the world with a line length of 9,259 km. There are branch lines to China through Mongolia and Manchuria. It was started in 1891 and completed in 1916..




*Source: https://www.google.com/search?q=transSiberian&source*

***Figure 12.200** : Trans-Siberian railway*

i. The importance of the Trans-Siberian Railway:

- The Trans-Siberian Railway gave a positive boost to Siberian agricultural crops. Wheat, rice, potatoes and sugar beet are grown. This facilitates substantial exports to central Russia and Europe.
- It influenced the territories it connected directly, as well as those connected to it by river transport.
- It attracts many foreign tourists in Russia, Siberia through creating accessibility to tourist attractions like Ural Mountains, Lake Baikal, and Moscow metro tunnel.
- The Trans-Siberian Railway encourages rural settlement in the inhabited areas of Siberia
- Development of towns. Trans-Siberian railway runs through important towns like ***Omsk, Novosibirsk, Irkutsk and Ulan-Ude,*** etc. These towns developed accommodation, commerce, health and education services.
- Improvement of industrial development through transportation of raw materials such as copper, phosphates, coal, iron, etc.
- Development of trade between the Eastern Europe and Asian countries like Japan, China and Siberian.
- Political and economic unity between the East and West Russia was achieved.

ii. Challenges of Trans- Siberian railway:

- Its construction led to clearance of forests as well as destruction of Ural Mountains
- It led to over exploitation of resources such as iron and steel from Karaganda field and oil from the west Siberian oil fields

- Loss of lives through accidents like derailing of the trains and sometimes collision.
- It led to urbanization in former natural environment areas with its related problems such as congestions, slums development, and pollution.

### d. Rotterdam (Europort in the Netherlands)

Rotterdam is a port located at the mouths of rivers Rhine and the Meuse on the North Sea. The name is derived from a stream known as Rotte. Today, the major development is concentrated on Euro Port on the seaward end of new waterway and not at Rotterdam. It is one the busiest port in the world. Rotterdam port serves a large rich hinterland of ***Belgium, France, Netherlands, Luxembourg and Switzerland***.


*Source: https://www.google.com/search?q=Rotterdam&source*

*Figure 12.201: Location of Rotterdam*

i. The factors which influenced the growth of Rotterdam

- Inland water transport:
  Rotterdam has a well-developed in-land water linkage to the interior of Western Europe.

These navigable rivers link the port to its hinterland: Elbe, Rhone and Danube.

- Strategic location:
  The port of Rotterdam is centrally located where sea routes converge such as the sea route to the North America, Africa and various parts of Europe and even Asia. It is an important waterway for Ruhr industrial region.

- Suitable climate:
  Rotterdam experiences a cool temperate climate. Like the other ports in the world, Rotterdam enjoys conductive weather conditions free from mist throughout the year.

- Establishment of industries:
  Rotterdam is located in a region of heavy industrialization. The major industries are oil refineries, food processing, ship building, petrochemicals, iron and steel industries. The importation and exportation of both raw materials and finished products through the port have led to its expansion making it the busiest port in the world.

- Large and rich hinterland:
  Rotterdam has a wide and rich hinterland which traverses the neighboring rich countries such as Belgium, Switzerland, Luxembourg, Germany, France, and Austria. The hinterland is rich in grains, mineral ores, iron and steel products.

  The port therefore handles a large volume of import and export goods which influenced its growth.

- There is a high level of technology:
  The high level of technology is used in the construction of canals and its maintenance, pipelines, railway lines that link the port to its hinterland.

- The availability of sufficient capital:
  This has facilitated the expansion of port activities over the years. Big projects for the development of the port were implemented such as the expansion of industrial storage facilities, construction of pipelines, canals, railways and high ways, etc.

- Proximity of Rotterdam to the North Sea:
  North Sea is one of the busiest international routes in the world. This proximity increases the amount of Cargo handled by the port, thereby fastening its growth and development.

- Low tidal range:
  The difference between the low tide and high tide at Rotterdam is very small. This allows large ships to use this port. Many ships are able to load and off-load their Cargo because of this unique characteristic.

- Favorable government policies:
  The government of Netherland supported the establishment, growth and development of Rotterdam port. It provided the capital for establishment of port structures, established the authority which was given responsibilities of running the port activities.

- Skilled man power:
  Being in an area that is developed with modern universities the port benefited from a large supply of skilled man power required in the port establishment.

ii. Problems facing Rotterdam Euro port:
  - Problem of congestion because of many water going vessels.
  - Pollution of the environment as a result of industrialization, urbanization, vehicles which releases fumes to the atmosphere.
  - Siltation of the river Rhine is a problem that faces the port.
  - There is limited land for further expansion of the port.
  - Overcrowding at the port due to many people.
  - Big Population at the port made housing very expensive.
  - High levels of unemployment because of high demand for jobs and this sometimes results into the problems of crimes

  - The problem of flooding because Rotterdam is located on the north part of Netherlands which is a low-lying area.
  - The problem of poor visibility resulting from fog and smoke at the port. This leads to accidents and sometimes delays delivery of cargos.
  - The problem of accidents by ships which often leads to the loss of Cargo and sometimes lives.
  - There is also problem of prostitution brought about by attraction from a large population.

iii. Steps being taken to solve the problem:
  - The construction of storm surge barrier automatically operated the control storm surges and minimizes flooding at the port. Dykes have also been constructed for this purpose.
  - There is an increased use of radar system to avoid collision of vessels during foggy weather conditions.
  - The port authority occasionally dredges the river Rhine and Maas thereby ensuring that they are free from silt and can be safe to ships.

- The industrial wastes are treated before they are released to the environment. This minimizes the case of pollution. The noise is also carefully monitored and regulated to avoid noise pollution.
- There is containerization to ensure safety of cargo, fast handling and dispatch of cargo.
- The port authority has also reclaimed land from the North Sea marshlands and the rivers to create more space for the port.

- There is a strict control of crimes through deployment of security personnel to monitor and discourage criminal acts at the port.

**e. St. Lawrence sea way (USA-CANADA)**

St. Lawrence seaway stretches from Port Duluth on Lake Superior to port St. Lawrence on the Atlantic Ocean. It covers a distance of 3,800 Km. It is the longest inland waterway in the world with the largest volume of traffic. It serves **Canada** and the **USA**. It allows passage of ocean going vessels. Before the sea way was constructed, large ships could only sail on the great lakes up to St. Lawrence town as far as Montreal. The construction of St. Lawrence seaway was a joint project venture between the governments of Canada and USA. The construction works began in 1954 and ended in 1959.

The main aim was to create deep water for navigation between Lake Ontario and Montreal. This would allow ocean going vessels to sail from the mouth of the St. Lawrence River onto the western shores of Lake Superior.


*Source: https://www.google.com/ stLaurence seaway&source*

*Figure 12. 202: St. Lawrence sea way*

i. Economic benefits of St. Lawrence seaway for the USA and Canada

- Cheap transport: The seaway has offered a cheap means of transport from the interior of North America to the Atlantic Ocean. The ocean liner finds it direct, quick and short to access the interior as opposed to the previous route through New York. This has enhanced the movement of people and goods.

- Creation of employment: Through transportation of raw material and finished products along the seaway, there has been an increased volume of traffic. This has created job opportunities.
- Generation of hydroelectric power: The construction of dams along the sea-way like Saunders and Beauharnous on Niagara Falls has led to the generation of abundant power. The power is cheap and reliable. It is used for both domes-tic and industrial use.
- Growth of Towns: St. Lawrence Sea Way has encouraged urbanisation along its shores. This is because the ports along it have attracted settlement. Examples of such towns are Quebec, Duluth and Hamilton.
- Increased volume of trade: St Lawrence Seaway has led to the increase of the volume of trade between the USA, Canada and the rest of the world. This has been due to the ease of transporting of goods such as iron ore, copper, wheat and manufactured goods.

- Development of tourism: The seaway with the spectacular Niagara Falls is a great tourist attraction. This has earned foreign exchange to the two countries.
- Development of industries: The seaway has contributed to the development of industries in the USA and Canada. The power generated from the dams is directly used in the industries. Likewise, water from the dams is used in cooling industrial plants.

ii. Problems of St Lawrence sea way

- Congestion, unemployment, high crime rate due to the growth of urban centers.
- High cost of maintaining the seaway like dredging to solve the problem of silting.
- Decline in fishing activities due to destruction of wetlands and fish habitant as a result of dredging and blasting as well as pollution of water.
- Many rocks which are used to adjust the level of water to improve navigation. These result into delays in movement.
- Increase of pollution due to oil and chemical spills as a result of enormous increase of cargo size as well as industrialization.

Application activity 12.4:

1. Explain the problems that were encountered during the construction of Tran- siberian and Tanzam Railways.
2. Analyse the factors for the growth of Rotterdam port in Europe
3. Briefly describe how Trans African Highway and St Lawrence seaway have contributed to development in their respective countries and continents.

## 12.2. Communication

Communication is a medium of sending and receiving information through various means. It is a very vital aspect of the society. Without communication, spatial interaction between people and communities would not be possible. People communicate to get needed things such as information, money, advice or just emotional support.

### 12.2.1. Meaning and types of communication

**Learning activity 12. 5:**

Observe the following images and explain how these devices are used for communication purposes


**a. Types or forms of communication**

There are different links, instruments and devices used in the transmission of information from one point to another. Early modes of communication included sending runners with verbal messages, fire and smoke signals, and later drums and horn blowing. The invention of writing led to improved communication as letters could be delivered to various destinations.

Those methods of communication were found to be slow and inaccurate in some instances and limited in terms of the distances they could cover. The rise in electrical technology led to a new concept in communication known as telecommunication, which is communication over long distances.

The current modes of communication include telegraph, telephone, fax, e-mail, courier, handwritten, television, radio, social networking.

The following are the main types of telecommunication:

i. **Telegraph:** Telegraph enabled messages to be transmitted by cables as a series of electrical impulses. The signals were in the form of the Morse code, which could be easily interpreted. Most places were thus linked by telegraphic cables. Undersea cables were also laid below the oceans.

ii. **Telephones:** This is where cables connected to a local exchange are used to transmit voice messages over long distances. The sound waves are changed into an electric current which is then transmitted to the receiver phone, where it is then interpreted by being re-transformed into sound waves that can be interpreted by human ear. Due to technological improvement, the cable fixed phones are being replaced by smart mobile phones which perform various communication tasks.

*Figure 12.203: Fixed telephone (left) and mobile telephone (right)*

iii. **Radio:** is a way to send electromagnetic signals over a long distance, to deliver information from one place to another. It also usually stands as a machine which sends out and receives messages using air waves to a large mass of people.


*Figure 12.204: Different images of Radio*

iv. **Television:** is a piece of electrical equipment which shows pictures through the air or along cables

***Figure 12.205:** Televisions*

v. **Internet:** Internet means "interconnected networks". It is a large system of connected computers around the world that allows people to share information and communicate with each other. It is a system that links devices worldwide.

***Figure 12. 206**: Internet devices*

**Application activity 12.5:**

Explain the most forms of communication used in Rwanda and why.

## 12.2.2. Importance of communication, problems affecting communication and their solutions

**Learning activity 12.6**

Many business people in the city of Kigali no longer need to travel to purchase their goods in the foreign countries. They use different types of communication to order for the goods and get them in few days in Kigali.

1. What do you think can be the consequences of such form of communication?
2. Explain the importance of communication.

### a. Importance of communication

The following are the main positive effects of communication:

- Communication system facilitates economic development by sending information to various locations of the world. Communication system connects industries and business communities to take right decisions at the right time by providing them with information and news related with business and financial matter. For example, it is possible to know about the price of the commodity prevailing at any part of the world quickly. This promotes domestic and international trade.
- Communication is the basis of organisational functioning: good communication is an essential tool in achieving productivity and maintaining strong working relationships at all levels of an organisation. It is only when necessary communications are made to subordinates and operators; about their jobs that action is possible due to communication.
- Communication sector has led to the creation of employment opportunities to a variety of categories of people such as journalists, media managers and users
- Investors in the sector of communication such as radio, television and social media (e.g. Facebook, WhatsApp, YouTube, etc. get more revenue and many of them belong now in the world's richest class.
- Communication facilitates easy dissemination of information to remote areas.

- Communication helps in building good public relations: good public relations comprise relations of the enterprise with outside agencies, particularly consumers and the public at large.

### b. Problems affecting communication

The following are the problems affecting communication:

- Inadequate capital: Many developing countries experience a problem of weak economies and few industries. They thus have insufficient funds needed to construct and maintain communication facilities.
- High taxes: there are high taxes attached to the importation of communication equipment as well as high operation charges.
- Inadequate technical know-how: This has hindered the growth of telecommunication since most countries have to rely on expatriates whose payments are very high.
- Natural barriers: desert, forest, rugged and mountainous terrains have hindered the establishment of communication facilities like telephone boosters.
- Competition: there is competition between the local companies involved in the sector and free online communication systems.
- Lack of skills: there is general lack of knowledge and skills to use telecommunication devices such as computers, radios, newspaper, etc.

### c. Possible solutions to the problems affecting communication

Drawing from the problems facing communication discussed above, it is evident that most of them can be overcome by way of reversing them.

- Political stability: there should be dialogue between countries and the use of peace talks should be emphasized.
- Investing in communication and where capital is not available, looking for ways of getting it through loans or aid.
- Countries should invest more on training their people so as to equip them with knowledge to hand the ever-changing technology. It is cheaper to train home-grown personnel than to hire expatriates.
- To increase the knowledge in technology: Use the recent technology radio, telephones, television, and internet to improve the standards of communication.
- Communication is the link between knowledge and information. Therefore, there is need to provide knowledge of the people to be able to communicate properly.

### d. Interrelationship between Transportation, Communication and Economic Development

1. Both transportation and communication play some major roles in the economic uplift of a country as they promote internal and external trade.
2. Transportation and communication systems help to promote the use of natural resources, mobility of skilled labour-force, diversification of markets, provision of fuel, increase in agricultural and industrial production.
3. Efficient transport and communication systems help to establish relationships among people in different parts of the world, these have also strengthened the feeling of unity among people in different cultural backgrounds.
4. Transport and communication systems help to create job opportunity for people living in the rural areas by connecting labourers and creating employment for them in the industries, however these have also solved the needs of industries and reduce unemployment.
5. The development of transport system also leads to development of industries because transport system utilizes the product of industries and both complement each other in different ways.
6. Efficient means of transport and communication have indeed shortened time, distance, and cost that would have been used to move and to deliver goods and information from one person to another.
7. Transportation and communication help to increase the size of the market of your products by helping you to transport your products across different countries which will help you to increase your sales in those countries that is, by penetrating new markets.
8. Through the effective transport and communication systems one will know how to strategies in terms of war and also curtail crisis from taking place at any point in time.

9. Government can swiftly evacuate or inform her people against any occurrence of natural disaster, outbreak of diseases and other social problems through the means of transportation and communication system.
10. The production and distribution units (farms, factories, central places) that are under primitive or high-cost transport conditions, had to be scattered to serve distant markets, have tended to become spatially concentrated in areas of greatest advantage. Market areas therefore have become even more extensive as transportation has improved. Similarly, supply areas have expanded. For instance, agricultural production has become more profitable and so wider areas of production are opened up from the central markets.

11. Transportation revolution has therefore significantly improved accessibility of places and therefore bringing more developments and growth. This is because transportation is the main vein through which developmental facilities and services are channelled. The level of transport development of

many areas therefore positively correlated to the level of economic growth and development.

12. Transportation plays a major role in the economy, which increases the production efficiency and links to the logistic systems.

## Application activity 12.6

1. Explain factors hindering effective communication in your area.
2. What is being done by Rwandan government to improve communication?

## End unit assessment

1. Examine the relationship between communication and transport.
2. Explain the role of the government in ensuring effective communication in Rwanda.
3. Referring to MTN, TIGO and AIRTEL explain the importance of telecommunication companies in the development of the country.
4. Explain the factors that have contributed to the development of transport in developed countries than developing countries.
5. Analyze the level of transport and the improvement of technology in communication in Rwanda and describe how this process can support the sustainable devel*opment of the country.*

# UNIT 13

## TRADE AND COMMERCE IN THE WORLD

# UNIT 13: TRADE AND COMMERCE IN THE WORLD

## Key Unit Competency:

By the end of this unit, I should be able to evaluate the impact of trade and commerce on the sustainable development of different countries in the world.

Introductory activity:

For different reasons, many countries come together and create regional bloc such as European Union or East African Community. Conduct your own research and answer the following questions.

1. Identify different regional integrations operating with Rwanda.
2. What advantages does a country benefit from being a member of a trading bloc?

### 13.1. Definition, types of trade and factors influencing international trade.

Learning activity13.1

Madame Kayitesi buys goods in large quantities from Inyange Industry. She owns one of the biggest shops in her village. Her products are bought by the local people and she takes some to the nearest markets in her district. Some of the products made by Inyange industry are exported overseas.

1. Identify the major imports of Rwanda
2. Mention the types of trade indicated in the passage.
3. Explain the factors influencing trade between Inyange industry and overseas countries.

#### 13.1.1. Definition of key terms

**Trade:** Is the activity of buying and selling or exchange of goods and services within a country or between countries. It also occurs between two individuals through the exchange. Trade is part of commerce.

**Commerce:** Is the activity of buying and selling of goods and services, especially on a large scale or quantity. It goes along with the activities such as insurance, transportation, warehousing, advertising that completes that exchange. Commerce stands as a wide system that includes legal, economic, political, social, cultural and technological systems that are in operation in any country or internationally.

Trade is simply the exchange of commodities, and this can take place at many levels. The earliest form of trade was probably ***"barter trade"*** in which one type of commodity was exchanged for another of equal value.

The present trade is based on the exchange of goods and services for money. It includes the following forms:

**a. Internal trade:** This is the exchange of commodities within a country. It is also known as domestic trade. Traders normally need to exchange what they have with what they don't have. It includes:

- Whole sale
  This occurs when traders buy goods in bulky from both the manufacturers and importers. They then break them into smaller units and sell them to kiosk owners, hawkers, shopkeepers and supermarket;

- Retail trade
  This is where traders buy goods from the wholesalers and sell them in detail to the individual customers.

**b. International trade:** This type of trade occurs between different nations of the world, on a global scale. Its rationale lies in the fact that no country can produce everything that it needs. It therefore has to acquire what it cannot produce from others through trade. It involves:

- Bilateral trade: it is a trade between two countries.
- Multilateral trade: it is a trade between many countries, through the exchanging **imports** where goods and services bought and brought into the country, and **exports** where goods and services are transferred to another country for sale.

### 13.1.2. Factors influencing international trade

The type and volume of trade that takes place at any level in any place is influenced by a number of factors. The most important factors are:

- Capital: This is the greatest single factor influencing trade. Money is the engine that runs trade. Traders require capital to establish their businesses, purchase their wares and transport the commodities. Where capital is inadequate the volume of trade will also be low.
- Demand and supply: For trade to take place there must be sufficient demand and good chain of supply of the items.

- Transport and communication: Trade depends highly on efficient means of transport and communication. For example, manufactured goods and other trade items need to be transported to the market. Traders also need to move from one place to another to effect various trade related transactions. Traders have to further communicate while placing orders and while establishing the market situation.
- Trade barriers: This includes the quota system for international trade, where a country may impose limits on imports and exports. They also include tariffs and duties levied on goods, which if increased may discourage the importation and exportation of some goods.
- Government policy: This is where the government influences trade in certain commodities through taxation. For example, the government levies heavy taxes on certain goods such as cigarettes and alcohol.
- Creation of trading blocs: The creation of regional common trading markets enhances trade due to increased cooperation between the member countries. Trade is further promoted because the market is usually expanded.
- Political climate of a country: Political problems such as wars affect both internal and external trade because wars discourage foreign investors and at times destroy industries; whereas good diplomatic relationship between countries encourages foreign investments.
- Population factors: population size, structure, distribution and the diversity between peoples affect the types of goods traded and the volume of international trade.
- Differences in natural resources: Natural resources are not evenly distributed in the world. This is mainly due to differences in climate, sols, relief and geological factors.

## Application Activity 13.1:

Discuss how the following factors influence international trade in Rwanda:

1. Regional integration
2. Government policy
3. Population

## 13.2. Causes of low levels of international trade in Developing Countries and importance of international trade in the development

### Learning activity 13.2

Most of the industrial products used in developing countries are imported from Europe, USA, ASIA etc. African countries also export agricultural products to the rest of the world but the gap between imports and exports in less developed countries still remains big.

1. Identify the products exported by European countries in Africa.
2. Outline the major exports of Rwanda to the developed countries.
3. Explain the causes of this inequality between exports and imports.

### 13.2.1. Causes of low levels of international trade in Developing Countries

The following are the major factors causing the low levels of international trade in Developing Countries:

- Access to foreign markets**:** The foreign markets are dominated by the goods and services from developed countries because they have better quality and produce more quantity of goods.
- Inadequate and insufficient domestic supply on the international market: this causes the increase in prices and this affects the final consumers.
- Most of the developing countries export unprocessed products due to shortage of industries or low level of technology. These unprocessed products also called raw materials are undervalued on international markets.
- Most of the developing countries and other low-income countries export bulk products such as horticulture products, fruits, vegetables and animal products. These perishable products account the risks to be damaged in transport process.
- Developing countries have also been concerned with the growing importance of free trade areas and customs unions in recent years, which now cover virtually all their major export markets, including Europe and North America since most of the major regional trading arrangements do not include them,
- Implications of anti-competitive practices by private enterprises in restricting the market access of developing countries to industrialized countries.
- Quota policy on the international market is negotiated only among the developed countries and developing countries must follow their resolutions.
- Capital inflows: the growing constraints on foreign aid and the difficulties in attracting increased foreign private financing and investment are affecting the growth prospects of countries lagging behind in global integration.

- Financial liberalization in developing countries has mainly comprised the reduction or removal of allocative controls over interest rates and lending, the introduction of market-based techniques of monetary control and the easing of entry restrictions on private capital

### 13.2.2. Importance of international trade in development

International trade helps in development as follows:

- Foreign trade and economic development: Foreign trade plays a very important role in the economic development of any country. Therefore, economic development of a country depends in part on foreign trade.
- Foreign exchange earnings: Foreign trade provides foreign exchange which can be used to reduce poverty. The foreign earnings are obtained through exportation of products especially agricultural products by developing countries.
- Market expansion: The demand factor plays very important role in increasing the production of any country. The foreign trade contributes to expand the market and encourages producers.
- Foreign investment: Besides the local investment, foreign trade encourages investors to invest in those countries where there is a shortage of investment.
- Increase in national income: Foreign trade increases the scale of production and national income of a country. To meet the foreign demand, we increase the production on large scale so Gross National Product (GNP) also increases.
- Price stability: Foreign trade helps to bring stability in price level. All goods which are not sufficient, have high prices. Those goods are imported and goods which are surplus can be exported. This stops fluctuation in prices.
- Specialization: There is a difference in the quality and quantity of various factors of production in different countries. Each country adopts the specialization in the production of specific commodities, in which it has comparative advantage. So all trading countries enjoy profit through international trade.
- To improve quality of local products: Foreign trade helps to improve quality of local products and extends market through changes in demand and supply as foreign trade can create competition with the rest of the world. The country competes with the foreign producers in foreign trade so it improves the quality and reduces the cost of production.
- Import of capital goods and technology: The inflow of capital goods and technology in the less developed countries has increased the rate of economic development, and this is due to foreign trade. Foreign trade is also responsible for spreading of knowledge and learning from developed countries to under developed countries.

- Better understanding: Foreign trade provides an opportunity to the people of different countries to meet, discuss, and exchange views and ideas related to their social, economic and political problems.

Application activity13.2:

1. Assess the role of international trade in the economic development of Rwanda
2. Suggest ways of reducing the gap between low exports and high imports in developing countries.

## 13.3. Major financial centers and trading blocs of the world

Learning activity 13.3

1. Make research and explain the objectives of International Monetary Fund (IMF).
2. Using specific examples, explain how the trading blocs improve the economic development of member countries.

### 13.3.1. Major financial centers

A financial centre is a location that is home to a cluster of nationally or internationally significant financial services providers such as banks, investment managers, or stock exchanges. A prominent financial centre can be described as an International Financial Centre (IFC) or a global financial centre and is often also a global city. Today, the two largest financial centres of the world in terms of volumes of capital circulating are London and New York. In 2017, the top ten world financial centre were London, New York City, Hong Kong, Singapore, Tokyo, Shanghai, Toronto, Sydney, Zürich and Beijing.

The power of a financial centre depends on its history, role and significance in serving national, regional and international financial activity. There are three prime factors for success as a financial centre: a pool of money to lend or invest; a decent legal framework; and high-quality human resources. The big financial centres also host the world biggest financial institutions like IMF, World Bank, etc.

### a. The main global financial centres

- **Amsterdam**. Amsterdam is well known for the size of its pension fund market. It is also a centre for banking and trading activities. Amsterdam was a prominent financial centre in Europe in the 17th and 18th centuries and several of the innovations developed there were transported to London.
- **Chicago**. The Illinois city has the «world's largest [exchange-traded] derivatives market» **Dubai**. The second largest emirate in the United Arab Emirates is a growing centre for finance in the Middle East, including for Islamic finance.
- **Dublin**. Dublin, in Ireland, is well known because of its International Financial Services Centre, "IFSC"). It is a specialized financial services centre with a focus on fund administration and fund domiciling. It also conducts activities such as securitization and aircraft leasing.
- **Frankfurt**. Frankfurt attracts many foreign banks which maintain offices in the city.
- **Hong Kong**. As a financial centre, Hong Kong has strong links with London and New York City. It developed its financial services industry. Most of the world's 100 largest banks have a presence in the city. Hong Kong is a leading location for initial public offerings, competing with New York City.
- **London**. London has been a leading international financial centre since the 19th century, acting as a centre of lending and investment around the world. London continues to maintain a leading position as a financial centre in the 21st century, and maintains the largest trade surplus in financial services around the world. London is the largest centre for derivatives markets, foreign exchange markets, money markets, issuance of international debt securities, international insurance, trading in gold, silver and base metals and international bank lending. London benefits from its position between the Asia and U.S. time zones, and has benefited from its location within the European Union**.**
- **Luxembourg**. Luxembourg is a specialized financial services centre that is the largest location for investment fund domiciliation in Europe, and second in the world after the United States. Three of the largest Chinese banks have their European hub in Luxembourg (ICBC, Bank of China, China Construction Bank).
- **Madrid**. Madrid is the headquarters to the Spanish company Bolsas y Mercados Españoles, which owns the four stock exchanges in Spain, the largest being the Bolsa de Madrid. As a financial centre, Madrid has extensive links with Latin America and acts as a gateway for many Latin American financial firms to access the EU banking and financial markets
- **Milan**. The city is Italy's main centre of banking and finance.
- **New York City**. Since the middle of the 20th century, New York City, represented by Wall Street, has been described as a leading financial centre. New York City remains the largest centre for trading in public equity and debt capital markets, driven in part by the size and financial development of the U.S.

economy. The NYSE and NASDAQ are the two largest stock exchanges in the world. Several investment banks and investment managers and the three major global credit rating agencies which are Standard and Poor's, Moody's Investor Service, and Fitch Ratings, have their headquarters in New York City.

- **Paris**. It is home to the Banque de France and the European Securities and Markets Authority. Paris has been a major financial centre since the 19th century. The European Banking Authority is also moving to Paris in March 2019.
- **Seoul**. South Korea's capital has developed significantly as a financial centre since the late-2000s recession. Seoul has continued to build office space with the completion of the International Financial Center Seoul in 2013. It ranked 7th in the 2015 Global Financial Centres Index, recording the highest growth in rating among the top ten cities.
- **Shanghai**. This is one of Chinese and world financial centre. It competes with New York and London. China is generating tremendous new capital and state-owned companies in places like Shanghai.
- **Singapore**. With its strong links with London,[82] Singapore has developed into the Asia region's largest centre for foreign exchange and commodity trading, as well as a growing wealth management hub. It is one of the main centres for fixed income trading in Asia.
- **Sydney**. Australia's most populous city is a financial and business services hub not only for Australia but for the Asia-Pacific region. Sydney is home to two of Australia's four largest banks, the Commonwealth Bank of Australia and Westpac Banking Corporation and to the Australian Securities Exchange.
- **Tokyo**. Tokyo emerged as a major financial centre in the 1980s as the Japanese economy became one of the largest in the world. As a financial centre, Tokyo has good links with New York City and London.
- **Toronto**. The city is a leading market for Canada's largest financial institutions and large insurance companies.
- **Zurich**. Zurich is a significant centre for banking, asset management including provision of alternative investment products, and insurance. Switzerland is not a member of the European Union, then Zurich is not directly subject to EU regulation.
- **Other** emerging financial centres are cities such as Mumbai, São Paulo, Mexico City and Johannesburg, etc.

**b. Examples of the financial institutions that make a city a powerful financial center**

**The International Monetary Fund**

The International Monetary Fund (IMF) was created in1945 and has Washington D.C. as the Headquarter. It began with 45 members.

The aims of IMF are to promote international economic cooperation and international trade, strives to help stabilize exchange rates among member countries. IMF takes a lead in advising member countries and ultimately helps to avoid financial crises. This includes developing standards that member countries follow, such as providing adequate foreign exchange reserves in good times to help provide for increased spending during recessions. The IMF also provides loans to help its members tackle balance of payments problems, stabilize their economies and restore sustainable economic growth.

**The World Bank**

The World Bank or the International Bank for Reconstruction and Development (IBRD) was founded in 1944. Its headquarter is in Washington D.C.

It was set up with the aim of reconstructing the war-affected economies of Europe (during the Second World War) and assisting in the development of the less developed countries of the world.

Today, the World Bank is more concerned with the development of member countries especially the developing ones. It gives loans for the purchase of capital goods necessary for development. In so doing, the World Bank concentrates on loans for projects that are clearly profitable. The World Bank's current focus is on achievement of the Millennium Development Goals (MDGs)

### 13.3.2. Trading blocs and regional integration

**A trade bloc** is a type of inter-governmental agreement, often part of a regional inter-governmental organization, where regional barriers to trade, (tariffs and non-tariffs barriers) are reduced or eliminated among the member states.

#### a. Advantages of trading blocs and regional integration

- Foreign direct investment: An increase in foreign direct investment results from trade blocs and benefits the economies of participating nations. Larger markets are created, resulting in lower costs to manufacture products locally.
- Economies of scale: The larger markets created via trading blocs permit economies of scale. The average cost of production is decreased because mass production is allowed.
- Competition: Trade blocs bring manufacturers in numerous countries closer together, resulting in greater competition. Accordingly, the increased competition promotes greater efficiency within firms. Generally, increased competition leads to increased volume of trade.
- Trade effects: Trade blocs eliminate tariffs, thus driving the cost of imports down. As a result, demand changes and consumers make purchases based on the

lowest prices, allowing firms with a competitive advantage in production to thrive. All these advantages translate into greater economic strength for the block.

- Market efficiency**:** The increased consumption experienced with changes in demand combines with a greater amount of products being manufactured to result in an efficient market.
- Increased regional specialization.
- Strengthens political unity among member states.

### b. Disadvantages of trading blocs and regional integration

Limited fiscal capabilities: Some regional integration agreements that involve the creation of a common currency most notably the European Union's lead to fiscal crises. Without regional integration, individual countries can control the supply of their own currency to suit the nation's economic conditions. When a higher entity controls that currency -- as is the case with the EU's Euro, individual countries have no power to vary the strength of their currency when their economy weakens.

Cultural centralization: Regional integration has a final non-economic disadvantage. Especially strong integration like the European Union can lead to the loss of unique minority cultures within a region. The European Union has a series of languages that it deems to be the official languages of the EU government. These do not include minority languages spoken by remote communities in Europe.

Loss of sovereignty: A trading bloc, particularly when it is coupled with a political union, is likely to lead to at least partial loss of sovereignty for its participants

Concessions: No country wants to let foreign firms gain domestic market share at the expense of local companies without getting something in return. Any country that wants to join a trading bloc must be prepared to make concessions.

Interdependence: Because trading blocs increase trade among member countries, a natural disaster, conflict or revolution may have severe consequences for the economies of all participating countries.

### c. Factors affecting regional integration

- Homogeneity of the goods produced among the member states can hinder trade. If countries produce the same goods, there is no need to trade amongst each other. This situation is seen among East African countries which produce almost the same agricultural products such as maize, sugar etc. this undermines trade among them.

- Some countries may have experienced a shortage in foreign exchange. They may not have enough foreign money to trade and buy from other countries. This may be because they do not earn enough from their exports.
- Countries may have different ideologies. They may not be comfortable with their cultures or opinions. This makes it difficult to synchronize / harmonize their economic strategies.
- In the trading blocs, trade is undermined by poor transport and communication. This is experienced mainly in developing countries. This makes it difficult to trade and move from one country to another.
- For business to flourish there must be a peaceful environment. Therefore, if a member state is experiencing political instability, it will affect trading relations in the whole bloc. This undermines trade among the member states.
- Some countries have trading partners who are not in the trading bloc. They prefer to trade with them rather than the member states of the bloc. These outside partner could be former colonial master which member states have closer trading ties with.
- Member states could experience lack of funds or capital. They are unable to pay for goods ordered. This interferes with the functionality of the trading bloc.
- Member states may not use the same language. There will be a language barrier among them making it difficult to communicate. This will make trading in the block more difficult and hinder economic integration.
- Countries in the bloc may have different levels of development. Countries that are more developed will benefit more from the common market. The less developed countries will feel unfair trading practices against them.
- In trading blocs, especially Africa, the member countries sell unprocessed primary goods. This limits trade because there are limited manufactured goods in the market.
- There is interference from developed countries that are not in the trading bloc. They impose conditions that limit trade among the member states. This will undermine the union.

### d. Problems affecting international trade

Trade, like other human activities faces some problems which may occur at regional as well as international level. They could be economic, social, political, environmental and cultural in nature.

- Protectionisms: There are ways of implementing a protectionist policy, and every country in the world protects some of its goods.

- Tariffs: The effect of high tariffs is to make imported goods equally or more expensive than home-produced articles.
- Quotas: If tariffs are ineffective in halting the inflow of cheap foreign goods, countries may resort to imposition of quotas. By a quota system a country refuses to import more than a specified quantity of a certain commodity.
- Subsidies: The government of a country may pay subsidies or give tax relief, in order to stabilize home prices. This involves assistance to home industry rather than penalization of foreign producers.
- Trading blocs: In recent times trade has been modified by the formation of economic unions such as EEC (European Economic Community). Though tariffs are broken down between the member nations and there is greater flow of the trade amongst them.

**e. Possible solutions to problems of international trade.**

- Joining and enforcing trading blocs like EAC, EEC**.**
- Common market or grouping which not only reduces tariffs and other restrictions within the group but at the same time raises tariff barriers against outsiders.
- Construction and rehabilitation of infrastructure.
- Political negotiations and discussions to reduce and ultimately end political instability and insecurity so that a favorable trading atmosphere is created.
- Improving the quality of manufactured goods so that they are attractive and competitive on the international market.
- Foreign investment to diversify domestic economy within countries. This may overcome the problem of similarity of goods on the market.

## Application activity 13.3

a. Discuss why should Rwanda make trade with other countries.

b. Analyse the challenges faced by Rwanda in carrying out trade with other countries.

c. "Gains from international trade are mostly beneficial to rich countries". Discuss.

d. Suggest what the city of Kigali can do to become an international financial center?

## 13.4. Case studies

### 13.4.1. Regional integration

**Learning Activity13.4:**

1. Describe the major objectives of EAC.
2. Analyse the challenges faced by ECOWAS member states in implementing its objectives as a regional bloc.

**a. The East African Community**

The East African Community (EAC) is an intergovernmental organization composed of six countries in the African Great Lakes Region of Eastern Africa. The country members are: Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda. The headquarters of EAC is at Arusha in Tanzania.

The organization was founded in 1967, collapsed in 1977, and was revived on 7 July 2000. In 2008, after negotiations with the Southern Africa Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA), the EAC agreed to an expanded free trade area including the member states of all three organizations. The EAC is an integral part of the African Economic Community.

In 2010, the EAC launched its own common market for goods, labour and capital within the region, with the aim of creating a common currency and eventually a full political federation. In 2013, a protocol was signed outlining their plans for launching a monetary union within 10 years.


***Figure 13. 207*** *East African Community Member States*

**Aims of EAC**

- To revive free movement of people, goods, money, and services.
- To create common (tax) tariff.
- To create large market for goods and services.
- To promote regional cooperation.
- To improve communication.
- To share electricity.
- To promote industrialization in the region

**b. Economic Community of West African States**

The Economic Community of West African States (ECOWAS). Established on May 28 1975 via the treaty of Lagos, ECOWAS is a regional grouping with a mandate of promoting economic integration in all fields of activity of the constituting countries.

Member countries of ECOWAS include Benin, Burkina Faso, Cape Verde, Cote d' Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal and Togo

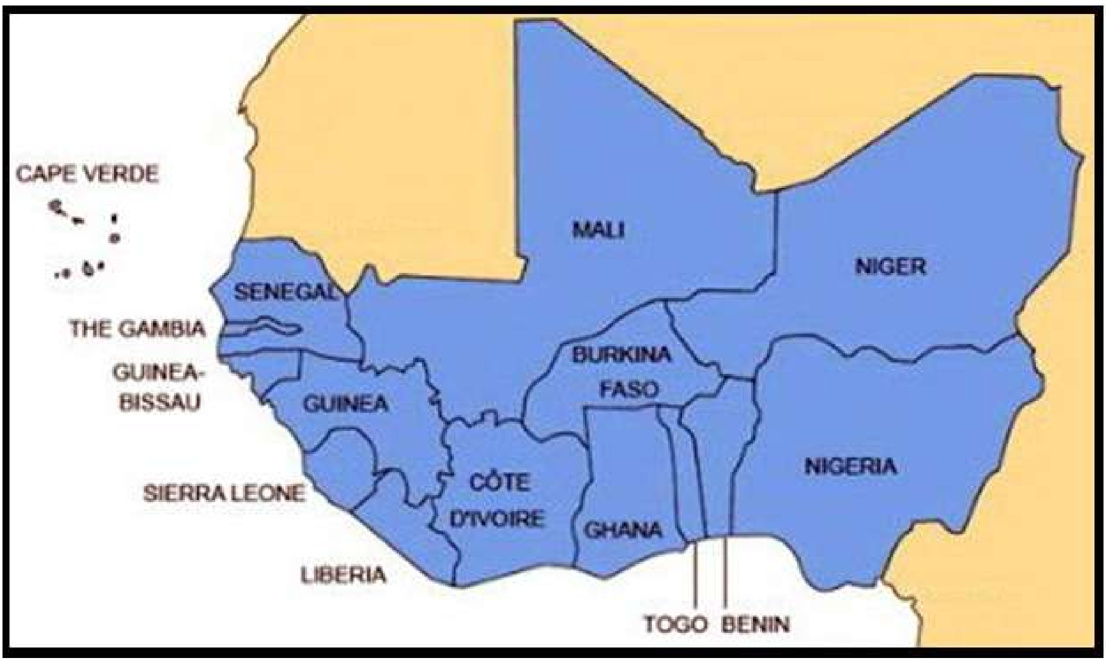



*Figure 13. 208 ECOWAS Member States*

**Objectives of ECOWAS**

- To promote economic cooperation
- To uplift living standards of member states
- To achieve and maintain economic stability of member countries
- To enhance free movement in member states without immigration formalities.

This regional organization has achieved the following:

- ECOWAS has frozen all customs and tariffs on goods originating within West African and this has led to industrial growth, pooling of resources through joint ventures by certain member states.
- It has decreased prices among the member states of some products like petroleum.
- It has increased technological exchange among the member states.
- There has been an improvement of communication in the region.

### 13.4.2. Trading Blocs

1. Organization of Petroleum Exporting Countries

   The Organization of Petroleum Exporting Countries (OPEC) is an organization of oil-producing countries. It controls 61 percent of the world's oil exports and holds 80 percent of the world›s proven oil reserves. OPEC's decisions have a huge impact on prices. The country members are: Algeria, Angola, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

**OPEC's three goals**

- To **keep prices stable**. It wants to make sure its members get what a good price for their oil. Since oil is a fairly uniform commodity, most consumers base their buying decisions on nothing other than price.
- To **adjust the world's oil supply** in response to shortages. For example, it replaced the oil lost during the Gulf Crisis in 1990. Several million barrels of oil per day were cut off when Saddam Hussein›s armies destroyed refineries in Kuwait. OPEC also increased production in 2011 during the crisis in Libya.
- **To coordinate and unify the petroleum policies** of its member countries and ensure the stabilization of oil markets.

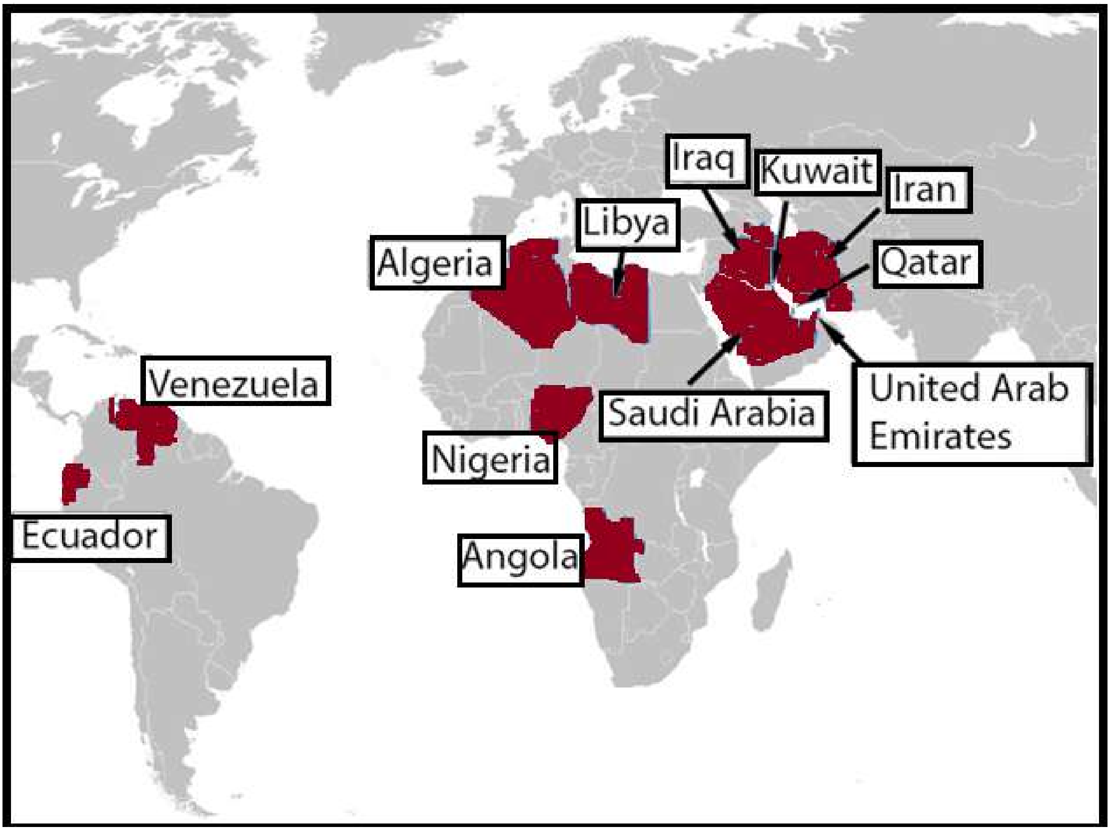



*Figure 13. 209 .Organization of the Petroleum Exporting Countries*

2. The European Union

The European Union (EU) is a union of 28 independent states based in Europe. It is the largest single common market in the world. The European Union has a common currency, the euro, which is acceptable in all member states. EU helps in promoting trade, agriculture and creation of employment.

Member states of the EU are Austria, Netherlands, Hungary, Belgium, Portugal, Latvia, Denmark, Spain, Lithuania, Finland, Sweden, Malta, France, Poland, Slovakia, Germany, Slovenia, The United Kingdom, Greece, Ireland, Italy, The Czech Republic, Estonia, Luxembourg and Cyprus.

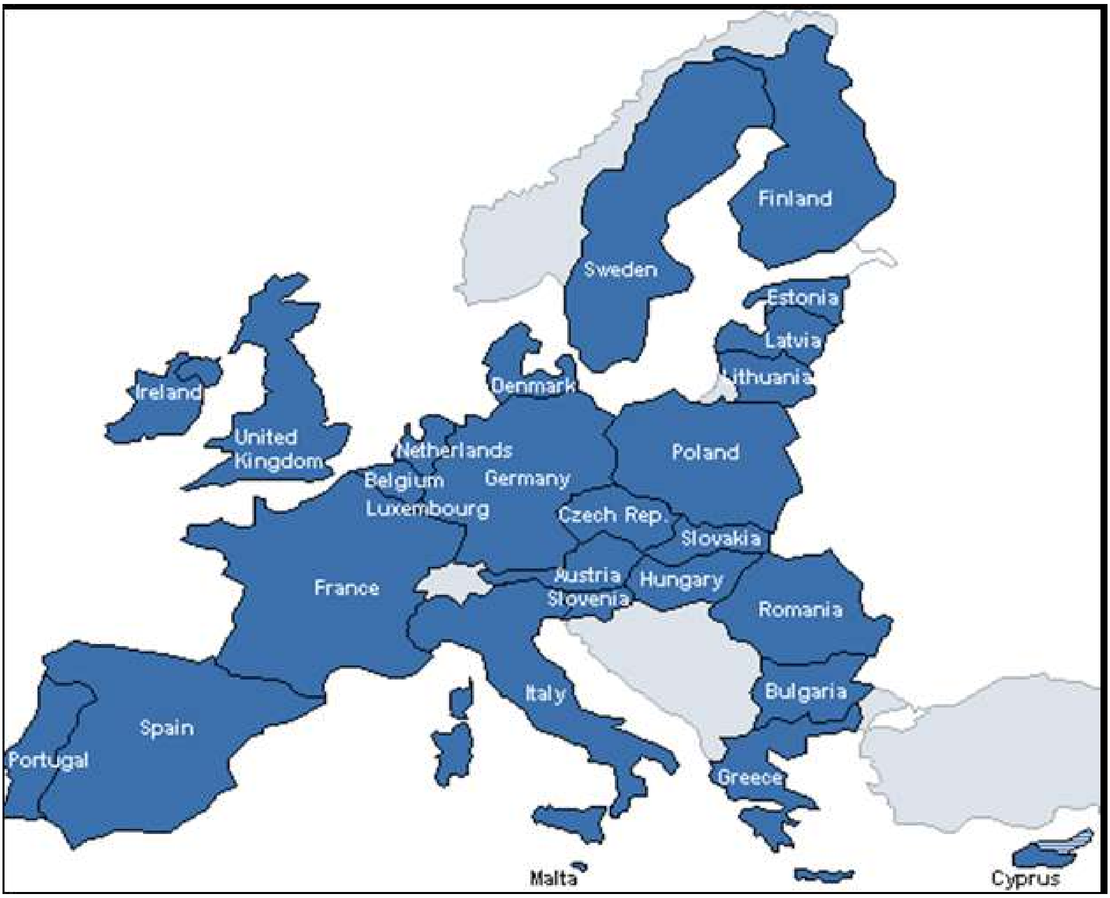



*Figure 13. 210. The European Union Member States*

### 13.4.3. The Patterns of World Trade

The volume of trade, the direction of trade and the types of goods involved in the trade vary greatly between different continents and individual countries.

i. Main Commodities involved in the World trade:
   - **Food stuffs;** grains, beverages, fruits, meat, spices
   - **Raw materials;** fibres, rubber, timber, vegetable oils, metals and other minerals
   - **Fuels;** coal, petroleum, natural gas
   - **Manufactured goods;** textiles, machines, chemicals etc.

Western Europe, North America and Japan are the major importers of raw materials and foodstuffs. They are the major producers and exporters of manufactured goods. These developed countries have invested heavily in developing countries which are the main suppliers of agricultural raw materials, minerals and oil.

ii. Major Trading Zones of the World:

The world's major trading zones are:

- Western Europe: this is the most industrialized and the most densely populated regions of the world. Its annual volume of trade is the largest in the world. More than a third of the world trade is concentrated in European Union member states.
- North America: Its foreign trade is second only to that of Western Europe. USA has the largest economy in the world. The country has varied economy, rich mineral resources, large concentration of industries and has heavily invested in many developing countries. The other notable country of North America which has been expanding its trade with USA and Western Europe is Canada.
- China: Has the second largest economy in the world after the USA. The country has also one of the fastest growing economies in the world. It has expanded its foreign trade in recent years. China has greatly increased its investments in developing countries.
- Latin America: It is a major producer of food stuffs, minerals and a major importer of manufactured goods
- Africa; The continent is less industrialized than other continents. Its main exports to the industrialized countries are minerals and tropical raw materials. Major imports are; manufactured products, consumer goods and mining equipment.
- Southern continents: Australia and New Zealand are highly developed but with a relatively small volume of world trade. The main exports are agricultural products.
- Japan: It has the third largest economy in the world. The country is highly industrialized. Its main exports include; manufactured goods, including steel, ships, electrical goods and machinery, automobiles and chemicals. Its main imports are oil from the Middle East, raw materials from Africa, Asia, Australia etc.
- South-East Asia: This is an important trading zone. It produces tropical raw materials such as; tin, rubber, timber, palm oil, petroleum from Malaysia and Indonesia. Other important raw material producing areas from this region are; Philippines, Burnei, Burma and Thailand.
- Middle Eastern states; This region possess more than half of the world's petroleum reserves. Crude oil and Natural gas are the main exports. In some countries of the region oil represents 85 to 95 per cent of exports.

## Application activity 13.4.

1. Describe the major aims of OPEC.
2. Explain how ECOWAS member states have benefited from this integration.

## End unit assessment

1. Draw the map showing the member countries of E.A. C.
2. Conduct your own research to identify different regional integrations operating with Rwanda and show their main objectives.
3. Examine the role of regional integration in the social, economic development of Rwanda.
4. Analyse the reasons for low level of international trade in developing countries.
5. What types of major commodities are involved in the international trade? With reference to any two major commodities from different parts of the world, explain geographical conditions which favour their production and state two major countries for each of the commodities which import them in large quantities.
6. With reference to either Western Europe or Africa discuss the geographical background of its export trade.

# UNIT 14

## WORLD MULTIPURPOSE RIVER PROJECTS

# UNIT 14: WORLD MULTIPURPOSE RIVER PROJECTS

## Key Unit Competence:

By the end of the Unit, I should be able to evaluate the impact of multi-purpose river projects on sustainable development of different countries in the world.

### Introductory activity

Observe the image provided below and answer the following questions:

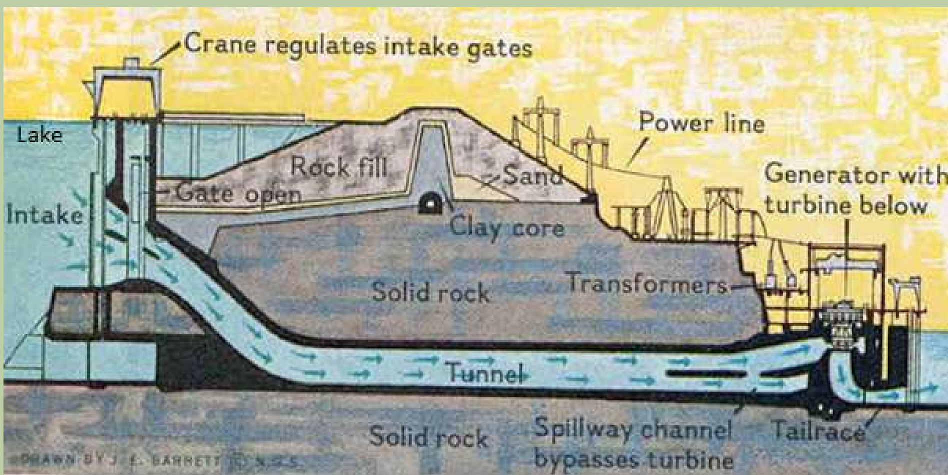
Aswan High Dam

1. What do you observe from the figure above?
2. What activity does that figure stand for?
3. Explain the two types of energy that you know and how they are produced.
4. Explain how the Multipurpose River Projects contribute to the sustainable development of countries and socio-economic welfare of population.

## 14.1. Definition, aim, objectives and importance of multipurpose river Projects

### Learning Activity 14.1.

Observe the sketch of a dam and answer the following questions:




*A sketch showing the structure of the dam*

1. List the elements found on this sketch of a dam.
2. Make a research and define a Dam and explain its importance to human activities.

### 14.1.1. Definition, aims and objectives of multipurpose river projects.

**Multipurpose River Projects**: A Multipurpose River Project refers to the project designed to use the water of rivers efficiently and improve its management for the benefit of humans and their activities for the sustainable development of the regions. These projects are based on dams built on rivers and they may be multipurpose, involving more than one purpose, for instance water storage for irrigation, and domestic uses, hydro-electric power generation, flood control, fishing, waterways transport among others. Many hydroelectric power projects serve more than one purpose, hence referred to as multi-purpose hydroelectric power projects. These projects contribute greatly to enhance the sustainable development of countries and the social economic welfare of inhabitants.

**A dam**: This is a constructed structure that forms a barrier across a river to regulate the flow of water.

**Aims of multipurpose river projects**: The aims of the multipurpose river projects are to increase the economic independence through the sustainable development of various economic sectors, the national wealth and the standards of living of inhabitants.

**Objectives of multipurpose river development**:

- To control flood.
- To provide water for irrigation, diversify agricultural production.
- To check soil erosion.
- To provide water for drinking and domestic purposes.
- To generate electricity for industries, villages and cities.
- To provide inland navigation.
- To encourage tourism and recreation.
- To preserve wildlife.
- To develop fisheries.
- To create employment opportunities.
- To promote industrialization and urbanization.
- Diversify the economy.
- Creation of settlements for the landless/surplus population.

**Hydro-electric power plant (HEP):** an hydro-electric power plant is constructed to generate hydro-electricity for industries and homes. As represented on the figure below, a hydro-electric power plant arrangement consists of basic sections such as dam, reservoir, penstock, control gates, turbines, power house which include generator and transformer and power lines.

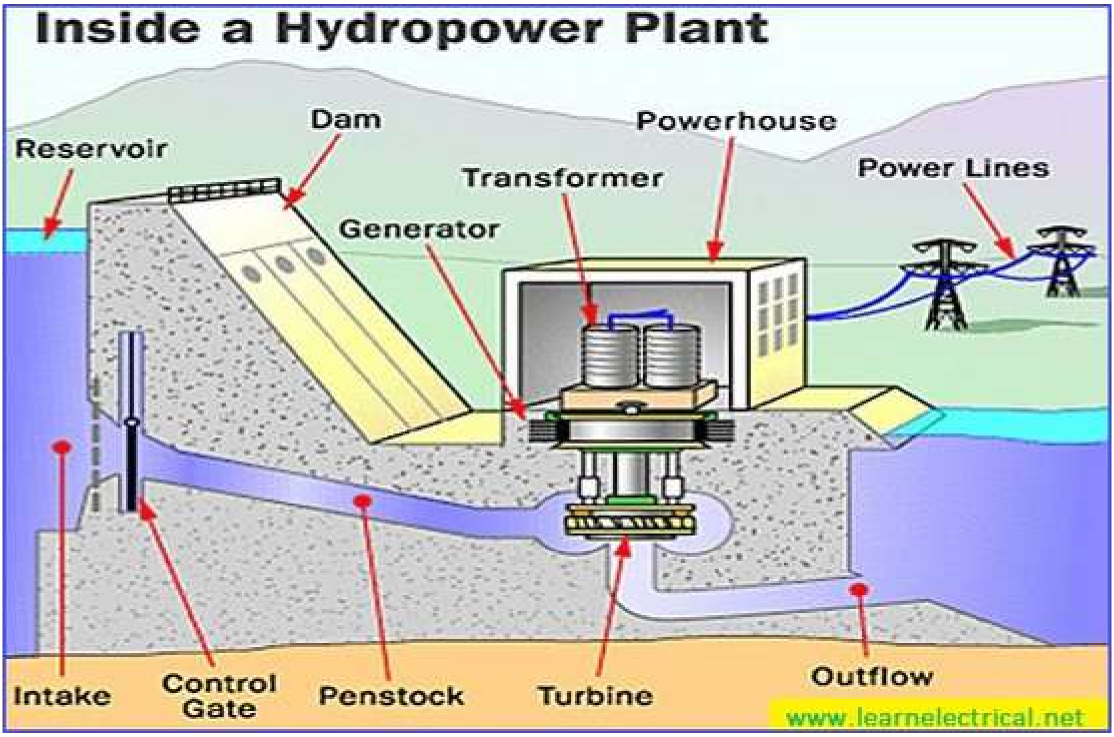



*Figure 14. 211: A typical Hydro Electric Power Station*

These basic sections are briefly described in the following:

**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).

**Reservoir**: The part of river where water will be stored is called Reservoir.

**Penstock:** Penstocks are generally made of reinforced concrete or steel to transport water from reservoir to turbine with less friction losses.

**Control Gate:** Also called crane is used to control over the water travelling in penstock.

**Turbines:** Water turbines are used to convert the energy of falling water into mechanical energy and enable generators to produce electrical energy from rotating shaft of turbine.

**Power House:** At the power house generated power from generator will be stepped up and supplied to transmission power lines.

**Power lines:** wires connected to the generators that carry electricity to homes, industries and mines.

### 14.1.2. Importance of multipurpose river projects for sustainable development

The benefits of river dam projects for the sustainable development of countries include:

- **Provision of cheap and reliable hydro-electric power**: Most river dam projects in Africa are used to generate hydro-electric power for both domestic and industrial purposes. This has saved valuable foreign exchange, which would have been used to import thermal power. In developed countries, hydropower costs less than most energy sources.
- **Provision of water**: The dams provide water for domestic, industrial and irrigation uses for local inhabitants residing nearby. The water stored behind dams is irrigation reservoir which helps in the growing of crops, especially during the dry season. This has reduced farmers' dependence on climate. Irrigation farming can be carried out to increase food supply.
- **River water is renewable source of energy**: In contrast of other sources of energy which are non-renewable because they are exhausted with time as they are exploited (e.g. wood, coal, petroleum), multipurpose river projects are mainly built on river water which is long lasting and one of renewable source of energy.
- **Development of tourism**: Some multipurpose river projects can be of tourist interests, thus earning foreign exchange, because river dam projects are associated with features like impressive architectural designs, waterfalls, dams and lakes which may be fascinating to the people that come to visit the places.
- **Generation of government revenue**: This is through taxation of workers' incomes and earning of electricity and water boards.
- **Employment opportunities**: River dam projects create employment opportunities for several people, especially those engaged in the production of hydro-electric power and supply of water for domestic, industrial and irrigated agriculture developed in the area. Provided employment raises people's standards of living.
- **Industrial development**: The projects have stimulated the development of industries as there is ample power that is generated. This enabled the boost of textile, brewing, sugar processing and steel rolling industries.
- **Development of infrastructure**: The projects have opened water transport routes or shipping routes (river navigation). Many other infrastructures such as development of towns, schools and hospital facilities among others have developed within the river valley.

- **Promotion of international relations**: There have been joint ventures in the development of river projects that have created co-operation among nations.
- **Flood control**: Dams are used to control flooding in flood-prone areas by regulating the flow of water downstream.
- **Reduction of importation**: There is reduction on costs incurred on the importation of fuel, manufactured products and foodstuffs since these are now produced locally.

### Application activity 14.1.

Knowing the aim and objectives of multipurpose river projects, explain why such projects are so important for the sustainable development.

## 14.2. Problems affecting Multipurpose River Projects

### Learning activity 14.2.

If the Government of Rwanda decides to construct a dam to generate hydro-electricity and water for industrial and domestic uses on river Nyabarongo, what problems can be faced by such a project?

The Multipurpose River Projects face many problems mostly in developing countries for their implementation or maintenance due to the **factors** briefly explained below:

**The projects are very expensive:** The projects require large funds to support construction activities. Limited resources especially in developing countries make this difficult or even completely impossible. Attracting private investors for financing multipurpose projects is difficult. Such projects also cause the displacement of people. The resettlement of people who are moved from areas where dams are built is very expensive. Once dams are constructed, in some instances there is insufficient capital to purchase the spare parts needed for efficient maintenance of machinery at the powerhouses.

**The local people have little gain from the project:** In some cases major benefits of large multi-purpose river projects go to industrialists, while the local peasants have little to gain.

**Construction of dams causes ecological problems:** The dams block the migration of fish, upsetting the ecological balance and putting several aquatic species in danger. The sudden release of large quantities of water from dams results in large-scale flooding downstream in low-lying plains. Large dams obstruct the free flow of river aquatic animals such as fishes. Floating and invasive vegetation is likely to kill the aquatic animals and vegetation.

**Problem of shortage in skilled human resources:** The establishment of multipurpose projects requires availability of skilled human resources for both construction of the project and maintenance of structures. These include professionals with varied expertise such as civil mechanical and irrigation engineers, hydrologists, and many other to be hired beforehand.

**Changes in river regime:** Some rivers do not have constant regimes and quite often are characterised by seasonality and fluctuation in water provision. This renders some projects unviable and unsustainable.

**Accelerated soil erosion, water evaporation and change in ecological conditions:** Some projects may be dogged by siltation of dams, excessive evaporation owing to increased surface area of created lake and change in ecological conditions. Clearance of forests causes the destruction of water catchment areas of the rivers feeding the dams. It further exposes the land to heavy rainfall which carries the top soil away which is deposited in the lower courses of the river. Siltation of dam floor may contribute to change in dam depth.

Large-scale irrigation may help in the spread of Bilharzia/Schistomiasis. Construction of large multipurpose river projects leads to the formation of man-made lakes. These lakes drawn rich agricultural lands ideal for crop production and human settlements.

Application activity 14.2.

*E*xplain problems resulting from the development of multipurpose river projects.

## 14.3. Solutions to the problems affecting Multipurpose River Projects

Learning activity 14.3.

Using geographical documents and internet, research on the solutions to problems affecting Multipurpose River Projects.

Many solutions to problems affecting multipurpose river projects have been suggested. The most important ones are briefly presented in the following paragraphs:

- Establishment of the project based on accurate environmental conditions such as the characteristics of river regime and seasonal fluctuations, to avoid situation where the project collapses soon after its establishment.
- Training people to do the maintenance of the machinery and infrastructures generated by the project. The lack of required home-grown skilled personnel can be addressed if governments plan early enough and invest in the area of human resource development, to improve their human resources capacity and thus reduce dependence on foreign expatriates who are always quite expensive to hire.
- Continuous monitoring and evaluation of projects and taking corrective measures are needed.
- Continued partnership and cooperation with donors and funding agencies to obtain soft or long-term loans with which to finance the project activities.
- Fight and contain the spread of Bilharzia/Schistomiasis over irrigated project areas.
- Resettle the landless due to the drawning of agricultural land by the man-made lake resulting from dam construction.

In order to maintain the viability of the projects, some of activities to undertake include:

- Removing in the waters the invasive species which are dangerous to aquatic lives.
- Allow sufficient time and money for extensive public participation to ensure that plans are optimal; that all sections of affected society are considered and; that local institutions are in place to sustain irrigated agriculture, particularly in respect of land and water rights;
- Afforestation: The increase of number of trees and vegetation protects the water catchment areas of the rivers feeding the dams. This reduces the fluvial erosion and other types of erosion which could damage the dams;
- Provide short-term support and/or skills for an alternative livelihood if irrigation removes existing livelihood.

### Application activity 14.3.

Discuss the impacts of multipurpose river projects in developing countries.

## 14.4. Case Studies

### Learning activity 14.4.

Read carefully the text that summarizes the three case studies of multipurpose river projects provided below and answer the questions that follow.

The Tennessee basin in USA was often devastated by floods and its economy depressed because the pioneer settlers and their descendants farmed using inappropriate traditional methods till the region became poverty-stricken. The soils were eroded, hill slopes were treeless, rivers which were filled with silt eroded from the surrounding hills became uncontrollable, causing huge floods on extensive parts of the region and many damages to lives and properties. The Tennessee Valley became one of the poorest parts of USA in terms of economic wellbeing.

In 1933, the president Franklin Roosevelt signed the act to establish the Tennessee Valley Authority (TVA). The TVA was created to become a regional economic sustainable development agency to modernize various economic and social sectors, including the development modern agriculture methods and industry, urbanization, generation of Hydro electricity, increase employment opportunities in the region

The Akasombo Dam, built on River Volta in Ghana was mainly Hydro-electric power oriented to supply industries and homes in the region. The project also aimed to control and regulate the flows and recurrent flooding of the River Volta, to promote agriculture through development of irrigated farming and communication, to enhance fishing and to create employment opportunities for the population and to improve the standards of living for the people in the area. In 1960, the Volta River Authority (VRA) was established by Kwame Nkrumah, the 1st president of Ghana, and was tasked to manage the development of the Volta River Basin, which included the construction and supervision of the dam, the power station and the power transmission network.

In Egypt, droughts and flooding of river Nile alternated. High-water seasons could destroy the whole crop, while low-water seasons could create widespread drought and associated famine. The project to construct Aswan High Dam in Egypt was approved by The Egyptian President Gamal Abdel Nasser. It was mainly agricultural irrigation oriented. In 1960 the construction began and was completed in 1976. The project was conceived with aim to develop sustainably the country in various economic sectors. The major objectives of the project are to prevent recurrent flooding which affects the Nile valley, to control and provide a regular flow of water for irrigation and increase the amount of irrigated land, to generate Hydro-Electric Power for both domestic and industrial purposes; to create a man-made lake (reservoir) where a fishing industry could be established, attract tourists and increase employment opportunities.

Huang He basin in China is regarded as the cradle of Chinese civilization or the "Mother River", usually a source of rich fertile soil and irrigation water. Its waters and the rich soil it carries bring agricultural abundance to support China's enormous population. The Yellow River, however, flooded more than 1,500 times in recorded history into and swept away entire villages. For instance, in 1887, the river flood killed an estimated 900,000 to 2 million people; in 1931, flood killed between 3.7 million and 4 million people. Another flood in 1943 washed away the crops in Henan Province, leaving 3 million people to starve to death. Due to damages caused by flooding waters, the river was given a name of China's sorrow and ungovernable.

From 1950, China government began to build levees and dams to hold the Yellow River back and control floods. The construction lasted over decades along Huang He and its tributaries for multiple purposes including flood control, generating hydroelectricity, promoting agriculture, developing industries and cities for a sustainable development of the region. Now answer the following questions:

1. 1. Identify the common problems faced by countries mentioned above before the establishment of multipurpose river projects.
2. 2. Identify common objectives found in multipurpose river projects of respective countries.
3. 3. Based on the text above, explain why a country can decide toconstruct a multipurpose river project.

### 14.4.1. The Tennessee Valley Authority (USA)

**i. Aims of The Tennessee Valley Authority**

The Tennessee Valley Authority (TVA) is a corporation formed for large-scale rehabilitation of a vast region which includes parts of seven adjoining states of Tennessee, Kentucky, Virginia, North Carolina, Alabama, Georgia and Mississippi, in the United States of America (*USA*). The Tennessee Valley Region is drained by the Tennessee River and River Timberland, both tributaries of the Ohio River which is a tributary of Mississippi River. The drained area is about 106,000 km$^2$.

Due to persistent flooding and soil erosion which marked the Tennessee basin for centuries, President of the USA, Franklin Roosevelt established in 1993 the Tennessee Valley Authority (TVA) to rehabilitate and to develop the entire region which was then one of the poorest parts of the USA.

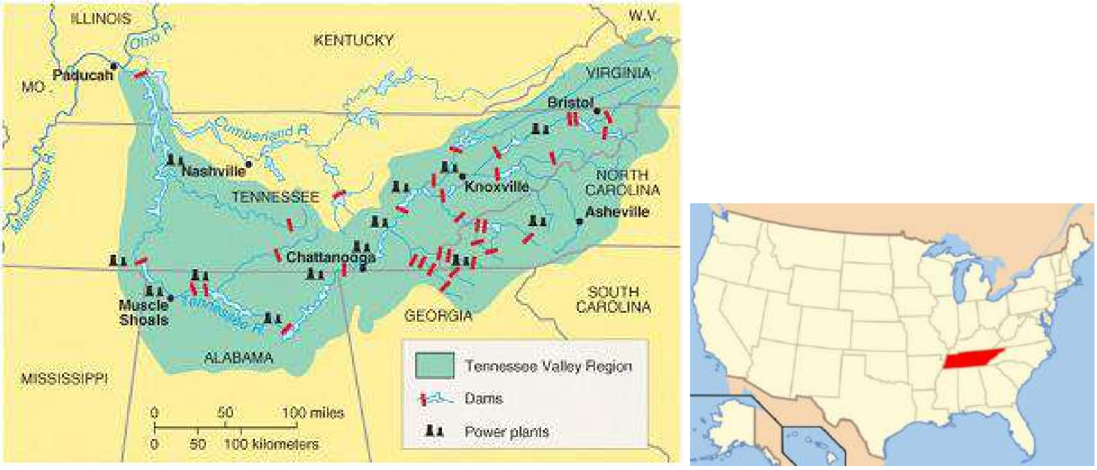



*Figure 14. 212: Map of area served by the Tennessee Valley Authority in USA*
***Source:*** *Tennessee Valley Authority, 2009*

### ii. Problems faced by the region before the creation of TVA

The region covered by TVA presented several problems for which urgent solutions were needed. The problems faced by the project include the following:

- Severe soil erosion**:** This was caused by poor methods of farming, deforestation on steep slopes and rapid population increase. These factors exposed the soil to erosion and running water created deep gullies in the area.
- Silting and flooding: They were so severe on Tennessee River and its tributaries. Tributaries often flooded causing recurrent deaths and destruction of properties.
- Famine: These were common among the local population. This is because the fertile top soils had been eroded leading to low and poor yields.
- High population growth: The pressure to get more land for cultivation caused clearance of forests. The continued traditional farming methods caused the exhaustion of soil nutrients.
- Poor housing facilities: The local administration authorities could not afford to provide sustainable and enough housing units and this caused the lack of decent accommodation.
- Poor living standards: Unemployment and poverty were widely spread in the area and people were not able to afford basic needs of life.
- Problem of transport: During periods of heavy rains, the rivers flooded and the transport of people and goods was compromised.
- Lack of fuel: There was severe shortage in fuel resources especially due to rapid deforestation within the region.
- Epidemics**:** Outbreak of diseases such as malaria and bilharzia attacked population due to constant flooding in the area.

- High government costs: Government expenses were very high especially in supply of food and drugs.

**iii. Strategies taken by the USA central government to solve the problems**

Strategies taken to solve the problems in Tennessee region were sequenced in various steps:

**Step 1**: Assignments tasked to the Tennessee Valley Authority

The following tasks were assigned to Tennessee Valley Authority when it was created:

- Building dams to control flooding of River Tennessee and its tributaries and later generate hydro-electric power. The generated electricity would be exported to other neighboring states thus reaping revenue for the state.
- Controlling severe soil erosion by putting in place sustainable conservation measures, and mechanisms for reclaiming badly eroded lands and flooded swamps in the area.
- Promotion of forestry through afforestation programs. These programs aimed to reduce flooding and soil erosion in the area.
- Improvement of the transport facilities such as roads, railways and water transport whose construction and maintenance were hindered by floods.
- Promotion of the industrial development to increase alternative employment opportunities to the people in the area, in the agriculture sector and industrial sector.
- Teaching inhabitants better farming methods to improve sustainably agriculture in the region.
- Providing enough and sustainable housing to accommodate the rapidly growing population.
- Conserving wildlife in the area.

- Controlling the spread of diseases such as malaria and Bilharzia that resulted from floods.

***Step 2****:* Concrete actions taken to control soil erosion

The following are concrete conservation measures taken by TVA to control soil erosion:

- Training of farmers: Experts were hired from outside the local area especially from other agriculturally advanced regions of USA like California and Southern USA to educate local farmers on how to improve their farming methods;
- Creation of demonstration farms: aimed at giving advice to farmers on modern

and better farming methods such as mixed farming and crop rotation;

- Re-afforestation programs: These were undertaken to plant young trees on ridges and hills. Their roots would bind the soil particles together and absorb excess water which was previously running off;
- Filling the Gullies: gullies were covered with brushwood to cover and trap soils and stones and eventually fill up the gullies;
- Terracing: this involved the cutting of a series of wide steps and construction of embankments on hilly slopes to reduce gradient and surface runoff;
- Introduction of modern farming methods: farms were mechanized in order to increase the production. The use of fertilizers and manure to maintain soil fertility was also applied.

***Step 3**:* Construction of Dams and results

- Several dams were constructed**:** Nine dams were constructed on the main Tennessee River and 23 on its tributaries. The major ones along the Tennessee River include Noris, Cherokee, Fontana, Chickamauga, Willson, Pickwick, Fort Loundon, Douglas, Kentucky, Guntersville, Hirwassee and Walts bar. All the dams can control floods, storing water, assisting navigation and generating hydro-electricity.
- The huge reservoirs created by the dams hold back enormous quantities of water: This reduced greatly the flood heights, and since then this water is released for irrigation purpose or holds water for navigation.
- Elimination of swamps: The management of swamps resulted in a complete elimination of malaria and bilharzia
- Development of tourism**:** Natural parks and man-made lakes were created. Camping, canoeing and hunting have been promoted. The scenic beauty around dams recreation facilities at wildlife reservations attract more tourists and increase foreign exchange.

- Supply of Electricity to industries**:** The TVA also directs the storage and release of water and generation of power at four dams owned by the Aluminum Company of America (ALCOA).

***Step 4:*** Construction of important infrastructures and industries

The major infrastructures and industries constructed include:

- Electric Power Station and urban development: Constructed power stations stimulated the growth of urban centres, for example, Memphis and Birmingham in Alabama State, Atlanta in Georgia and many others across the region. By 1953, 80% of homes in the region were electrified, compared with 3% at the beginning of the project in 1933. Today the full-scale rural electrification has been a great achievement for the TVA.

- Transport Infrastructures**:** Roads, air and railway transport networks were constructed in the region. Navigation on created dams on Tennessee and transportation of freights and passengers over a distance of 1.050 km are known to be among the most efficient worldwide.
- Educational and research institutions**:** Various Institutions of learning such as Universities, Colleges and Schools were constructed in Tennessee Region. All research centres were established with linkage to universities and colleges.
- Industrial centres: Industries were constructed to generate employment opportunities to the people. Major industries include Aluminum manufacturing, fertilizers industry like phosphates, paper mills, chemicals, pharmaceuticals, automobiles and food processing plants.
- Health centres and hospitals: Several health centres and hospitals were constructed to improve the health of states within the Tennessee catchment area. These are able to serve not only the seven states of the region, but the international community as well.

iv. Benefits of TVA for sustainable development of the region

TVA projects strongly stimulated the development of all social, industrial, economic, educational and cultural sectors. There are many benefits that resulted from this multipurpose Tennessee project. The following are some of them:

- The control of floods and soil erosion has been successfully and sustainably mastered.
- Cheap hydro-electric power was availed**:** This attracted diversified industries that offered employment within the Tennessee valley.

- Diversified food products: Milled grains, baked foods, confectioneries and beverages and many others are produced in the region.
- Local farmers joined the established demonstration farms: Farmers were trained on better farming methods to control soil erosion and increase crop yields.
- Diversified and improved transport networks: This encouraged significantly the local and international commerce.
- Many and diversified industries in the region process ores and other raw materials: Raw materials that were formerly processed in the North East of USA are now processed in the Tennessee region.

- Tourism was greatly promoted: The region covered by TVA earns the government of USA foreign exchange as a tourist attraction destination;
- The production of motor vehicles, boats and aircraft parts: Constitute Tennessee's largest industry in terms of contribution to overall TVA's states economies.

### 14.4.2. Akasombo Dam – The Volta River Project (Ghana)

**i. Location and site of Akasombo Dam**

The construction of the Akasombo Dam was the first Ghanaian project undertaken by the **Volta River Authority** (VRA) in 1960. The dam is located on River Volta near the Akasombo town in southern Ghana. The site has been chosen because it was where the river valley was narrowest and surrounded by a rock strong enough to hold the dam.


*Figure 14. 213: Location map of Lake Volta and Akasombo Dam in Ghana*

**ii. Aims and objectives of the project**

The project **aimed** at constructing Akasombo Dam and Volta Lake, one of the longest man-made lakes in the world. The dam is 111 m high and 660 m long at the top and 366 m at the bottom. A man-made lake; called Volta Lake, was formed behind the dam covering an area of 8502 sq.km. The Lake extends for 400 km with a shoreline of 7,250 km.

**The dam was built with the following objectives:**

- To provide cheap electricity to run the smelter: called Volta Aluminum Company (VALCo) located at the new port of Tema and to increase the Ghana's domestic and industry supplies of power.
- To control and regulate the flows and recurrent flooding of the River Volta.
- To promote agriculture through development of irrigated farming but also to provide a major inland waterway.
- To construct the Lake Volta to enhance fishing and supplement population in animal proteins.
- To create employment opportunities for Ghanaian population to improve the standards of living for the people in the area.

*Source: Copyright ©2018. created by Ghana*

*Figure 14. 214: Akasombo Dam on the River Volta in Ghana*

**iii. Factors favouring the establishment of the Akasombo river project**

Both natural, human and economic factors contributed to the establishment of Akasombo Dam project. The most important factors are given in the following paragraphs:

- The heavy and well distributed rainfall provides regular and reliable supply of water in Volta basin. This makes the flows more regular and energy produced relatively constant.
- The availability of land. The region around Akasombo is sparsely populated.
- The hard basement rocks provided a firm foundation for construction of the dam.
- The River Volta crosses a narrow gorge located at Akasombo valley in the south eastern part of Ghana where River Volta cuts through Akwapin hill.
- A large market - There is high demand for the power generated for both industrial, especially the Volta Aluminum Company (VALCo) and for domestic use, and high demand for other products from the multipurpose project.
- Foreign investors - the foreign investors especially from USA and Britain provided a support in form of skilled labour.
- The availability of capital to construct the complex to provide power and set up flood controls, from the World Bank and Britain.
- The creation of Volta River Authority (VRA) whose primary task was to manage the development of the Volta basin, which include construction and supervision of the dam, the power station and the power transmission network.
- The government policy to develop a large-scale multipurpose project to promote economic development.

### iv. Importance of Akasombo Dam

The construction of Akasombo Dam resulted in numerous benefits which contributed greatly to increase the government economy in various sectors and improved the welfare of population. The following are some of them:

- Hydro-electricity production promoted industries, port cities and international co-operation.
- The generation of hydro-electric power (HEP) has significantly reduced the expense of importing petroleum oil for thermal power stations thus saving foreign exchange.
- Cheap electricity is supplied to VALCo smelter.
- Ghana can process much of the bauxite (Aluminum ore) instead of shipping it in raw state which is bulky.
    - ❖ Akasombo dam allowed the development of numerous industries at Tema, Accra, Tokoradi and Kumasi cities. Industrial development has enabled Ghana to become less dependent on import of some food stuff and to process locally some of agriculture products, e.g. cocoa.

- It has enabled the development of ports and urban centres. For instance, Tema is an industrial city home of the Aluminum smelter. Other centres such as Accra, Takoradi offer a wide range of social and economic services.

- The dam supplies electricity to Ghana's neighbors such as Togo, Benin and Ivory Coast. This has strengthened economic co-operation between Ghana and her neighbours.
- Development of transport, fishing and tourism.

- Irrigation has promoted agriculture. New farming activities developed along the shorelines of Lake Volta as it became valuable resource for irrigation. It is a potential source for irrigation which enabled Ghana to grow various crops among others such as rice, sugarcane, maize and vegetables.
- Farming has greatly improved and diversified. The Akasombo Dam and Lake Volta are great tourist attractions which bring in foreign exchange.
- The project has generated employment opportunities to many people, for instance, people involved in the distribution of electricity in the cities of Accra, Tema, Tokoradi and others.
- The project has raised the people's standards of living and has helped in the diversification of the economy from being predominantly agricultural to industrial, mining, fishing and tourism, hence multipurpose development.

**v. Problems associated with the Akasombo dam project**

The following are some problems have been reported as the consequences of the project:

**a. Flooding of traditional farm lands and displacement of people and properties**

- The construction of Akasombo Dam was completed in 1965. Water flooded traditional farm lands behind Akasombo Dam, and 80,000 people were displaced with 200,000 animals belonging to them. The flooding was caused by the rising water of the Lake Volta, the largest artificial lake in Africa. 120 buildings that made up 700 villages prior to resettlement were abandoned and destroyed. The impacts on the environment was so great in such a way the natural vegetation, animals, road networks in the area covered by the Lake Volta were submerged.
- There was high cost of resettlement. The displaced population did not like the houses that were provided and had no money to improve them. Relocated population was not happy with the allocation of new lands. People resented the loss of their old farm lands in which they could grow vegetables or keep goats.

**b. Inadequate power supply**

- Initially, the dam's power production capacities greatly overreached the actual demand. Due to the development of H.E.P., other power sources lost market, which discouraged other producers.
- Since the dam's inception, increasing demands for power exceeded what can be provided by the current structure and resulted in the doubling of hydro-power production needs.
- The Volta Aluminium Company needed a lot of power for smelting Aluminium and it consumed more than half of the power produced, so several areas were deprived of the use of electricity.

**c. Seasonal lowering lake levels and decreasing in power output**

- A trend of lower lake levels has been observed, sometimes below the requirement for operation of the Akasombo dam. During periods of drought, there is reduction in the lake levels which decreases the expected power output. For instance, in the beginning of 2007, there were great concerns over the electricity from the Akasombo dam due to lower water levels in the Lake Volta reservoir.

**d. Environmental and economic problems**

- Lake Volta became a habitat for disease vectors like water snails and mosquitoes, which are found in stagnant water, this led to spread of bilharzia and malaria respectively.
- It has been reported that the lake floor is being silted by sediments, which reduce the depth and the water storage capacity of the lake.
- The creation of the Lake Volta in the centre of the country, divided the country into two, e.g. East and West. This became a barrier to communication.
- The development of industries such as Aluminum smelter and oil refining at Tema led to environmental pollution.
- Since there was less power available for domestic use and others uses, high prices were charged for electricity and it became expensive to many people.
- The development of the project has been dependent on overseas finance, and the companies like VALCo were mainly concerned with their commercial interest and hence profit repatriation.

### vi. Solutions to problems resulted from Akasombo Dam

Many solutions have been envisaged to solve problems that resulted from the construction of Akasombo Dam. These solutions are briefly highlighted and described below:

- The dam's power plant initially opened with four units, with a total installed capacity of 588 MW. This was upgraded in 1972 with the Addition of two units to generate 912 MW. These two units were upgraded in 1999 and 2005 respectively to generate additional 170 MM each increasing the total generation capacity of the dam to 1,020 MW.

- 80 % of electricity generated by the dam is supplied to the America-owned Volta Aluminium Company (VALCo), while the remainder is supplied to Ghana and her neigbours, mainly Togo and Benin.
- By 1981, a smaller dam was built near the town of Kpong, downstream from Akasombo. This project aimed to generate an addition 400 MW of power to that produced by Akasombo dam, to supply local industries and socio-economic activities.
- Further upgrades to Akasombo have become necessary for maintaining hydropower outputs.
- The 80.000 people displaced due to the construction of the project were resettled into 52 resettlement villages.

### 14.4.3. Aswan High Dam (Egypt)

**i. Aims and objectives of the project**

Aswan High Dam is located in southern Egypt, on River Nile. The construction of the dam started in 1960 and was completed in 1970. The dam is about 3830 metres long and 111 metres high. Its base is 980 metres wide. The completion of the construction resulted in the creation of a man-made lake known as Lake Nasser, one of the longest reservoirs of the world. The reservoir was named after Abdel Nasser, the president of Egypt at the time. The lake covers an area about 550 km long and 16 km large. Lake Nasser is 35 km at its widest and has 5,250 sq. km. The lake extends into Sudan. The dam generates 2,100 megawatts (MW) of electricity and is able to resist by its weigh the great pressure of River Nile.


*Figure 14. 215: Location of Aswan High Dam and Lake Nasser in Egypt*

The project to construct Aswan High Dam was conceived with aim to develop sustainably the country in various economic sectors. The major ***objectives*** of the project are:

- To prevent recurrent flooding which affects the Nile valley during the rainy season, mostly in August and September.
- To control and provide a regular flow of water for irrigation, during both the dry and rainy seasons.
- To enable the country to grow enough food to feed the growing population.
- To increase the amount of irrigated land.
- To generate Hydro-electricity Power for both domestic and industrial purposes.
- To create a man-made lake (reservoir) where a fishing industry could be established.

***Source:*** *https://www.water-technology.net/projects/aswan-high-dam-nile-sudan-egypt/*

***Figure 14. 216****: Structure of Aswan High Dam in Egypt*

**ii. Factors favouring the construction of Aswan High Dam**

The success of the construction of the Aswan High Dam was a result of a combination of the following factors:

- Strong basement rock: The dam was constructed where a strong basement rock to support heavy dam structures existed. This provided a firm foundation for the dam.

- The channel was narrowed where the dam was constructed. This made the construction cheaper and easier.
- Presence of large capital invested: The construction and the maintenance of the dam were made possible by funds provided by the Soviet Union and Egypt goverments.
- Availability of skilled labour: Russian experts and egyptians semi-skilled labour were hired to construct the project.

- Advanced technology involved in the general work of dam construction which included strong turbines which produce high power voltage.

### iii. Importance of Aswan High Dam for the sustainable development of the region

The Aswan High Dam Project has contributed greatly to the Egyptian economy and the welfare of rural and urban population. This became a source of government revenues, creation of employment opportunities for many people. The importance of Aswan High Dam can be summarized in the following:

- **Flood control:** The dam enabled the control of floods and regulated the flow of the River in the Nile valley. People's lives and properties are safe in the Nile valley. This saved money which was formerly spent on displaced people. The reservoir created provides water in times of droughts.
- **Production of Hydro-electric power (HEP):** Aswan High Dam has an output of about 2100 MW. The production of (H.E.P). has led to the development of diversified industries in the region, such as iron and steel, textiles; mining industries especially oil drilling (Petro-chemical) and sugar refining especially in Cairo and the free zone area of the Nile delta. The establishment of industry has created employment opportunities to the majority of local Egyptians.
- **Provision of power for domestic purpose:** There has been a program of rural electrification, especially along the Nile and in rural villages because of the presence of the Aswan High Dam.
- **Improvement of agriculture sector:** Irrigated land area of Egypt has increased by 25 percent since Aswan High Dam is established. Farmers can now grow several crops in the year, such as maize, wheat, barley vegetables and others.
- **The water in the region is supplied on regular basis:** L. Nasser holds with 80 % of its water going to Egypt and 20 % to Sudan. The water stored is used for irrigation.
- **Promotion of fishing:** Lake L. Nasser has promoted the fishing industry,
- **Promotion of tourism**: The Aswan High Dam and Lake Nasser are tourist attractions. This enables to earn foreign exchange.
- **Reduction of costs to import fuel:** The construction of the dam has resulted into a significant reduction of costs incurred on the importation of fuel petroleum products.

### iv. Problems associated with the construction of the Aswan High Dam

The construction of Aswan High Dam involved a number of problems. The most important are briefly presented below:

- **There was displacement of people and their livestock:** 42,000 people who used to live in the region that is now covered by Lake Nasser were evacuated 1,300 km by rail across Nubian Desert to Khasm El Gibra.

- **A lot of cost for resettling displaced people**: Much fund was involved to relocate people since they were given double their foremen hectares of land and the irrigation and electric power had to be provided from the new dam.
- **Pollution of water, soil and air:** this was due to the establishment of industries in the area.

- **Increase of diseases like bilharzias and malaria**: The outbreak of these diseases was caused by stagnant water, This causes great expense to the government economy in treating its people.
- **High evaporation of water:** It is estimated that 25% of water is lost through evaporation because of high temperatures. The high evaporation rates lead to increased saline deposits in the soil which are associated with decreased yield.

**v. Solutions to the problems associated with Aswan High Dam**

Some solutions have been put forwards to solve problems caused by the Aswan High Dam.

- Regular dredging is carried out to remove waste matter which affect the drainage of the new valleys.
- Treatment of waste (recycling) is performed before their disposal. Some environmental laws have been set to regulate dumping in the river.
- Construction of levees to control overflow of water that resulted in floods.
- Use of ferry and steamers to ease the communication around Lake Nasser.
- Spraying to control diseases such as Bilharzia spread by snails from the stagnant water which gives a breeding ground for them.
- There is a legislation against brick making along the river bank.
- Farmers are sensitized to the use of organic manure as opposed to inorganic fertilizers to reduce salinity and soil pollution.
- Sensitization of population for new settlement plans: There has been a general sensitization for new settlement along the river bank against dumping of garbage in the river which is partly responsible for making the river burst its banks.

### 14.4.4. Huang He River Project (China)

#### i. Location of Huang Ho River

Huang He called the Yellow River (formerly known as the Hwang Ho), is located in China. The river originates from the Northern part of mount Bayan Ha of Tibet plateau in Qinghai province and runs Eastwards, a distance of 5,464 km to empty in the Bo-hai Sea at Shantong.

The river flows through 9 provinces namely Qinghai, Sachuan, Ganso, Ningxia, Inner Mangolia region, Shanxi, Shaanxi and Shanang.


***Figure 14. 217**: Huang Ho the longest and largest river after Yangtze River*

The project Huang Ho Basin Development covers parts of provinces highlighted above, over an area of 750,000 km2. The main tributaries of the Huang Ho in its lower riches include Taohe, Jighe, Welhe, Luohe, Fehhe, Yihe and Qinhe. The Huang Ho River is China's longest and largest river after the Yangtze River, with over 30 tributaries feeding it.

Huang He is a shifting, turbulent and silt laden stream that often overflows its banks and sends its flood waters across the North Eastern China's plain. It gets nearly 45 % of its water from glaciers and vast underground springs of the Qinghai-Tibet Plateau. The word **Huang** means Yellow. It refers to the color of the river's waters, for the river carries a heavy load of silt.

*Source: https://abcnews.go.com/International/china-meet-yellow-river/story?id=16468814*
*Figure 14. 218: Map showing how the River Hwang-Ho valley is cultivated for crop production*

**ii. Problems faced in Huang Ho Basin**

The following are some of challenges faced in the Huang He basin:

- **Several foods along the Huang He River**: The flooded areas of Huang Ho valley suffered from considerable damage to life, housing and properties, transport and communication. The flood problems are often exacerbated by deforestation. About 500 people die from them in Yunnan province alone. In September 2003, torrential rains and floods destroyed 17,000 homes in Hennan Province and forced more than 200,000 to flee their homes in Hennan and neighbouring Shaanxi Province. Floods trigger mudslides, cutting of power and telephones, destroying roads and bridges. These caused stresses, famine and spread of diseases among people.

- **Severe soil erosion and large silt load**: The river carries a large amount of soil. It was estimated that every cubic metre of Huang He contains 37, 6 kg of silt. The heavy load of sediment causes the yellow river to constantly deposit the soil along the bottom of the channel which raises the bed, contributing to the floods.
- **Irregular flow and change of river course:** The amount of river discharge depends on the seasonal variation of the river regime which is high in volume in the rainy season and low discharge in the dry season. When floods occur, the river breaks out of the levees into the surrounding lower flood plains and adopt a new course, which result in more damage to people living in the lower reaches.

- **The river faces a threat of drying up:** The Huang He River has dried up more than 30 times since 1972. Increased drying up is caused by increased storage surface of water due to the construction of dams, and the flowing of the river through a desert dry land of Tengger desert and Ordos desert.
- **High population growth rate**: This created pressure on land by an increased agricultural irrigation. There is also an increased demand for the river water owing to population increase.
- **Problem of pollution**: Huang Ho River faces the problem of pollution. The river crosses the major coal producing industries areas and huge population centres. Over 4,000 .petrochemical factories are located in Huang Ho river basin, and all of the fish species found in the Huang Ho have become extinct because of dams, falling water levels, pollution and over fishing.

**iii. Aims and objectives of Huang Ho Basin Development project**

In 1950 the government of China created a multipurpose project called "***Huang Ho Basin Development***". The major aim was to control devastating floods and to sustainably develop areas around the yellow river.

The major objectives of the project are meant:

- To reduce the risks of flood to lives and properties;
- To produce energy and increase the discharge during dry periods;
- To retain silt and store water for irrigation;
- To provide water for home consumption and industries.

**iv. Importance of the project**

The Huang-Ho Basin development project is of **outmost importance** for China in various economic sectors. The project has contributed to the sustainable development of the region, as briefly presented below:

- **Several dams were built**: over 40 dams were built along Huang He and its tributaries to regulate the flows of water and to produce hydro-electric energy. Activities of construction were sequenced between 1960s and 2010s. The most documented hydroelectric power stations of the project include *Sanmenxia, Xialangdi, Sanshengong, Qintong Gorge, Luijiiaxia, Lijlaxia Dam, Yuanguoxia, Lianqio, Bapanxia, Da George Dam, Li Geong Dam, Wanjiazhi Dam and Laxiwa Dam*.

- **Development of cities and settlement centres**: Several cities were created and greatly expended in the Huang He basin (see the map below). More than 400 million people have settlements in the Huang-Ho river basin. This was possible because of the multi-functional projects focusing on the development of traffic (roads, navigation on Huang-ho River year round), ecology, economic and flood prevention for the cities along the river that attract people to settle in the area for employment opportunities. The most important cities are represented on the map below.


***Source**: Annie Wu, 2015*

**Figure 14. 219**: *Important cities developed along River Huang He*

.

- **Creation of reservoirs**: Some dams were created with the main purpose of storing water. For instance *Longyang gorge, Liujia Dam, Xialangdi Dam*
- **Floods control**: The regulation of rivers' flow has virtually eliminated floods that regularly submerged the northern china's plain.
- **Food production**: The crops grown are rice, wheat, maize, soyabeans, potatoes, sweet potatoes and cereals. This uspports a large population living along the river basin.
- **Remarkable expansion of irrigation**: Irrigation of the dry areas of the northern part of China was made possible with the help of the Huang-Ho River. irrigated area increased from 0,8 million hectares in 1950 to 7.5 million hectares in 2000.
- **Tourist attraction**: Many tourist centres along Huang He promote the tourism industry. The touristic features include the Hukou falls in Shaanxi, the caves, stone statues and the Huang-Ho river dams, among others. Tourism is a major foreign exchange earner in China.
- **Industrial development** is facilitated by the Huang-Ho River. A number of industries have developed in the region, such as petrochemical factories and

mining industries. The river provides significant amounts of water to industries to cool the machines.

### v. Challenges

The area faced, however, challenges associated with water crisis. Some of problems are briefly presented below:

- Increased rate of water demand and use resulting from high population growth and regional economic development caused the drying up of the flow of the river.
- Parts of the river especially in mountain area remain frozen in winter season during which water remains frozen, and the water supply from precipitation is limited.
- The Yellow river crosses some arid and semi-arid region. Thus precipitation and water sources are limited.
- The land surface change from slope land to terraces has involved expansion of irrigation activities which affected the regional hydrology and rive flow.

### vi. Measures to solve problems related to water shortage

There is a water transfer from the South to the North project to channel through the ground canal from River Yangtze where water sources are relatively rich in the South to the Huang Ho where water resources are limited.

## Application activity 14.4.

1. Discuss the problems faced by the region before TVA project was created.
2. Discuss the strategies used to solve identified problems in the region of concern.
3. Explain the benefits of TVA projects.
4. Identify aims and objectives of multipurpose river projects in the studied countries.
5. Compare factors that favored the construction of multipurpose river projects in Ghana and Egypt.
6. Based on each of the case studied in this lesson, compare problems faced by respective countries before the establishment of multipurpose river projects.
7. Based on each of the case studies analyzed above, explain problems that result from multipurpose river projects in both developed and developing countries and how these problems are solved.

## End unit assessment

1. Describe the benefits and the challenges of multipurpose river projects, and suggest ways to overcome those challenges.
2. Compare the importance of Tennessee Valley Authority and Huang He Basin Development project in the sustainable development of USA and China respectively.
3. Referring to Aswan and Akasombo dams, explain how multipurpose river projects can contribute to the sustainable development in the other developing countries.
4. Discuss the economic impact of Tennessee Valley Authority and Huang He Basin Development Projects to their respective countries.
5. Considering the requirements of constructing a multipurpose river project, identify the factors that can favour or limit such project in Rwanda.
6. Based on the case studies studied in this unit, explain the economic advantages that Rwanda would benefit if it had constructed a multipurpose river project.

# UNIT 15
# ENVIRONMENTAL CONSERVATION AND TOURISM

# UNIT 15: ENVIRONMENTAL CONSERVATION AND TOURISM

## Key unit competence:

By the end of this unit, I should be able to evaluate the impact of conserving natural resources and tourism on the sustainable development in the different countries of the world.

### Introductory activity:

Observe the photograph below and answer these questions:

1. Identify the economic activity taking place in the photograph.
2. Describe the vegetation shown in the foreground of the photograph.
3. Why is it important to conserve wildlife in national parks?

## 15.1. Definition, components and factors of environmental degradation

Learning activity 15.1:

a. Identify the physical features shown on the photograph above.

b. Explain human and physical factors that accelerate environmental degradation.

### a. Definition of the environment

The word **Environment** is derived from the French word “Environ” which means “surrounding”. Ordinarily, environment refers to all things that surround us. Our surrounding includes ***biotic* factors** like human beings, plants, animals, microbes and ***abiotic* factors** such as light, air, water, soil, etc.

**Environmental degradation** refers to the deterioration of the Earth’s natural surroundings because of excessive exploitation of the available resources: water, air, flora, fauna, soil etc**.**

**Environmental conservation** is the act of protecting the environment against destruction.

b. **Components of the environment**

- **Abiotic environment:** It includes all non-living things like rocks, minerals, water, weather conditions.
- **Biotic environment:** It includes all living things like plants, animals, Micro-organisms.

c. **Factors responsible for environmental degradation:**

- **Overpopulation:** Rapid population growth puts strain on natural resources which results in degradation of our environment. Mortality rate has gone down due to better medical facilities which have resulted into increased lifespan. A big population simply means more demand for food, clothes and shelter. You need more space to grow food and provide homes to millions of people. This results into deforestation which is another factor of environmental degradation.
- **Pollution**: Pollution, in whatever form, whether it is air, water, land or noise is harmful for the environment
- **Deforestation**: Deforestation is the cutting down of trees to make way for more homes and industries. Rapid growth in population and urban sprawl are two of the major causes of deforestation. Apart from that, use of forest land for agriculture, animal grazing, forest harvesting for fuel wood and logging are some of the other causes of deforestation. Deforestation contributes to global warming as decreased forest size puts carbon back into the environment.
- **Swamp reclamation**:The extensive drainage of swamps or wetlands has serious effects on the environment. This has resulted into inadequate water supply and the drained areas soon become arid.
- **Bush burning:** This is done by different societies for different reasons. Burning of the vegetation results into the land being left bare thus the exposure of the top soil to wind and running water hence erosion and soil deterioration.
- **Urbanization:** Urbanization refers to the increase of population in urban areas and the horizontal expansion of urban areas. Urbanization is, therefore, associated with the expansion of the city over the natural environment, the increase of traffic congestion, smoke, acidic rainfall, global warming, etc.
- **Extraction of minerals:** Mining and quarrying of rocks lead to exhaustion of minerals, destruction of scenery beauty, increased pollution, mining operations release effluents that contaminate water.
- **Natural Causes**: Things like avalanches, quakes, tidal waves, storms, and wildfires can destroy nearby animal and plant groups to the point where they can no longer survive in those areas.

Application activity 15.1

Compare the main factors of environmental degradation between the city of Kigali and the Northern province of Rwanda.

## 15.2. Consequences of environmental degradation, methods of environmental conservation and importance of environmental conservation.

Learning activity 15.2:

1. Observe the photograph above and identify the phenomena that took place in this area.
2. Explain the effect of the human activity shown on the photograph above on the environment.

**a. Consequences of environmental degradation**

- Deforestation reduces rainfall, drives climate change and desertification. This creates severe climatic conditions that impact on various human activities mainly agriculture.

- Flooding destroys agricultural land, crops, loss of properties, lives and contaminates safe drinking water.
- Accelerated soil erosion due to deforestation making the land to become unproductive.
- Increased landslide leads to large expanses of bare land and this limit human occupancy.
- Silting of rivers, seas and oceans this has led to reduction in size of water bodies and this affect the climate of the surrounding areas and the productivity of the land.
- Increased sedimentation: This leads to the reduction of water levels in river, streams, swamps and lakes and finally the occurrence of drought.
- Increased global warming: This leads to gradual rise in world temperature which destroys Ozone layer, high evaporation rates and aridity.
- Desertification: This reduces the land productivity due to the spread of desert - like conditions such as very low rainfall, high temperature and low humidity.
- Impact on human health: Areas exposed to toxic air pollutants can cause respiratory problems like pneumonia and asthma. Millions of people have died of indirect effects of air pollution.
- Biodiversity loss: This is the reduction of large plants and animals. Biodiversity is important for maintaining balance of the ecosystem in the form of combating pollution, restoring nutrients, protecting water sources and stabilizing climate. Deforestation, global warming, overpopulation and pollution are some of the major causes for loss of biodiversity.
- Ozone layer depletion: Ozone layer is responsible for protecting earth from harmful ultraviolet rays. As the ozone layer will deplete, it will emit harmful radiations back to the earth.
- Loss for tourism industry: Environmental damage in the form of loss of green cover, loss of biodiversity, huge landfills, increased air and water pollution can be challenges to tourism.
- Economic impact: This is when the country invests much money to restore degraded zones. For examples, the government of Rwanda is spending much to assist people affected by recurrent natural hazards. The economic impact can also be in terms of loss of tourism industry.

### b. Methods of environmental conservation

The conservation of the environment can be done through different ways such as the following:

- Environmental education and awareness through the mass media (radios, newspapers, etc).
- Introduction of better farming methods which help to maintain soil fertility

and to prevent soil erosion.

- Enacting of laws protecting the environment like forest, wetlands, wildlife, etc.
- Establishment of national parks and wildlife reserves to protect the wild animals.
- Developing alternative sources of energy like solar energy, hydro- electric, biogas energy etc.
- Treatment of industrial wastes before discharge into lakes, rivers, oceans etc.
- Afforestation and reforestation as trees help to protect catchment areas, control surface run off and the balance of weather and the ecosystem in general.
- Controlling population growth and its negative effects through birth control and family planning.

**c. Importance of environmental conservation**

Environmental conservation is important for many reasons, including protecting the ozone layer, maintaining animal and human food chains and making efficient use of non-renewable resources. It saves our natural resources, reduces pollution, preserving potable water, by saving water we would be saving the lives of plants, animals and mankind. That's how conservation would benefit the environment.

### Application activity 15.2:

1. Identify the negative impacts of environmental degradation in your area.
2. Describe the areas of Rwanda that mostly experience environmental degradation and suggest the measures to be taken for environmental conservation.

## 15.3. Pollution

Learning activity 15.3:

Observe the photographs above and:

a. Differentiate the types of pollution shown.

b. Apart from the types of pollution shown on the photographs, what are other forms of pollution?

c. Explain how pollution affects man and the environment.

The term **pollution** may be defined as all processes that lead to the contamination of the environment or the introduction of contaminants in the environment that causes instability, disorder, harm or discomfort to the eco-system.

### 15.3.1. Main types of pollution

i. Air pollution: This refers to all harmful substances that can be transported in the air we breathe such as smoke, car-fumes, etc. which cause health issues to people and animals or affect property.
ii. Water pollution**:** This refers to all the processes that lead to the addition of toxic and harmful substances like industrial effluents to both surface and underground water thereby, contaminating it and making it less safe for use.
iii. Land/soil pollution**:** This is a process of increasing dumping of waste materials on/to the land such as agricultural fertilizers, industrial wastes, etc.

iv. Noise pollution: This is the harmful or annoying level of noise. It is common in urban centers where there are many vehicles, big trucks, trains and near airports and industries.

### 15.3.2. Causes of pollution

- Fossil fuels such as coal, oil and petroleum, is the leading cause of the greenhouse effect and is responsible for rising of global temperature.
- Gases emitted by automobile contain unburned hydrocarbons, carbon dioxide-oxide of nitrogen that contributes to acid rain, smog and global warming.
- Chemicals such as pesticides, herbicides used in farming activities pollute the soils while killing micro-organism in an area.
- Disposal of garbage from large cities leads to the contamination of land. The garbage consists of high synthetic and plastic materials that take longer to decompose than the primary biodegradable waste materials.
- Industries discharge their wastes into nearby water bodies thus polluting them.
- Nuclear tests done in open water surfaces pollute them hence affecting aquatic life.

### 15.3.3. Effects of pollution

- Pollution leads to the reduction of fresh air which is very vital for humanity and animals during respiration.
- It is the main factor of global warming or greenhouse effect, water borne diseases such as typhoid, cholera and bilharzia.

- Air pollution leads to air borne diseases of respiratory system such as bronchitis, lung cancer, and tuberculosis.
- Heavy pollution affects visibility which can cause traffic accidents.
- It also leads to the formation of acid rain. When such rain reaches the ground, it pollutes and spreads pollution even into surface and underground water bodies.
- Destruction of the Ozone layer due to different gases emitted in the atmosphere. Therefore, dangerous solar radiations reach the earth surface.
- Soil pollution leads to the formation of barren land, which is not productive unless fertilizers and soil additives are utilized.
- The use of atomic bombs results into the pollution of the land reducing its productivity as well as malfunctions of the human bodies.

### 15.3.4. Solutions to the problems of pollution

- Treatment of the pollutants before their disposal so as to reduce the degree of toxicity and harm they can have on the water bodies.
- Setting laws to prohibit the discharge of toxic wastes into international water bodies.
- Building of sea wages treatment plants before it is discharged into lakes and river
- Car manufacturing countries are redesigning their car engines and exhaust systems so as to ensure further combustion and thereby reduction in the level of concentration of toxic gases.
- Clean up areas where oil spills, a cleaning exercises has been undertaken to remove oil substance from the surface of the water and make water clean.
- The issue of nuclear test can be overcome by signing several treaties through organizations like United Nations and NATO.
- Introduction of environmental friendly techniques of controlling weeds and pests such as physical and biological methods.
- Construction of elongated chimneys high into the sky will protect the surrounding areas from the immediate disastrous effect of pollution.

#### Application activity 15.3:

Describe the human activities that accelerate pollution in your environment and suggest measures to reduce pollution.

## 15.4. Catastrophes

**Learning activity 15.4:**

On May 4, 2018, the Online Journal Umuseke.com reported that within the last four months about 180 people lost their lives, 4000 hectares of crops, many bridges and roads were destroyed because of natural catastrophes. This is a serious environmental issue.

1. Referring to your knowledge on the physical and human geography of Rwanda, what are the causes of such catastrophes in Rwanda?
2. What forms of catastrophes do you observe in your local environment?

**A catastrophe** is a large-scale disaster or a horrible event. We have natural catastrophes and non-natural calamities.

### 15.4.1. Natural catastrophes

A natural catastrophe is an unexpected event, caused by nature

**Table showing natural catastrophes**

| Type of catastrophe | Definition and causes |
|---|---|
|  Earthquakes | **Earthquake** is the vibration or shaking of the ground due to sudden release of energy stored in the rocks beneath the earth surface.<br><br>Earthquakes may result from a combination of factors like faulting, volcanic eruption, landslides where for example faulting causes vibrations which would spread far from the center of disturbance. |
|  Drought | **Drought**: This is a prolonged period of low rainfall and shortage of water resulting from too much sun shine. |
|  Flood | **Flood:** This is an overflow of a large amount of water beyond its normal limit. This means that water spreads to cover areas that are normally dry land.<br><br>Floods are caused by prolonged heavy rainfall on extensive plains and meandering river courses. |

| | |
|---|---|
|  **Tsunamis** | **Tsunamis:** This is a series of waves in a water body caused by the displacement of a large volume of water, generally in an ocean or a large lake.<br><br>Tsunami is caused by earthquake and volcanic eruption that leads to displacement of water in different directions. |
|  **Wind** | **Wind:** This is air in motion above the surface of the earth. It is caused by differences in pressure. Air moves from areas of high pressure to areas of low pressure.<br><br>The wind with high speed causes enormous catastrophes where it passes such as destruction of houses, etc. |
|  **Volcanic eruption** | **Volcanic eruption** is a process through which a stream of solids, gases and ash is violently ejected to a height of several miles from a volcano.<br><br>Volcanic eruption results from the increase of temperature within the mantle (interior of the earth), and this forces molten materials to erupt. |

**Diseases:** A disease is a disorder of structure or function in a human, animal, or plant. It produces specific symptoms or affects a specific location and is not simply a direct result of physical injury, e.g. cholera, tuberculosis; AIDS, etc. Poor hygienic conditions cause diseases like cholera while disease like AIDS are caused by virus called Human Immune Virus (HIV)

### 15.4.2. Non natural catastrophes /calamities

**Non-natural catastrophes:** These are disasters or emergence situations of which the principal, direct causes are identifiable human actions or deliberate causes.

- **i. War:** It refers to a state of organized armed conflict between countries or groups within a country. Wars are caused by misunderstanding and mistrust between and among the parties involved. These could be flowing from social, economic, ideological, political or cultural matters.
- **ii. Famine:** It is a widespread scarcity of food that may apply to any faunal species, which phenomenon is accompanied by regional malnutrition, starvation, epidemic and increased mortality. Famine is caused by droughts, floods, crop failure due to pests and diseases, rapid increase of population, bad government policies and political instability.
- **iii. Fire:** A state, process, or instance of combustion in which fuel or other material is ignited and combined with oxygen, giving off light, heat, and flame. High atmospheric temperatures and dryness (low humidity) offer favorable circumstance for a fire to start.

### 15.4.3. Effects of catastrophes

- Loss of lives and destruction of properties. This happens when buildings fall down due to earthquakes, floods, Tsunamis, etc.
- Droughts wither the plants and human beings face hunger and starvation. Animals and birds die; some move away to look for food.
- Population decreases in places where catastrophes occur due to displacement and death of people.
- Agricultural and industrial productions are negatively affected by pests and diseases.
- Occurrence of water borne diseases like bilharzia which is caused by water snails in stagnant water.
- Catastrophes reduce the capacity of the soil to store nutrients and water, thus make the environment drier.
- Catastrophes can lead to mudslides, soil erosion and landslide in mountainous areas.
- The government spends a lot of money for restoring the damages. This money would be used in other developmental projects.
- Degradation of the crust by sediments on the earth surface by stripped soils or the weathering of rocks at their base where they are in contact with the soil.

### 15.4.4. Solutions to catastrophes

It is not possible to stop catastrophes. But it is possible to reduce the damage they cause. People can do the following:

- Building terraces and channels. These help to drain the standing water.
- Droughts can be controlled by afforestation, whereby the levels of air moisture and precipitation are increased.
- Water reservoirs can also be constructed so that they are used to irrigate the farms and seedlings.
- Increasing roughness of the soil surface. This entails cropping techniques that leave large clods on the soil surface or ridges perpendicular to the direction of the prevailing wind.
- Increasing plant cover. Wind-speed can also be cut by increasing plant density. Since this is clearly not easy in arid zones, it is particularly important to ensure sound crop residue management, keeping residues on the ground so as to increase roughness and protect the soil surface. This is better than ploughing in, which would only slightly improve soil structure and resistance to wind.
- Practice modern agriculture. These include use of fertilizers, irrigation and improve food storage facilities.
- Government must provide budget to control catastrophes. It has also to assist farmers by giving them loans they can use to improve sustainable farming practices and techniques.
- Prevention of human-caused fires through education and environmental modification. This includes silviculture activities, people's participation, and education enforcement.
- Building houses that can resist to earthquakes.
- For the prevention of the wars, people should discuss any differences that arise. This is good as it helps to resolve conflicts. Fighting should never be an option.

## Application activity 15.4:

1. Rwanda experiences many catastrophes each year:

   a. Describe the common catastrophes in Rwanda.

   b. Identify the most affected regions in Rwanda and why.

   c. Explain the effects of catastrophes on sustainable development of Rwanda.

2. Identify the types of natural catastrophes common in your area and suggest ways to mitigate them.

## 15.5. Tourism

### 15.5.1. Definitions, major tourist areas of the world and factors affecting the development of tourism in the world.

Learning activity 15.5.1:

Observe the above photograph and answer the questions below:

1. Identify and explain the main physical features observed.
2. Explain how the mountain shown influences tourism in the area.
3. Besides mountainous areas, identify other tourist areas of the world.

**a. Definitions**

- **Tourism** is a travel from one place to another for the purpose of leisure, research, business, instruction and education.
- **Eco-tourism / ecological tourism (green tourism)** is the practice of involving the community living around the tourist attraction sites in the management and conservation of such sites and the surrounding environment.
- **Domestic tourism** is whereby the local people visit places of interest within their country for study, pleasure or recreation.
- **International tourism** involves organized tours by people from their countries to other countries.

**b. Major tourist areas of the world.**

Our world is full of indescribable beauty, both natural and artificial, and it is unclear whether one life really enough to really experience all that. Most of us will probably never see anything the world has to offer us, but it's worth a try. The most areas of the world are:

- New York as the headquarter of international organization like United Nations, World Bank, etc.
- Europe as a developed continent with magnificent cities such London, Paris, Geneva etc.
- Rome, Mecca and Jerusalem as religious centers.
- Historical sites like pyramids of Egypt, Great Wall of China,
- National parks and resorts like Disney World in Florida (USA), Disney in Paris (Europe), Akagera (Rwanda).
- Beaches in Germany, Seychelles and along coastal lands.
- Mountainous regions like Alps, Himalayas, Kilimanjaro, Rockies, Atlas, Appalachians, Birunga in Rwanda, etc.

### c. Factors affecting development of tourism in the world

- **Climate:** A favorable climate especially sunny condition attracts people from cooler northern countries to tropical regions.
- **Political stability** favors the development of tourism as the average tourist tends to be easily frightened away from an area with insecurity.
- **Capital:** Acquired funds help to develop tourist physical and human resources.
- **Government policy:** Governments set explicit policies of encouraging tourists to visit their countries by creation of board which plan, market and manage the tourism industry. This is one of the responsibilities of Rwanda Development Board (RDB) in Rwanda.
- **Accessibility:** Improvement of means of transport like roads, airport, favor the development of tourism.
- **Accommodation:** Tourists will be influenced to travel to those destinations where they are assured of decent and affordable accommodation.
- **Advertisement:** Tourist attractions are made known to the local and international community using mass media. This information markets wildlife and other tourist attractions.
- **A wide range of tourist attractions** in a particular area attracts many tourists both local and international tourists.

### Application activity 15.5.1:

1. Explain how physical features contribute to the development of tourism industry in the world.
2. Mountain gorillas, Rwandan culture, water bodies have contributed to the recent development of tourism industry in Rwanda. Is it true? Support your answer.

## 15.5.2. Importance and impact of tourism

### Learning activity 15.5.2:

Read the passage below and answer the following questions:

Many tourists come to Rwanda. They bring money to consume while being in the country. Some appreciate our culture, create friendship with Rwandans and even when they go back to their countries they tell their friends what they have seen in Rwanda.

1. Explain different ways tourism industry contributes to the development of a country.
2. What can be the negative effects of tourism?

**a. Importance of tourism in the world**

- Tourism is a big foreign exchange earner. Countries benefit from the sale of licenses to tour operators who are taxed on their profits and entrance fees to tourism sites. Tax from tourist hotels is a source of revenue to governments.
- It offers employment to thousands of people in both public and private sectors.
- It enhances the development of industries particularly the accommodation and service industries.
- It enhances the development and the general improvement of infrastructure. Roads leading to tourist attractions are well maintained. Airstrips to such places have been constructed.
- Improvement in the standards of living where people earn income because tourists buy basic needs and luxuries.
- It enhances the development of international cooperation between countries.
- A profitable tourism tends to lead to renewed interest in the protection of wildlife and natural resources so that continued existence lead to sustainable development.
- Tourism expands market for locally produced commodities/goods. The demand for certain items may increase as tourism develops.

### b. Impact of tourism on the environment

The following are the major impacts of tourism on the environment:

- **The loss of biodiversity:**
  - Protected animals in the national parks may escape and harm people and damage their crops and animals.
  - Tourists leave fire on the camping and picnic sites which causes damages to vegetation. This may lead to the loss of valuable forest
- **Pressure on the water resources:** Water, and especially fresh water, is one of the most critical natural resources. The tourism industry generally over uses water resources for hotels, swimming pools, golf courses and personal use of water by tourists. This can result into water shortages and degradation of water supplies, as well as generating a greater volume of waste water.
- **Land degradation:** Important land resources include minerals, fertile soil, forests, wetland and wildlife. Increased construction of tourism and recreational facilities have increased the pressure on these resources and on scenic landscapes. In areas with high concentrations of tourist activities and appealing natural attractions, waste disposal is a serious problem and improper disposal can be a major despoiler of the natural environment - rivers, scenic areas, and roadsides.
- **Air and noise pollution:** Air and noise pollution from airplanes, cars, and buses, as well as recreational vehicles such as snowmobiles and jet skis, is an ever-growing problem of modern life.
- **Sewage:** Construction of hotels, recreation and other facilities often leads to increased sewage pollution. Wastewater has polluted seas and lakes surrounding tourist attractions, damaging the flora and fauna. Sewage runoff causes serious damage to coral reefs because it stimulates the growth of algae, which cover the filter-feeding corals, hindering their ability to survive.

## Application activity 15.5.2:

1. Make a field trip and discuss the impacts of tourism industry on the local environment.
2. Tourism benefits both the country and the people living around the visited areas or national parks. Explain this in the context of Rwanda.

### 15.5.3. Problems affecting the tourism in the world and the prospects

## Learning activity 15.5.3:

Read the following passage and answer questions that follow:

In developing countries there is high population growth; people have begun encroaching on areas reserved for national parks and game reserves. Poaching, deforestation is the order of the day. The need for agricultural land and settlement has led to reduction of forested areas hence affecting tourism.

1. Identify and explain problems affecting tourism in relation to the passage.
2. Analyse other human activities that affect tourism industry which are not mentioned in the passage.

#### a. Problems affecting tourism in the world and prospects

The following are the problems associated with the tourism industry:

- **Climate changes:** Due to global warming and climate changes, regions which used to be well-watered and which formed favorable habitats for animals and plants are becoming drier.
- **Decline in wildlife:** Incidences of poaching where animals are killed for game, meat, skins and tusks have led to a decline in the population of wild animals.
- **Encroachment on national parks** due to population pressure, and this is threatening the survival of tourism industry.
- **Violence or political instability** limits the number of tourists coming in the country.
- **Diseases:** they destroy plants, kill wild animals and tourists. Diseases like malaria, sleeping sickness, river blindness etc., scare away tourists.
- **Less supportive government policy:** For example, when the government

fails to eradicate poaching, encroaching or to set advantages that attract tourists such as getting entry visas etc.

- **Poor management skills:** This is in terms of lack of skilled labors in form of international chefs, leisure and hospitality specialists etc.
- **Under developed tourist attraction sites** such as historical sites, forest without accommodation facilities, poor catering services.
- **Hostility:** Some individuals attack tourists and rob their properties.

### b. Solutions to the problems of tourism

- Improvement of tourism facilities and amenities: transport services and infrastructures, accommodation, security, etc.
- Making the publicity of tourist attractions through television, newspapers, internet, etc.
- Ensuring anti- poaching and patrol: regulation against hunting and killing of game animals and bush burning in areas gazette for wildlife have to be institutionalized.
- Vigorous programs to control the spread of diseases.
- Training tourism workers in customer care management and service delivery.
- Enforcement of laws governing wildlife protection to ensure wildlife sustainability to attract tourists.
- More game reserves should be gazetted where more wildlife can be protected and conserved to ensure a variety of wildlife which attracts more tourists.

## Application activity 15.5.3:

Show how shortage of land and poor means of transport are barriers to the development of tourism industry in developing countries.

Suggest measures being taken by Rwanda to develop the tourism industry.

### 15.5.4. Case studies

**Learning activity 15.5.4:**

Draw the world map and locate the following countries and their major tourist attractions.

a. Switzerland.

b. East African Countries.

c. USA.

**a. Tourism in East African Countries**

East African Countries receive tourists originating from worldwide but the majority are those from countries within Africa, Europe and North America and some others from Asia.

i. Major tourist attractions in East African Countries

- Great abundance of wildlife: animals like elephants, rhinoceros, hippopotamus, lions, leopards, cheetah, zebras, giraffes, buffaloes and antelopes.
- Coastal beaches and fringing coral reefs on the coasts of Dar es Salam and Mombasa.
- Beautiful scenery (Mount Kenya, Kilimanjaro, volcanoes in Rwanda, block mountains, Great Rift Valley).
- Pleasant and healthy climate which is moderate.
- National parks: Lake Nakuru, Masai Mara, Tsavu, Akagera National Park, Queen Elizabeth National Park, Serengeti National Park, Ruvubu National park, etc.
- Cultural diversity, they have unique costumes, traditional dances (Intore in Rwanda), music and crafts.
- Drainage features like Lake Victoria, Lake Tanganyika, Lake Kivu, Rift valley Lakes, swimming, sun bathing, all attracts tourists.
- Historical sites e.g. archeological sites like Olduvai gorge, the famous Fort Jesus, Kasubi tombs for the fallen kings of Buganda, museums, Kings' palace (Nyanza -Rwanda), etc.

ii. Factors influencing tourism industry in East African Countries

- Availability of a wide range of tourist attractions that are found in various countries of East Africa.
- Supportive government policy. E.g. tax concessions to tourists, eradication of poaching, gazetting of national parks.
- Ideal tropical climate: the warm tropical climate is enjoyed by many visitors from the cold regions such as Europe and North America.
- Relative political stability compare to other African countries guarantees tourists security and safety.
- Well-developed accommodation facilities in form of hotels and lodges of the international standards.
- Effective advertisement both at home and abroad to make tourists aware of the existing attractions and facilities.
- Skilled labors in form of tour guides, game rangers, chefs who can prepare international dishes and spirits or wines.
- Good hospitality offered by the people in East Africa especially those who work in the hotels, transport sector, and as tour guides.
- Presence of capital to inject in the tourism industry as provided by local banks and private sector.
- Good international relationship with other countries such as U.K, Germany, USA, Canada, has promoted tourism.

**b. Tourism in USA: Case study of tourism in the state of Florida**

The state of Florida is renowned for its white sandy beaches, camping sites, Fort Myers Sanibel Island, Orlando resort hotel, Amelia Island, National parks and Zoos (De Soto, dry Tortugas) and endless summer which attract tourists when it is winter elsewhere in United States of America and Europe.

**Factors that favored tourism in Florida**

- A reliable transport and communication network of railway, air, water and road.
- Presence of tour agencies and operators.
- Massive advertisement both in USA and abroad.
- Natural beauty of Florida.
- Several species of beautiful birds such as Bald Eagle, Caracara, Pelicans Whooping and sand hill cranes and others.
- Availability of capital to invest in infrastructure development.
- The amazing architectural building designs especially along Miami Beach.
- Beautiful climate: sunny and cool breezes.

- Skilled labor force working in the tourism sector.
- Presence of the variety of wildlife ranging from mammals to reptiles.

### c. Tourism in Switzerland

Tourism is one the leading economic sectors in Switzerland. Switzerland has three main topographic regions namely Jura mountains in the Northwest, Alps in the South and Central Swiss plateau or Mittelland. Other tourist attractions are water bodies (like river Rhine, lake Lucerne, Lake Geneva), conducive climate, wild life with diversity of plants and animals, culture especially paintings, music, architecture, etc.

**Factors that have favored the tourism industry in Switzerland**

- Geographical location of Switzerland: it is located in heartland of rich and developed industrialized region of Europe: France, Germany, Italy.
- It has developed the winter sport of Ski and Alpinism in the summer.
- It is endowed with a variety of relief that provide scenic beauty.
- Drainage system (Rhine river) in Switzerland is another attraction.
- A well-developed hotel, motels and lodging sector has provided adequate accommodation.
- The Swiss have a well-developed transport and communication networks.
- Swiss hospitality is no doubt a boost to tourism.
- The development of package tours.
- Massive advertisement through magazines, the internet, posters, phone short massages.
- Abundant and cheap hydro-electric power. This has enabled Switzerland to electrify her Railway system.
- It has political stability and her policy of neutrality, Switzerland has remained stable since Napoleonic wars.
- Relatively stable Swiss economy.
- The presence of many international bodies (International Committee for the Red Cross: ICRC, FIFA, etc.)
- Availability of capital from well-developed banking system.

Application activity 15.5.4:

1. Compare the tourist attractions in Rwanda with those of Switzerland.
2. Analyze the factors influencing tourism industry in East Africa and relate them with those of Florida in USA.

## End unit assessment

1. Account for the persistent famine in many parts of Africa.
2. Discuss the impact of tourism on sustainable development of Africa.
3. Famine is one of the threatening calamities in Africa. Suggest measures most governments can do to reduce famine in developing countries.
4. The world is currently facing the problem of environmental degradation. Suggest measures to protect the environment.

# REFERENCES


Afedrary, L. (2015). Soil erosion. Retrieved from https://www.monitor,co.ug/Farming.

Anders, N. (2016, June 25). Amedzofe Village. Retrieved May 6, 2018, from Amedzofe Village -Touring Travelling Ghana: http://amedzofevillage.com/en/2016/06/25/akosombo-dam-and-volta-lake/

Aswan. (2000, February 12). wwwbtbegypttamcom/aswan. Retrieved April 23, 2018, from https://sites.google.com/site: https://sites.google.com/site/wwwbtbegypttamcom/aswan

Authority, T. V. (2009, March 22). Rowellsapushistory. Retrieved May 6, 2018, from https://rowellsapushistory.wikispaces.com: https://rowellsapushistory.wikispaces.com/Tennessee+Valley+Authority

Babishangire B.Bernadette B, Bwebare Byamugisha . (1995). Comprehensive and systematic notes on world problems and development. Kampala: Aristoc booklex LTD.

Bamusananire E et al. (2013). Geography for Rwanda secondary schools. Advanced level Senior Five. Fountain.

Bishop, V. a. (2001). Water Resources: Processes and Management. London: Collins Publishers.

Buckle C. (1978). Landforms in Africa. London: Longman.

Bunnet R.B. (1973). General Geography in diagrams. Pearson Education South Asie Pte Ltd.

Bunnet R.B. (1984). Physical geography in diagrams for Africa. Longman.

Bunnet R.B. (2010). Physical geography in diagrams for Africa. Kigali: Longman.

Bunnet, R. B. (2008). General Geography in Diagrams Longman. London: PEARSON Longman.

BYAMUGISHA, B. (2010). Focus on world Geography . Kampala: KABS publishers LTD.

Byamugisha, B. (2010). Physical Geography: A Systematic Study in Geomorphology and Climatology for advanced level students. Kampala: Kabs Publishers Ltd.

Byamugisha, B. (2010). Sysematic Study in Geomorphology and Climatology for Advanced level Students. Kampala.

Byamugisha, B. B. (1995). Comprehensive and systematic notes on world problems and development with answered questions. Kampala: Aristoc Booklex Ltd.

Byizigiro, V., & Biryabarema. (2009). Soil erosion. Kigali: Rwanda Natural Science.

Cheng Leong, G. a. (1999). Human and Economic Geography. 2nd Ed. Great Clarendon Street: Oxford University Press.

Christopherson, R. W. (2012). An Introduction to Phyisical Geography: Geosystems. New Jersey: Pearson Prentice Hall.

Collins Buckle. (2007). Landforms and landscapes in Africa: AN introduction to Geomorphology. Ednburgh: Pearson Education Limited.

Conrad K. (2015). IGCSE Geography support. Retrieved from https// kisigcsegeography.wordpress.com.

CoolBen. (1996, January 1). https://adst.org/. Retrieved May 6, 2018, from ADST: https://adst.org/2016/06/dont-give-dam-feud-financing-aswan-high-dam/

ESchooltoday. (2008 - 2017). eSchooltoday. Retrieved from https://www.eschooltoday.com.

Gabler, R. P. (2009). Physical Geography. Belmont: Brooks/Cole, Cengage Learning.

GILLIAN C. MORGAN, GOH CHENG LEONG. (1982). Human and Economic Geography. New York: Oxford university press.

Glencoe. (1999). Earth Science: Teacher Wraparound Edition. Westerville: McGraw-Hill.

Henrie M.K. (2009). Principles of Physical Geography. Kampala: Compsolutions.

Herbert H. G. (1983). World Geography Revised. United States of America: Follett Social Studies, Allyn and Bacon,Inc.

Historica, N. (2013). Exploring the intersection of science. Retrieved from The Natural Historian.com.

Islam, T. (2008, November 12). Tripod. Retrieved February 18, 2018, from Continental Drift: http://saif181.tripod.com/index.html

John Whitton. (1984). Dictionary of Physical geography. New York: Nwe York .

Kallie, S. (2017 , July 16). The Yellow River. Retrieved May 6, 2018, from www.thoughtco: https://www.thoughtco.com/yellow-river-in-chinas-history-195222

Karuggah R. & Kibuuka P. (2009). Certificate Geography Form 1. Nairobi, Kenya: Oxford University Press.

Kichodo, H. M. (2009). Principles of Physical Geography: Advanced Level Geography. Kampala: HMK.

KICHODO, H. M. (2011). world problems and development. Kampala: Camp solutions.

Kichodo, H. M. (2011). World Problems and Development: Advanced Level Geography. Kampala: HMK.

Lorenz, A. (2012, June 2). Old and New China Meet Along the Yellow River. Retrieved May 6, 2018, from https://abcnews.go.com/International: https://abcnews.go.com/International/china-meet-yellow-river/story?id=16468814

Marshal, T. (2001, January 15). Wikipedia org. Retrieved March 14, 2018, from Wikipedia Web Site: https://en.wikipedia.org/wiki/Lists_of_countries_by_mineral_production

Mcmaster, D. N. (2000). Mapreading for East Africa Longman. Edinburgh: Longman.

Miles. (2001, January 15). Wikipedia. Retrieved February 11, 2018, from Wikipedia: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSZAVk6yonsdmFUdAUfWw9O86j6_3LP27u3mv7e2k3G7BFwJcA7

Minns, W.J. (1984). A geography of Africa. Macmillan.

MonkHouse, F.J. (2008). Principles of physical Geography. London: Hodder Education.

Mwise Thomas, et al. (2015). Geography syllabus advanced level s4-6. Kigali: Rwanda education board.

NAPA-RWANDA. (2006). National adaption programs of action to climate change. Kigali: Ministry of lands, environment, forestry, water and mines.

Ndehedehe, C. E. (2017). Analysis of hydrological variability over the Volta river basin using in-situ data and satellite observations. Journal of Hydrology: Regional Studies, 88-110.

Nzabona A.C.N (1998). Physical Geography for Advanced level: Questions and essay guides. Published in Kampala (U).

Safari Sibo et al. (2013). MK SENIOR 5 SECONDARY GEOGRAPHY STUDENTS BOOKS. Kampala: MK.

S-Cool.CO.UK. (n.d.). Elluviation and illuviation processes of weathering. Retrieved from https://www.google.rw/search.

SENTAMU, S. A. (2011). Statistics and geography of the world. Kampala.

Strahler, A. (2011). Introducing Physical Geography, 5th Ed. Boston: John Willey and & Sons Inc.

Strahler, A. a. (2008). Visualizing Physical Geography. Hoboken: John Wiley & Sons.

Tjeerd, H. M., & van Andel and Brendan, J. (2018, January 12). ENCYCLOPÆDIA BRITANNICA. Retrieved February 11, 2018, from ENCYCLOPÆDIA BRITANNICA: https://www.britannica.com/science/plate-tectonics.

Toor, A. (2013, April 3). The Verge. Retrieved May 6, 2018, from theverge.com: https://www.theverge.com/2013/4/3/4175514/china-rivers-disappear-from-the-map-water-supply-crisis.

UK ESSAYS. (March, 2015). The importance of the Nile River. Environmental science essay.

UNICEF. (2008). Rwanda earthquakes: Unicef responds to immediate needs of children and women affected by earthquakes. Kigali: Unicef.
Water Technology. (1983, January 1). Retrieved May 6, 2018, from www.water-technology.net: https://www.water-technology.net/projects/aswan-high-dam-nile-sudan-egypt/
Water-resources. (2010, Jan 1). https://www.nextgurukul.in/wiki/. Retrieved April 23, 2018, from Multi-purpose-river-projects: https://www.nextgurukul.in/wiki/concept/cbse/class-10/geography/water-resources.
Waugh, D. (2009). Geography: An Integrated Approach. London: Nelson Thornes.
Whitton, J. B. (1984). Dictionary of physical geography. New York: PEGUIN BOOKS.
Whittow J. (1984). Dictionary of physical geography. Penguin books.
Wu, A. ( 2015, September 21). The Geography of the Yellow River. Retrieved May 6, 2018, from chinahighlights: https://www.chinahighlights.com/yellowriver/geography.htm

**WEBSITES**

http:// the freedictionary.com/
http://agritech.tnau.ac.in/agricultural_engineering/greenhouse.
http://umunyamakuru.com/fr/rwanda-vers-une-solution-de-lenergie-electrique/
http://www.fonerwa.org/portfolio/akanyaru-watershed-protection-project. Retrieved on 17.3.2017
http://www.globalnewlightofmyanmar.com/the-greenhouse-effect-and-the-global-warming/
http://www.midimar.gov.rw/index.php?id=2 Retrieved on 19.3.2018
http://www.monitor.co.ug/Magazines/Farming/How-air-pollution-affects-agriculture
http://www.thenewstrack.com/top-10-main-causes-of-global-warming-2014/
https://courses.lumenlearning.com/earthscience/chapter/wave-coastal-features/
https://en.wikipedia.org/wiki/listontap.com/top-10-effects-global-warming-2
https://fr.slideshare.net/slidematters/coral-reef-33469633
https://kids.britannica.com/students/assembly/view/145503
https://news.nationalgeographic.com/2017/11/climate-change-sea-level-water-will-come-jeff-goodell/
https://oceanservice.noaa.gov/facts/coral_bleach.htmlstationary.
https://seriouslysilly.wikispaces.com/file/view/8.5+The+Greenhouse+Effect.pdf. Retrieved on 18.3.2018
*https://thenaturalhistorian.com/2013. Naturalis Historica: Exploring the intersection of science*
https://www.clearias.com/erosion-deposition-wind-waves/
https://www.economist.com/sites/default/files/imagecache/640-width/images/print-edition/20171202_STP002_0.jpg
https://www.flickr.com/photos/oxfameastafrica/5933226731
https://www.google.rw/imgres?imgurl

https://www.google.rw/search. (n.d.). *Google search*.
https://www.google.rw/search?q=types+of+ocean+waves&dcr
*https://www.google.rw/search?tbm=isch&q=Global+soils&backchip*
https://www.google.rw/search?tbm=isch&q=Global+soils&backchip
https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch5s5-5-4-1.html
https://www.s-cool.co.uk/a-level/geography/soils/revise
https://www.slideshare.net/AshishNain/ashish2011-a22biv

# 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.
**Agro-based industries:** Are industries which process/ use agriculture products as raw materials.
**Agro-forestry**: It is a combination of agriculture and forestry for more diverse, profitable, productive and sustainable land use.
**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)
**CFCs**: Chlorofluorocarbons; are fully halogenated paraffin hydrocarbons that contain only carbon, chlorine, and fluorine, produced as volatile derivative of methane, ethane, and propane.
**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.
**Climate:** The average weather conditions at specific place over a lengthy period of time (> thirty years).
**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.

**Concessions:** A thing that is granted, especially in response to demands after a compromise

**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. agri-

culture, 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.
**Embezzlement:** Theft or misappropriation of funds placed in one's trust or belonging to one's employer.
**Encroach:** To take over someone's space or to advance gradually on someone's territory beyond limits.
**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).
**FAO**: The Food and Agriculture Organization of the United Nations is a specialized agency of the United Nations that leads international efforts to defeat hunger.
**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
**Glacie**r: 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
**Hydro-electric power plant** (**hydro-electric power station):** Is a power generating station which utilizes the potential energy of water at a high level for the generation of electrical energy by converting potential energy to kinetic energy.
**Hydroelectricity** (Hydro-electric power): Is electricity made from the energy of free-falling water. The term refers to the generation and distribution of electricity derived from the energy of falling water or any other hydraulic source.
**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.
**Irrigation** is the application of controlled amounts of water to plants at needed intervals. Irrigation helps grow agricultural crops, maintain landscapes, and revegetate disturbed soils in dry areas and during periods of less than average rainfall. Irrigation also has other uses including crop production, including forest protection and preventing soil consolidation.
**Isostasy**: Principle describing the flotation of the lithosphere, which is less dense, on the plastic asthenosphere which is denser / the state of balance, or equilibrium, which sections of the earth's lithosphere (whether continental or oceanic) are thought ultimately to achieve when the vertical forces upon them remain unchanged
**Isostatic compensation**: Crustal rise or sinking in response to unloading by denu-

dation or loading by sediment deposition, following the principle of isostasy.

**Isostatic rebound**: Local crustal rise after the melting of ice sheets, following the principle of Isostasy.

**Latitude:** A distance on the earth surface measured in degrees north and south of the equator

**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.

**Meanders:** Curved bends of a river in either middle or lower stage

**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

**Multipurpose project**: A project designed to serve more than one purpose. For example, multipurpose river project that provides water for irrigation, recreation, fish and wildlife, and, at the same time, controls flood or generates electric power.

**NGOs**: They are usually non-profit and sometimes international organizations independent of governments and international governmental organizations and are active in humanitarian, educational, health care, public policy, social, human rights, environmental, and other areas to effect changes according to their objectives.

**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.
**Penstocks**: Are generally made of reinforced concrete or steel to transport water from reservoir to turbine with less friction losses.
**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.
**Poaching:** The illegal practice of hunting or stealing wild game.
**Power House**: House where generated power from alternator will be stepped up and supplied to transmission lines
**Power** is the capacity of **energy**, which is being used, while energy is 'joules', power is 'joules per second'. Well, in another words Power is 'watt' and Energy is 'watt-hour'. Another difference is that energy can be stored whereas power cannot be stored.
**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.
**Silviculture:** A branch of forestry dealing with the development and care of forests
**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.
**Soil:** Top layer covering the earth surface**.**
**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.
**Starvation**: A prolonged lack of food, often causing death.
**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.
**Sustainable development** is the organizing principle for responding human needs and meeting human development goals while at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and today's ad future societies depend.
**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.
**Tariffs:** A tax or duty to be paid on a particular class of imports or exports.
**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.
**Turbines**: Water turbines are used to convert the energy of falling water into mechanical energy.
**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.
**Water navigation:** Connecting banks of a river or lake, or connecting ports of a sea, by means of ship. It will be a part of the navigation as there will be no other means of travel other than through water
**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.
**Yazoo or deferred tributary:** A tributary stream of the differed junction type or a river prevented from joining the main river by levees.