THE PHYSICAL GEOGRAPHY OF EAST AFRICA (P250/1)

This paper consists of three (3) sections A, B and C. Section A consists of two (2) questions based on Map reading and Photographic Interpretation all of which are emphasizing the aspects of physical geography. This section is compulsory. Section B consists of three (3) questions on the physical geography of East Africa. Section C contains three (3) questions on Climatology, Vegetation and Soils of East Africa. Candidates are required to answer one (1) question from Section B and one (1) question from Section C. All questions carry 25 marks.

COURSE OUTLINE

1. The solid structure of the earth
2. The continental drift
3. Rocks
4. Weathering and Mass wasting
5. Evolution of relief landscape/landforms in East Africa
6. Glaciation
7. Rivers, riverine landscapes and drainage patterns
8. Coastal geomorphology
9. Classification of lakes
10. Weather and Climate of East Africa
11. Vegetation of East Africa
12. Soils of East Africa
13. Map reading and photographic interpretation

Reference Books

- ***Landforms in East Africa by Collin Buckle***
- ***Physical Geography in Diagrams for East Africa by R.B Bunnett***
- ***General Geography in Diagrams by R.B Bunnett (yellow cover)***
- ***Principles of Physical Geography by Monkhouse***
- ***Map Reading and Photographic Interpretation by D.N McMaster***
- ***Secondary School Atlas***
- ***Various Pamphlets***
- ***The Internet***

INTRODUCTION:

Geomorphology is a branch of physical geography that deals with the study of landforms and landform processes or the scientific study of the origin and development of the earth's landforms. A landform is any feature produced by geomorphic processes. Landforms are either ***intrusive*** i.e. formed within the earth crust or ***extrusive*** i.e. formed on the earth surface.

Geomorphic processes are the building processes that usually lead to an increase in elevation and relief. Geomorphic processes are either ***endogenic (endogenetic)*** or ***exogenic (exogenetic)***. **Endogenic** processes (***Earth Movements***) originate from within the earth crust and are a result of convectional forces. They include ***faulting, folding, crustal warping and vulcanicity***. **Endogenic** processes are of two types, namely; ***Epeirogenic*** and ***Diastrophic*** forces. **Epeirogenic or Vertical** forces operate up and down in the earth crust, e.g. crustal warping and faulting while **Diastrophic or Lateral** forces operate horizontally or laterally (sideways) within the crust, e.g. faulting and folding.

Exogenic processes operate on the earth's surface. They are brought about by climate changes. They include;

(a) Denudational (degradation) processes such as weathering, mass wasting and erosion. Denudation is destruction or removal (wearing down) of the landscape by the work of weathering, mass wasting and erosion. Denudation leads to a reduction in elevation and relief.

(b) Deposition (aggradation) by water, wind, ice, living organisms, evaporation & precipitation and of organic matter. Deposition involves the laying down of transported materials by rivers, waves, wind and glaciers. Deposition builds up landscapes.

Geomorphology therefore deals with all these processes, the landforms they produce and how these landforms affect man.

THE STRUCTURE OF THE EARTH

The solid structure of the earth is of great significance to geomorphologists. This is because the evolution of relief landforms is entirely derived from the earth's solid structure. The solid structure of the earth is basically divided into three layers, namely, the crust, the mantle and the core.

The Crust (Lithosphere):
This is the outer shell or layer of the solid earth. It is made up of rocks that are brittle and have low density. The crust is commonly known as **Lithosphere**. The crust is made up of two layers, i.e. the ***continental crust*** and the ***oceanic crust***.

(a) **The Continental Crust (SIAL)** – This is the outer most layer of the solid earth with an average depth of about 65km in thickness. This layer is composed of **light rocks**, mainly Silica (Si) and Aluminium (Al) hence the name ***SIAL***. These rocks have an average density of 2.7g/cc. They are also known as ***Sialic plates***.

(b) **The Oceanic Crust (SIMA)** – This follows beneath the continental crust and forms a thin layer between the continental crust and the mantle. It has an average thickness of about 6 - 10km with an average density of 3.3g/cc. This layer forms the bottom of the oceans and seas hence the name oceanic crust. It is mainly made up of **denser or heavy rocks** of Silica (Si) and Magnesium (Mg) hence the name **SIMA**. This layer is also known as ***Simatic plates***.

Therefore the crust in general extends to about 75km in depth and at its maximum depth the crust has temperatures of about 1200^0 C.

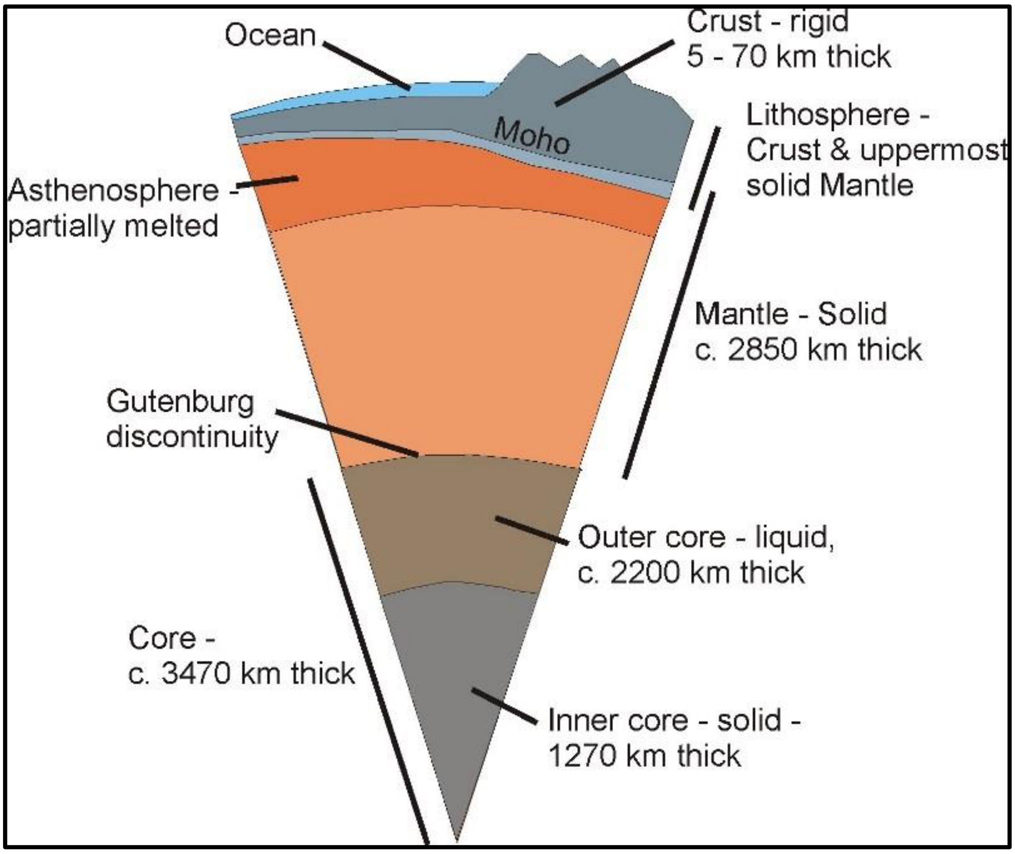
The Mantle (Mesosphere):
Beneath the crust is a layer of rocks called the mantle. The mantle rocks have a relatively high density and are in a ***semi-molten or semi-plastic or quasi-fluid state***. This layer has very hot temperatures of about 5000^0 C. It is composed of rocks with high mobility and generates convective currents that drive the crustal plates on which continents are seated causing earth movements. The mantle is separated from the crust by a layer of discontinuity known as the ***Mohorovicic*** or ***M-Discontinuity*** or simply ***Moho*** (*The Moho is named after* ***Andrija Mohorovicic*** *(1857-1936), a Croatian meteorologist and seismologist*). This layer protects the crustal rocks from being melted by the hot temperatures of the mantle.
The mantle is responsible for seafloor spreading, landform development and earthquakes.

NB: Asthenosphere - Layer of the upper mantle with a thickness of 125 mi; it is composed of molten rock, on top of which the lithospheric plates slide.

The Core (Barysphere):
This is the deepest interior of the earth. It is divided into two layers, i.e. the **outer core** and the **inner core**. The outer core is believed to be in a molten state and is composed of Iron and Nickel. The inner core is believed to be in a solid state and is mainly composed of Iron. The core is a region of extremely hot temperatures which can go up to 5500^0C. The core is separated from the mantle by the ***Gutenberg Discontinuity***.

In conclusion, the structure of the earth's interior has a vital link with the landforms which evolve on the earth's surface because the interior of the earth is a source of various endogenic forces that have led to the formation of numerous physical features or landforms.

Solid Structure of the Earth



CONTINENTAL DRIFTING

As early as the 17th century, the present distribution of continents and oceans was already an issue of great concern. *(The speculation that continents might have 'drifted' was first put forward by Abraham Ortelius in 1596)*. Up to the 20th century the information about the distribution of continents was still greatly disputed. However what has been agreed upon is that the continents broke away or separated from a large landmass and drifted apart in what is popularly known as the ***continental drift***.

The term ***continental drift refers to the large scale movement of continents relative to each other across the earth surface to their present positions to form continents, such as, Africa, Australia, Antarctica, North America, South America, Asia, and ocean basins of the Pacific, Indian and Atlantic oceans.*** Most continents are located in the northern hemisphere as compared to the southern hemisphere.

Several theories have been put forward to explain the movements of continents. These theories have been grouped into two (2); the first group of theories includes those theories that lack scientific evidence but help to explain theoretically the occurrence of continental drift as such less emphasis is put on these theories. They include the Biblical theory, Moon theory, Expanding and Contracting theory, Polar Wandering theory, to mention but a few. The second group of theories are those put forward during the 20th century. These include F.B Taylor's theory, Alfred Wegner's theory, the expanding earth theory, Harry Hess' theory of sea floor spreading and the Plate Tectonics theory.

1. ALFRED LOTHAR WEGENER'S THEORY

In 1912, a German geologist and meteorologist, Alfred Wegener, proposed the theory of continental drift, which states that parts of the earth's crust slowly drift atop a liquid core. Wegener published this theory in his 1915 book, ***'On the Origin of Continents and Oceans'***. According to him, about 280 million years ago (MYA) - Permian period - the earth was made up of one super continent or landmass known as **Pangaea** meaning "*All-earth*". Pangaea is said to have been situated somewhere near the South Pole. It was surrounded by a large expanse of water known as ***Panthalassa***. Around 200 million years ago, during the Jurassic period Pangaea split into **Laurasia** and **Gondwanaland**. The two were separated by a narrow water body called the sea of ***Tethys or Universal Sea***. By the end of the Cretaceous period, the continents were separating into land masses that look like our modern-day continents. Laurasia drifted northwards to form the northern continents while Gondwanaland remained in the south to form the southern continents.

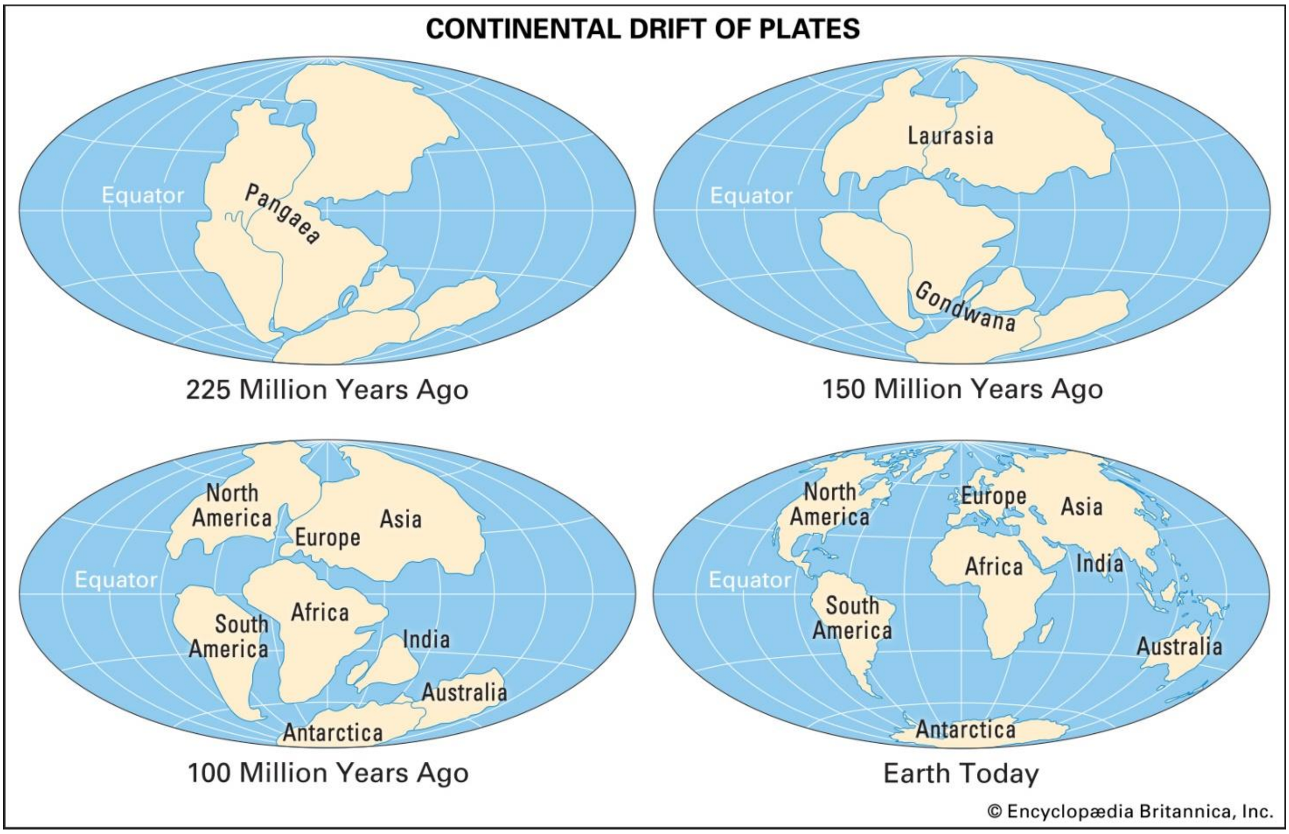
About 135 MYA Laurasia split into Eurasia and North America while Gondwanaland split into South America, Africa, India, Australia and Antarctica. During the drifting, ocean basins between the continental blocks became wider forming the present day ocean basins. In the north, Eurasia drifted eastwards while North America drifted westwards. In the south, Africa moved to attain its position astride the equator, India drifted northeastwards to join Eurasia, South America drifted westwards and northwards towards the Equator to join North America and Australia drifted away from Antarctica.

Wegener asserted that each piece drifted apart like solid rafts on a vast ocean of more plastic rock.

Criticisms of Wegener's Theory:

- Wegener was a meteorologist and not a geologist, thus he had no business in the geologist field where he was less informed.
- Wegener was unable to provide a convincing explanation for the physical processes which might have caused this drift.
- Wegener's reference to the centrifugal or gravitational force of the Earth's rotation was rather too weak to drag massive continents from their original positions.

Today it is agreed that no force from outside the earth is strong enough to cause continental drift. All forces responsible must be from within.



2. FRANK BURSLEY TAYLOR'S THEORY (1908)

In 1908, F.B Taylor proposed another theory of Continental drift. According to him, there were two landmasses, namely, Laurasia and Gondwanaland. Laurasia was situated near the North Pole while Gondwanaland was near the South Pole. Later both Gondwanaland and Laurasia drifted northwards and southwards respectively towards the equator. Taylor argued that the basins of the Indian and Atlantic oceans were left behind during the drifting of the continents. He attributed the force which caused the drifting to the gravitational pull of the moon, which came closer to the earth and that its tidal pull dragged the continents toward the Equator. He further proposed that the continents were dragged through the ocean floors towards the equator, wrinkling their Equator-facing fronts to produce the Himalayas and Alps. He adds on that during the collision Laurasia and Gondwanaland broke down into different continents. Laurasia broke into Europe, Asia, North America and numerous islands while Gondwanaland formed Africa, South America, Antarctica, India and Australia.

Criticisms of Taylor's Theory:

- ✓ Scientists argued that his proposition of the moon's tidal pull lacked evidence, thus undermining the credibility of the continental drift observation. Also the moon has no force strong enough to pull such huge continents from their polar locations.
- ✓ He didn't explain why the moon came closer to the earth.
- ✓ He explains the formation of the Himalayas and Alps as a result of the collision between Laurasia and Gondwanaland but he did not give any explanation for the formation of earlier mountain chains such as the Appalachians.

3. HARRY HESS' THEORY OF SEAFLOOR SPREADING

This is one of the modern theories of continental drift. This theory was proposed by Harry Hammond Hess in the early 1960s. While serving in the U.S. Navy during World War II, Hess was keenly interested in the geology of the ocean basins. In between taking part in the fighting he was able to conduct echo-sounding surveys in the Pacific and made several observations about the nature of the ocean floor. He noted that the ocean floor had large mid-ocean ridges with shallow trenches and the ridges consisted of young rocks compared to the rocks that made up the rest of the ocean floor.

To explain this he asserted that the interior of the earth (mantle) is like a giant convective current system whereby the magma nearer the core is heated, expands and rises. Magma rises through the cracks and seeps out onto the ocean floor along the mid-oceanic ridges, creating new seafloor. The newly deposited rocks displace the older rocks horizontally widening the ocean floor while continents move away from each other. It is noted that the gap between the continents of Africa and South America is widening.

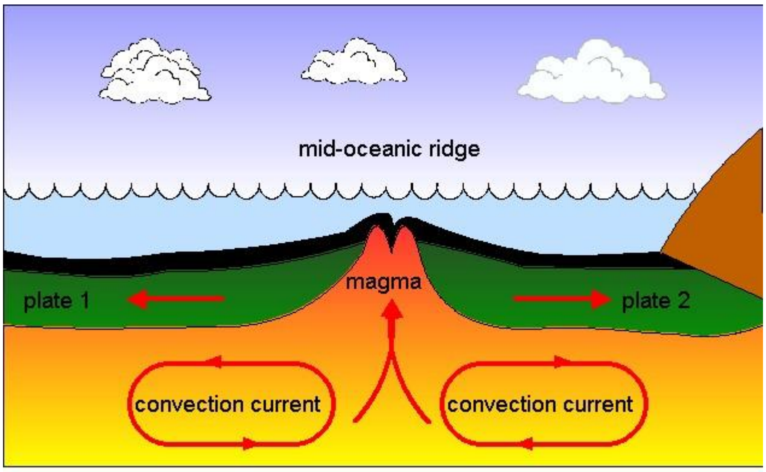
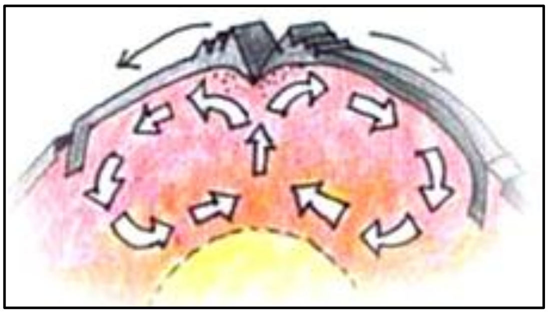
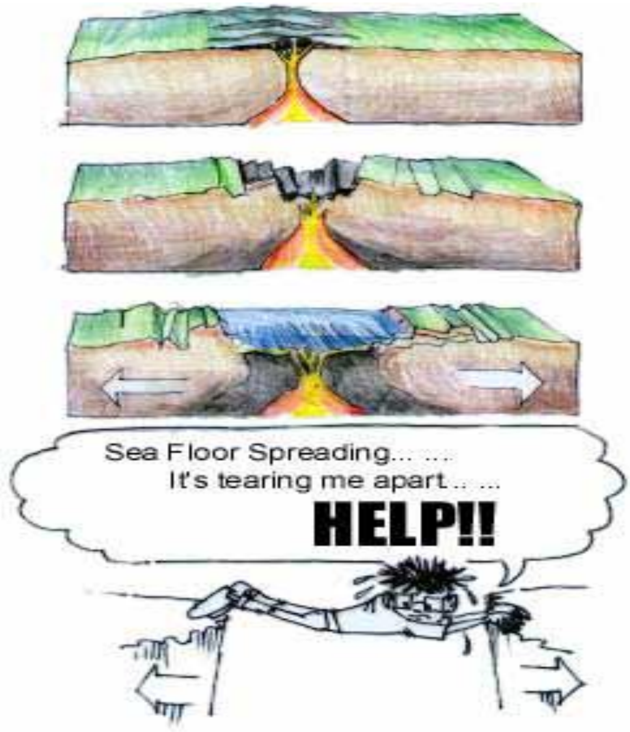


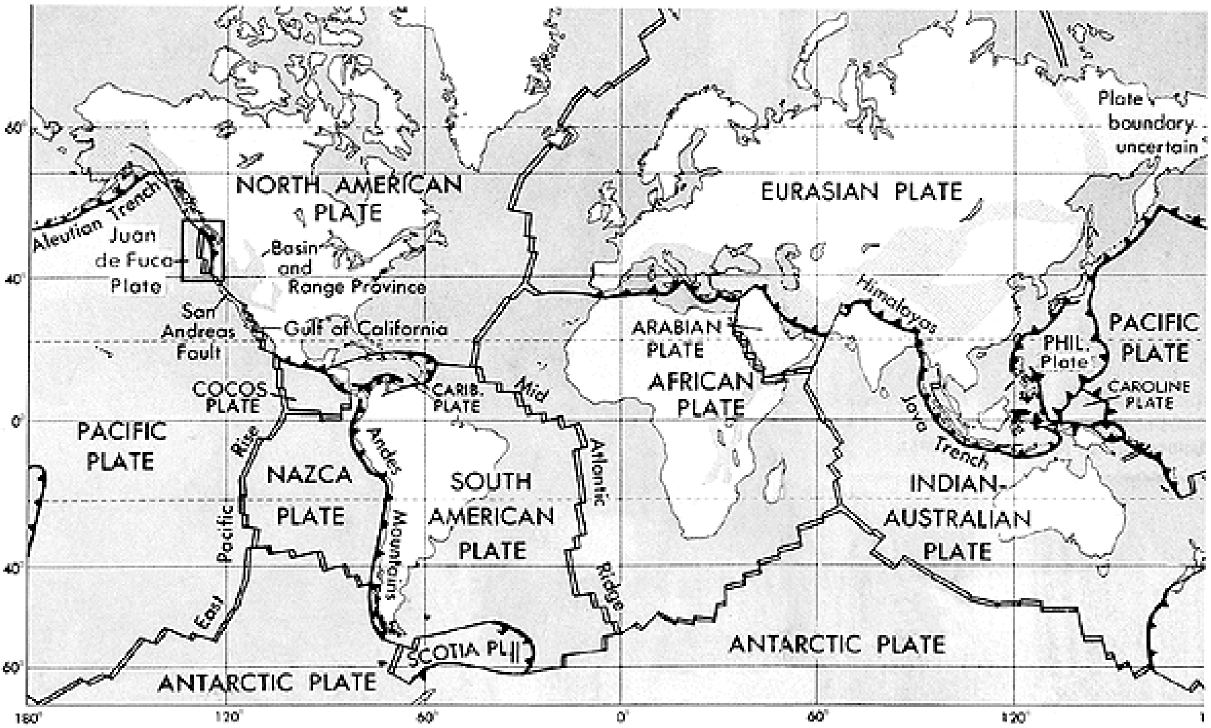
Plate 1 and plate 2 move apart. Magma rises, cools and solidifies forming new igneous rock. This is sea-floor spreading and is a constructive plate boundary.





4. THE THEORY OF PLATE TECTONICS

The theory of plate tectonics is a relatively new scientific concept. The theory was formulated in the 1960s and 1970s as new information was obtained about the nature of the ocean floor, Earth's ancient magnetism, the distribution of volcanoes and earthquakes, the flow of heat from Earth's interior, and the worldwide distribution of plant and animal fossils. ***Plate tectonism is a process involving the horizontal movement of tectonic plates of the earth's crust on which continents and ocean beds rest***. The theory asserts that earth's outermost layer, the lithosphere, is broken/divided into 7 large, rigid pieces/blocks called ***tectonic plates***: the African, North American, South American, Eurasian, Australian, Antarctic, and Pacific plates, as well as several minor plates such as the Arabian, Nazca, and Philippines plates.

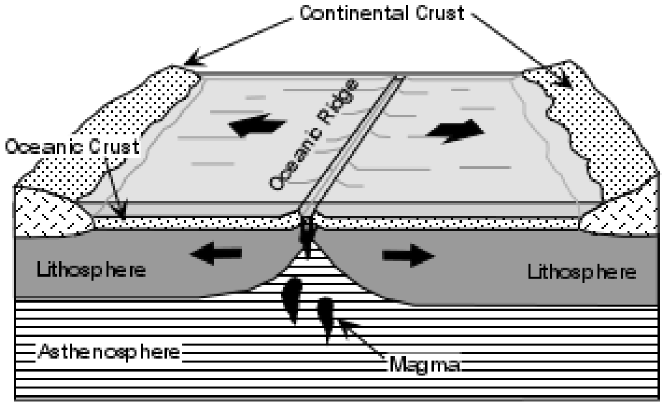


The plates are rigid and mobile, floating on the semi-fluid or semi-molten rocks of the upper mantle (asthenosphere) and are dragged towards or away from each other [*The plates are all moving in different directions and at different speeds (from 2 cm to 10 cm per year--about the speed at which your fingernails grow) in relationship to each other. The plates are moving around like cars in a demolition derby, which means they sometimes crash together, pull apart, or sideswipe each other*]. The movement of the tectonic plates is driven by ***convection currents in the mantle***. The currents are produced by heat from radioactivity, geo-chemical and geo-physical reactions in the earth's interior. [*The source of heat driving the convection currents is radioactivity deep in the Earth's mantle*] The convective currents rise and on reaching the crustal layers move horizontally forcing lateral movement of overlying plates. Since continents form part of the crustal plates they carry along the continental landmasses resulting in continental drift. These plates are loosely divided by mid-ocean ridges such as the mid-Atlantic ocean ridge and the mid-Pacific ocean ridge.

Tectonic plate movements create a distinct plate boundary/margin. Plate margins or boundaries are zones of instability and the changes that take place at the margins lead to the formation of major landforms such as fold mountains, volcanic mountains, plateaus and rift valleys. Boundaries have different names depending on how the two plates are moving in relationship to each other;

- crashing:- Convergent Boundaries; pulling apart:- Divergent Boundaries,
- or sideswiping:- Transform Boundaries

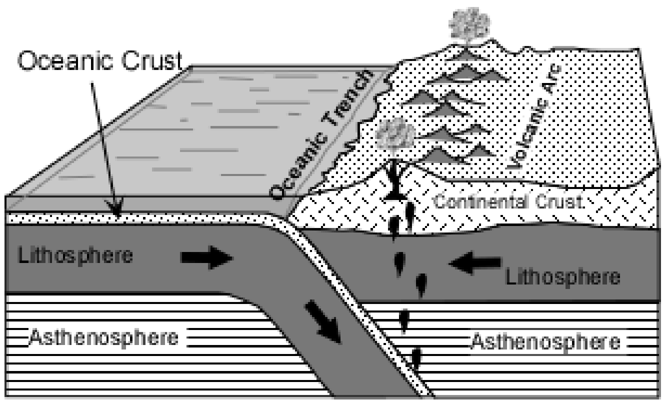
❖ **Divergent Boundaries (Constructive/Passive Margins)** – These exist where plates are moving away from each other resulting in the formation of new crust. On the ocean floor this spreading produces mid-ocean ridges formed as magma seeps into the cracks created. Examples include the Mid-Atlantic ridge and the East Pacific Rise. Where a divergent boundary crosses the land a ***rift valley*** is formed due to the tensional force of the moving plates causing cracks, called ***faults***. Examples include the East Africa rift in Kenya and Ethiopia, and the Rio Grande rift in New Mexico. Plate separation is a slow process. For example, divergence along the Mid Atlantic ridge causes the Atlantic Ocean to widen at only about 2 centimeters per year.



Diverging Plate Boundary
Oceanic Ridge - Spreading Center

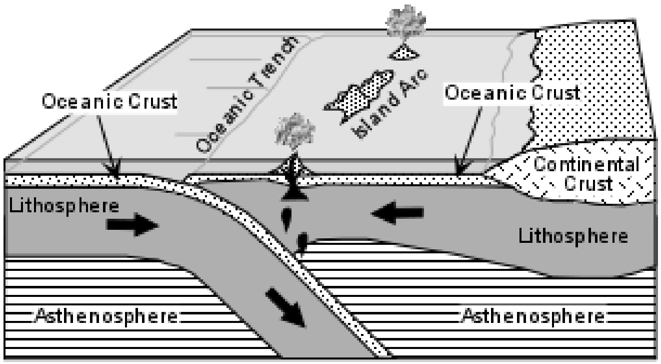
- **Convergent Boundaries (Destructive/Active Margins)** – These exist where two plates move toward each other. The results differ, depending upon what types of plates are involved.

  - **Oceanic Plate and Continental Plate** - When a thin, dense oceanic plate collides with a relatively light, thick continental plate, the oceanic plate is forced under the continental plate; this phenomenon is called ***subduction.*** The regions where plates are destroyed are called ***subduction zones*** and create ***trenches***. As the oceanic plate subducts or sinks into the mantle, its rocks are destroyed and absorbed into the mantle resulting in the production of magmas. These magmas rise to the surface and create a **volcanic arc** parallel to the ***trench***. An example of this type of collision is found on the west coast of South America where the oceanic Nazca Plate is crashing into the continent of South America. The crash formed the Andes Mountains, the long string of volcanoes along the mountain crest, and the deep trench off the coast in the Pacific Ocean (the Peru-Chile Deep Sea Trench). Other examples of trenches include the Java trench, Marianas trench, Aleutian trench and Tonga trench.



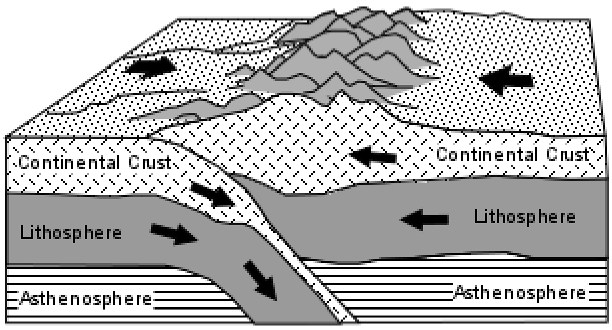
Ocean - Continent Convergence

  - **Oceanic Plate and Oceanic Plate** - When two oceanic plates collide, one may be pushed under the other to form a trench and magma from the mantle rises, forming an ***island arc*** at the surface such as the Japanese islands, the Aleutian Islands, the Philippine islands, or the Caribbean islands.



Ocean - Ocean Convergence

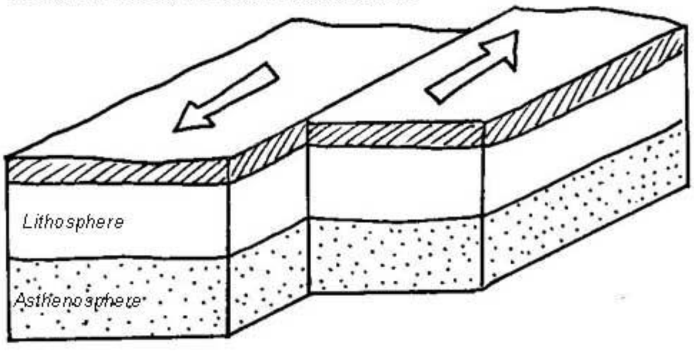
- **Continental Plate and Continental Plate** – When two continental plates collide with one another, fold - thrust mountain belts develop along the zone of collision. E.g. the India/Australian plate collided with the Asian plate creating the Himalayan Mountains. The occurrence of ancient fold - thrust mountain belts such as the Appalachian Mountains of the Eastern U.S., the Urals of Central Russia, and the Alps of southern Europe, are evidence of ancient continental collision margins. (**OROGENESIS**)



Continent- Continent Convergence

❖ **Transform Boundaries (Conservative Margins)** - This type of boundary forms when two plates are **sliding past** each other. It leads to displacement of land on either side of the fault. The most popular example of this is the **San Andreas Fault in California** where the North American plate is sliding past the Pacific plate**.** Others include the **Owen Fracture** near the Gulf of Aden and the **Romanche Fracture** off the coast of West Africa. Earthquakes are common along such boundaries.

CONSERVATIVE PLATE BOUNDARY



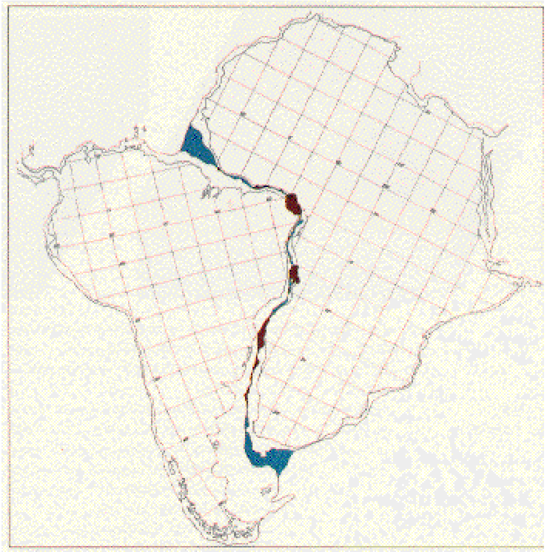
NB. Plate movements give rise to vulcanicity and earthquakes, especially along the edges of plates.

A Summary of Plate Margin Movements and Associated Geological Processes and Landforms:rggggggc"ccvvv ccccccccccccccccccccccccccxccdddd

Type of Margin	Plate Movements	Geological Processes / Associated Landforms	Example
Constructive	Two plates moving away from each other	• divergence • upwelling of magma • creation of new lithosphere • volcanism • mid-oceanic ridge formation • earthquakes ***Land is created***	**Mid-Atlantic Ridge** - America's moving away from Eurasian and African Plates. (divergence of 2 oceanic plates) **East African Rift Valley** (divergence of 2 continental plates)
Destructive	Two plates moving towards each other (oceanic crust towards continental crust)	• convergence • subduction • creation and upwelling of magma • volcanism • mountain building (either fold mountains or Island Arc) • deep-sea trench formation • earthquakes (deep focus) ***Land is destroyed***	**Andes** Nazca plate sinking underneath the South American Plate
Collision	Two plates moving towards each other (continental crust towards continental crust)	• convergence • collision • fold mountains formed • earthquakes (deep / shallow)	**Himalayas** - Indian plate moving into Eurasian Plate
Conservative/ Transform	Two plates moving sideways past each other	• horizontal movement • stick-slip process • earthquakes (shallow) ***Land is neither created nor destroyed***	**San Andreas Fault** - North American and Pacific Plate

EVIDENCE TO JUSTIFY CONTINENTAL DRIFTING

1. **Visual/Jig-saw fit** - There is a noticeable jigsaw fit between many of our continents for example, the East Coast of South America and the West Coast of Africa have a good visual fit like a jigsaw puzzle. This fit is not only on the surface but also at 2000m depth. This suggests that at some point in time the continents were once assembled together before drifting apart.



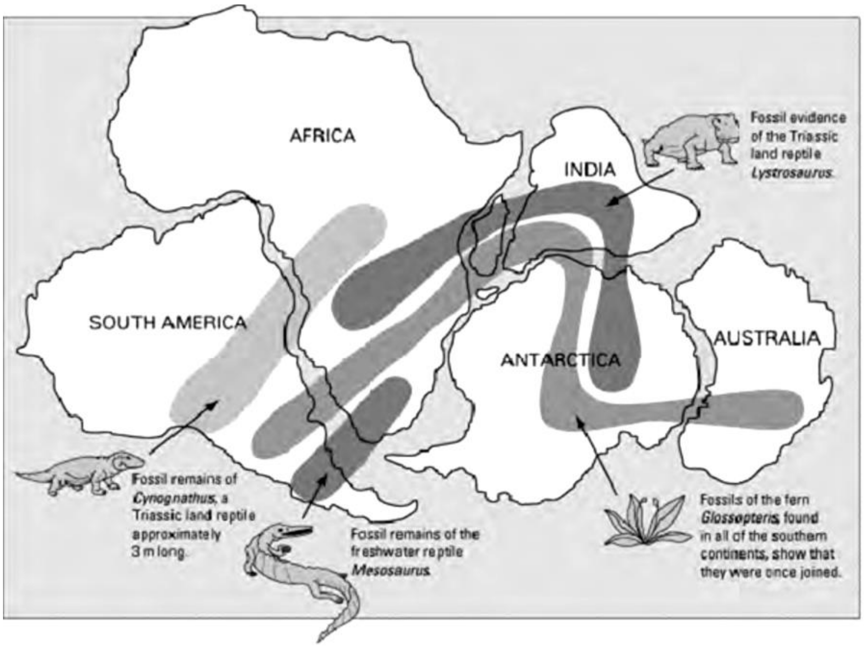
2. **Geometric fit** – It is noted that the west coastline of Africa and the east coastline of South America fit almost exactly into each other if rotated through an angle of 57^0 with rotational points at 40^0N and 30^0W.

3. **Matching geology** - A number of continents show evidence of matching geological sequences with rocks of similar age, type, formation and structure occurring in different continents on either side of the same ocean. For instance broad belts of rocks in Africa and South America have matching geology, for example, rocks in Brazil and Gabon are similar in type, structure and age. Also the Appalachians Mountains in Eastern USA show a geological match with Caledonian Mountain belt in NW Europe and if they were fitted together would form a single continuous mountain belt. This is a clear indication that the continents were once together.

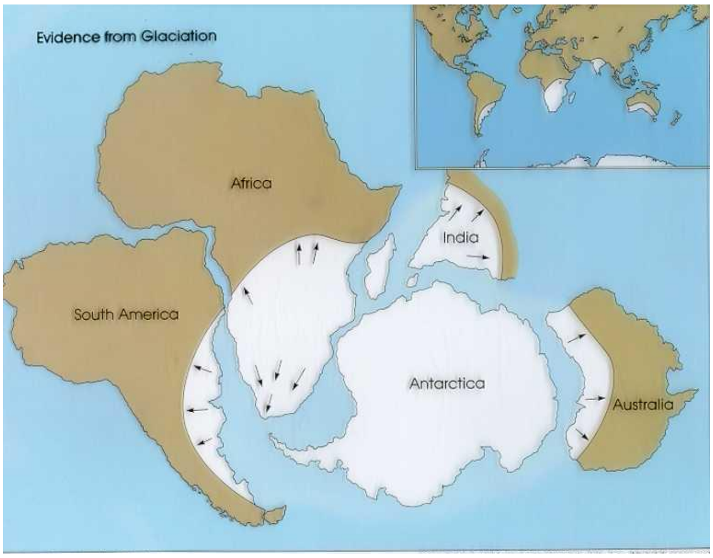
4. **Similar oil beds** – The similarity of oil beds in Brazil (S. America) and Angola (Africa) indicates a common origin and evolution of oil generating organisms, i.e. swamps. Therefore these areas must have been one geological unit with common oil beds but were only separated due to continental drifting.

5. **Matching orogenic belts or zones** – The alignment of fold mountain belts matches across different continents, i.e. the mountain chains seem to continue from continent to continent. For example, the Appalachians mountains in Eastern USA show a geological match with the Caledonian mountains in NW Europe and if they were fitted together would form a single continuous mountain belt while the Cape ranges of South Africa appear to be a continuation of the fold mountain ranges of Falkland Islands in South America.

6. **Fossil Evidence -** A fossil is any evidence of ancient life. Identical fossilized plant and animal species have been found in many different continents. It is most likely that these life forms once lived all together on a single continent, for example fossils of ***Mesosaurus*** (a freshwater reptile) dating back 280 million years were found in both eastern South America and South Africa and nowhere else, yet it is known from the fossil that this animal could not swim; ***Lystrosaurus*** and ***Cynognathus*** are both land-dwelling reptiles that lived during the Triassic Period; their fossils are found only on the present-day continental fragments of Gondwanaland. Because they are both land animals, they certainly could not have swum across the oceans currently separating the Gondwanaland continents. Therefore, it is logical to assume that the continents must once have been connected. Plant Fossils, such as ***Glossopteris*** (a tree-like plant) have been found in South America, Africa, India and Australia.



7. **Glacial Evidence** - During the Late Paleozoic era or Carboniferous period (about 300 MYA), massive glaciers covered large continental areas of Gondwanaland. Evidence for this glaciation includes layers of glacial deposits called till (*Dwyka tillites*) and striations (scratch marks) in the bedrock beneath the till which have been found in parts of South Africa, South America, southern Australia and India. This suggests that these continents were once together during this glacial time but later on drifted away from each other.



8. **Lateritic Evidence** – Laterites are soils formed under tropical conditions such as hot temperatures and heavy rainfall. However, these lateritic soils have been found in temperate areas such as North America, Britain and parts of Russia. This is an indication that by the time these laterites were formed, such areas were in the Tropics and have since then drifted to temperate regions.

9. **Coral Evidence** – Coral reefs only grow in tropical waters whose temperatures are as high as 20^0C. However evidence of coral reefs has been found in temperate areas of Greenland and Oxford (England) which experience cold temperatures. This is due to the fact that these areas were lying across the equator where suitable conditions led to the formation of coral reefs. These regions later drifted to temperate areas carrying with them the already formed coral reefs.

10. **Similarity in fauna and flora (Living organisms)** - There is a marked similarity in the distribution of plants and animals across continents which made up Gondwanaland. Since large oceans separate these continents such animals could not have migrated freely across these wide oceans. The Brazilian coast of South America and the West coast of Africa have plant and animal species that are similar, particularly the tropical rainforests in the Congo basin of Africa and the

Amazon basin forest in South America. This suggests that these two continents were once together and experienced similar climatic conditions for a long period of time.

11. **Salt Evaporates** – Salt evaporates only form in hot dry climates. However evidence of large amounts of salt evaporates has been found in areas such as the southern states of USA, Germany, Britain and the foothills of the Ural Mountains in Russia. It is believed that these deposits were formed during the time when Laurasia was at the equator and experienced a hot dry climate.

12**. Proximity of continental blocks to the North Pole** than the South Pole in the southern hemisphere where they were formerly located is an indication that the continental blocks have been moving and are still moving northwards, hence supporting the theory of continental drift.

13. **Paleomagnetism and Polar Wandering** – This is the most conclusive evidence of continental drift. When hot rocks solidify they are magnetized in the direction of the magnetic north at that time. When geologists measured the paleomagnetism of geologically recent rocks, they found it was generally consistent with Earth's current magnetic field, however the paleomagnetism of ancient rocks, though, showed different orientations. This meant that the rocks have been moved as Wegner had suggested. Paleomagnetic studies show that the most recent period of continental drift in the earth's history began about 200MYA in the early Mesozoic era, when the present continents split off from a single giant continent, Pangaea.

14. **Tectonic Activity** – The occurrence of frequent tectonic activities such as earthquakes, vulcanicity and faulting is evidence of continued continental drift. Such activities mostly occur at plate boundaries and are signs of instability within the earth's interior which ultimately causes movement within the crust hence drifting of continents.

- Scientists/Geologists have discovered that the gap between South America and Africa is widening at an average rate of 2-3cm per year. Also the Red Sea, which originated as a rift valley that began to spread apart about 20m years ago and is now over 300 km wide.

EFFECT OF CONTINENTAL DRIFT ON RELIEF AND LANDFORMS

The theory of continental drift can be used to explain the formation of many relief landforms in East Africa. The theory helps to explain the origin of various forces that have created various landforms in East Africa. Such forces include faulting, folding, crustal warping and vulcanicity. The interior of the earth is in a semi-fluid state due to heat generated by radioactivity and geochemical reactions. This heat creates convective currents;

- When convective currents collide the create compressional forces, causing folding, faulting & vulcanicity.
- When convectional currents move apart they create tensional forces,
- When convectional currents sink back into the mantle the cause down warping of the crust.
- When convectional currents rise up in the mantle the cause vulcanicity and up warping (**Epeirogenic uplift**) as well as faulting of the crust.
- When rocks fracture they release pressure which had accumulated in them for a long time. This sudden change in rocks result into shock waves within the earth crust causing tremors normally called **earthquakes.**

The major landforms resulting from the above forces include block mountains, volcanic mountains, rift valleys, basins, to mention but a few.

REVISION QUESTIONS

1. Account for the present day distribution of continents and ocean basins.

2. Justify the theory of continental drift using specific examples from the southern continents.

3. Explain the relevance of Wegener's theory of continental drift to the understanding of the present day distribution of continents and ocean basins.

4(a) What is meant by plate tectonics movements?

(b) Explain the influence of plate tectonic movements on the development of relief landforms in EA.

Approach

- ***Define plate tectonic movements, outline the assumptions of the theory including;***
- ***The cause, major plates and the major plate boundaries.***

- *In part (b) Show how plate tectonism generates tensional; compression forces and vertical movements which led to the occurrence of faulting, vulcanicity, warping and folding.*
- *Explain the formation of landforms produced by these tectonic processes.*

5. Examine how Wegener's theory of continental drift explains the formation of relief landforms in EA.
6(a) What is continental drift?
(b) Account for the occurrence of continental drift.
7. Examine the relevance of Wegner's theory of continental drift in explaining the present position of continents.
8(a) Distinguish between lateral and vertical earth movements.
(b) Examine the relevance of the plate tectonic theory in the understanding of the present distribution of oceans and landmasses.
9(a) Explain the theory of plate tectonism.
(b) Examine the evidence put forward to support the plate tectonic theory of continental drift.

ROCKS

A rock is a combination or an aggregate composition of minerals in a solid state. In other words a rock is combination of one or more minerals/elements in a solid state. The Earth's outer solid layer, the **lithosphere**, is made of rocks in great variety, of different degrees of hardness, coherence and permeability. The minerals that form rocks may be inorganic or organic substances which undergo the process of **lithification** or **diagenesis** (rock forming process). All minerals are formed from one or more of eight main elements, namely oxygen, silicon, potassium, sodium, calcium, magnesium, iron and aluminium.

The study of rocks is of immense help in understanding how the present landscape has come to be what it is. Rocks are classified into two broad categories;
(i) Classification according to geological age
(ii) Classification according to mode of origin or formation.

Classification according to mode of origin is the most widely used because classification according to age is rather complicated since rocks change characteristics after a very long time. There are three types of rocks based on origin of mode or formation:
Igneous rocks (fire-formed); Metamorphic rocks (derived or changed); Sedimentary rocks (laid down or stratified).

IGNEOUS ROCKS

These are "***fire-formed***" rocks resulting from the cooling, solidification and crystallization of molten magma through the process of vulcanicity. They may be deposited either within the earth crust to form intrusive rocks or onto the earth surface to form extrusive rocks. The magma is from the mantle where intense heat caused by radioactivity and geochemical processes in the earth's core keep the underlying rocks in molten form and creates convective currents. The convective currents exert pressure on the crustal rocks creating cracks or fault lines or fissures through which the hot rocks or magma is either intruded or extruded and on cooling forms crystalline rocks.

Characteristics of Igneous Rocks:
- They are hard
- They do not contain fossils because they're not formed from plant and animal remains
- They do not occur in layers, i.e. they're not stratified
- They are crystalline in nature or have crystals.
- Some are spongy in nature such as pumice
- Some are dark colored such as basalt

Types of Igneous Rocks:
As magma is pushed from the mantle into the crust, it cools at different levels of the crust and forms various types of igneous rocks as noted below;

Volcanic/Extrusive Rocks – These are formed by the solidification and crystallization of lava on the earth surface. They have ***very small crystals*** due to ***fast rate*** of cooling and exposure to oxygen. They are generally ***hard***. Examples include ***obsidian, rhyolite, basalt, trachyte and***

andesite. They mainly found in features such as volcanic mountains like Mt. Elgon, Mt. Kenya, Mt. Kilimanjaro, as well as lava plateaux like Yatta.

Andesite

Basalt

Obsidian

Rhyolite

Intermediate/Hypabyssal Rocks – These are formed due to cooling and solidification of rising magma just beneath the earth surface (at a ***relatively shallow/moderate/medium/average depth***). They cool at a ***moderate rate*** and have ***mid-size crystals***. Hypabyssal rocks are less common than plutonic or volcanic rocks and often form dikes, sills, laccoliths, lopoliths, or phacoliths. Examples include ***quartz, dolerite and porphyry***. They're formed in features such as dykes and sills in Turkanaland.


Quartz

Dolerite


Porphyry

Plutonic/Abyssal Rocks – These cool and solidify at ***great depth*** within the earth crust. The magma cools and solidifies ***very slowly*** due to absence of oxygen thus forming ***large or coarse grained crystals***. Typical intrusive formations are batholiths, laccoliths, sills and dykes. Examples include ***granite, diorite, pumice, gabbro syenite and peridotite***. They are seen on the surface only after being exposed by prolonged erosion, e.g. the exposed batholiths at Ssingo, Mubende.

Granite

Diorite

Gabbro

Type	***Formed at***	***Rate of cooling***	***Size of crystals***	***Examples***
Volcanic	Surface	Fast	Small	Basalt, Rhyolite, Trachyte, Andesite
Hypabyssal	Shallow depth	Medium	Medium	Quartz, Porphyry, Dolerite
Plutonic	Great depth	Slow	Large	Granite, Syenite, Gabbro, Diorite

Magma that is ejected into the crust varies in its chemical composition and this in turn affects its viscosity, rate of cooling and the process of crystallization. Acidic igneous rocks have a high amount of silica making them viscous, immobile and cool rapidly e.g. granite and rhyolite;

intermediate igneous rocks have an average amount of silica which makes them fairly mobile e.g. andesite while basic igneous rocks have little silica which makes them very mobile e.g. gabbro and basalt.

Igneous rock in East Africa are found around volcanic highlands such as Mt. Kenya, Mt. Kilimanjaro, Mt. Elgon, Mt. Muhavura and Mufumbiro, etc. the East African rift valley, to mention but a few.

SEDIMENTARY ROCKS

They are also called "***derived***" rocks. These are formed by the weathering, erosion, transportation and deposition of sediments (weathered particles or materials) of former rock masses and organic matter by water, wind, ice, mass movement or glaciers and laid down in layers or strata. The layers or strata are then compressed, cemented, compacted and hardened by the pressure of successive layers deposited on top, in a process called ***Lithification or Diagenesis***.

The layers or strata are separated by a bedding plane, which usually indicates where one phase of deposition has ended and another begun. Layers can be horizontal, gently sloping of steeply dipping.

Characteristics of Sedimentary Rocks:
- They contain fossils of dead plants and animals
- They have no crystals
- They have layers or are stratified
- Strata or layers are either horizontal, gently sloping of steeply dipping.
- The layers or strata are separated by bedding planes of cementing materials.
- The cementing may be done by calcite, silica, or hematite agents.

Formation of Sedimentary Rocks
- Weathering of pre-existing rocks, i.e. igneous and metamorphic or the parent rocks
- Erosion and transportation of weathered particles or sediments by wind, ice and running water
- Deposition of sediments by wind, ice and running water on dry land, valleys or basins
- Stratification or sorting or layering of deposited materials in successive layers called strata. As the settling takes place the rock fragments are graded by size. The larger heavier pieces settle out first. The smallest fragments travel farther and settle out last.
- Compression of stratified materials by the overlying weight of subsequent depositions
- Compaction or hardening of compressed layers due to further deposition reducing pore space.
- Cementation of deposited layers by calcite (calcium carbonate), silica, or hematite (red iron oxide) agents. Cementation happens as dissolved minerals become deposited in the spaces between the sediments acting as glue or cement to bind the sediments together.
- Consolidation and transformation of sediments into different types of sedimentary rocks.

N.B. The process of sedimentary rock formation takes millions of years to complete.

Sedimentary rocks may be classified into three types according to mode of origin;

- **Mechanically formed sedimentary rocks** – They are formed from the ***breakdown***, ***deposition*** and ***compaction*** of detrital sediments such as sand, silt, clay and gravel by physical weathering. The deposited materials accumulate and with time they are cemented and consolidated into a mass of sedimentary rocks. Sediments include clay, gravel and alluvium (deposited by water); moraine, boulder clay and gravel (deposited by ice); and loess (deposited by wind).
  Examples of resultant rocks include ***sandstone, mudstone, clay, tillite, shale, breccia, siltstone and conglomerate***.

Breccia

Conglomerate

Sandstone

Shale


Mudstone

Siltstone

Organically formed sedimentary rocks – They are formed from the decomposition of organic remains (dead organisms) the hard parts or skeletons of which have accumulated, compressed, compacted and later cemented into organic sedimentary rocks over long periods of time. For instance coral polyps form ***limestone rock or coral rock or reefs*** at Mombasa, Malindi & Dar es Salaam; plant remains were compressed usually in a swamp environment to form ***coal*** (lignite, bituminous & anthracite) in Ruhuhu valley (SW Tanzania).

Limestone

Coal

Chemically formed sedimentary rocks – They are formed from the chemical precipitation and evaporation of salt solutions in hot tropical regions. When water evaporates, salt pans are left behind as a residue or deposit, which dries up, are compacted, cemented, consolidated and transformed into a hard rock. Examples include ***rock salt, dolomite, potash, borax, gypsum and soda ash***. These can be found at L. Katwe in SW Uganda; Lakes Magadi & Natron.

Rock salt


Dolomite


Gypsum

Formation or type	Examples
Mechanical	Shale, clay, mudstone, sandstone, tillite, conglomerate, breccia, siltstone
Organic	Limestone, coal
Chemical	Dolomite, rock salt, borax, gypsum, soda ash

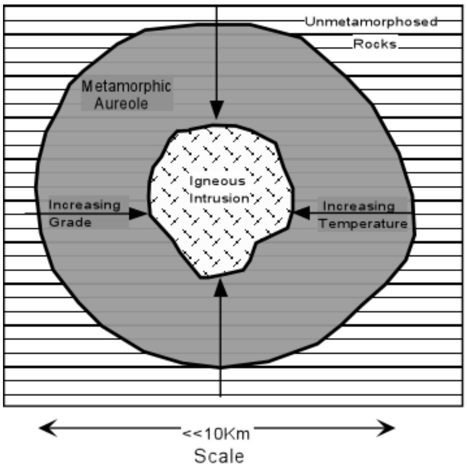
METAMORPHIC ROCKS

These are "***changed***" rocks. They are formed from the transformation of pre-existing rock types (igneous or sedimentary), by intense heat and pressure, which alter rock structure and chemical composition, in a process called ***metamorphism***. The original rock (protolith) is subjected to heat and pressure, (temperatures greater than 150 to 200 °C and pressures of 1500 bars) causing profound physical and/or chemical change to produce new rocks. Metamorphic rocks are formed at great depth compared to other rock types. They are in general compacted and resistant to erosion.

They may be formed simply by being deep in the Earth's crust, subjected to hot temperatures and the great pressure of the rock layers above it. They can form from tectonic processes such as continental collisions, which cause horizontal pressure, friction and distortion (folding). They are also formed when rock is heated up by the intrusion of hot molten rock called magma from the Earth's interior where they are recrystallized and hardened into metamorphic rocks.

If the pre-existing rock is changed to a metamorphic rock due to pressure, such a metamorphic rock is called a ***Dynamic Metamorphic Rock***, and the process is known as ***Dynamic Metamorphism***. This may be due to compression by the weight of overlying rocks or by earth movements like faulting and folding exerting pressure on existing rocks.

If the pre-existing rock is changed to a metamorphic rock due to heat, such a metamorphic rock is called a ***Thermal/Contact Metamorphic Rock,*** and the process is known as ***Thermal Metamorphism***. This is usually due to the intrusion of hot magma from the mantle transforming the country rocks into metamorphic rocks in a zone called ***aureole***.



If the transformation is due to both heat and pressure, the resultant rock is called a ***Thermal-dynamic metamorphic*** **rock** and the process is called ***thermal-dynamic metamorphism***.

When heat and pressure are too intense, the metamorphic rock may be changed to a molten state and recycled into an igneous rock.

Examples of metamorphic rocks include; ***gneiss (derived from granite), quartzite (derived from sandstone), slate (derived from clay), schist (derived from shale), marble (derived from limestone) and coal/graphite (derived from organic matter)***.

Gneiss

Marble

Quartzite

Schist

Slate

Original rock	**Metamorphic rock**
Granite becomes	Gneiss
Sandstone	Quartzite
Clay	Slate
Shale	Schist
Limestone	Marble
Organic matter	Graphite

The Effect of Rock Type on Landform Evolution in East Africa

Igneous rocks produce intrusive and extrusive landforms such as volcanic highlands, lava plateaux, volcanic plugs, batholiths, dykes, craters, to mention but a few.

Sedimentary rocks create landforms from deposition of either eroded materials, organic materials or precipitation of certain chemicals from sea water such as coral landforms like barrier reefs, fringing reefs and atolls. They also create karst landforms such as caves, stalactites, stalagmites, pillars, etc. Alluvial deposits produce deltas, levees, flood plains, etc. Glacial deposits create drumlins, kames, etc. At the coasts sand bars, spits, beaches, etc. are created.

Metamorphic rocks create uplands when the rock is hard like quartz and when the rock is soft like clay they create arenas.

N.B. Students to research about the economic importance of rocks in East Africa.

REVISION QUESTIONS:

1. Account for the formation of igneous rocks in EA.

Approach
- *Define igneous rocks*
- *Explain the process of formation*
- *Identify the major types of igneous rocks,*
- *State and give the Characteristics, examples of each sub-type and areas where they are found in EA.*

2. Explain the influence of rock types on landform development in EA.

3(a) With the aid of diagrams, account for the formation of different rock types in EA.

(b) Outline the economic importance of rocks in EA.

4(a) Describe the processes which have led to the formation of sedimentary rocks.

(b) Explain the importance of sedimentary rocks to EA.

Approach
- *Define sedimentary rocks*
- *state the characteristics of sedimentary rocks*
- *Describe the processes / conditions of formation*
- *Identify and Explain the formation of the three types of sedimentary rocks*
- *Give examples of each type and where they are found*
- *In part (b) explain the positive and negative importance of sedimentary rocks*

5(a) Describe the formation of igneous rocks.

(b) Explain the influence of igneous rocks on landform development in EA.

6. Examine the processes responsible for the formation of various rock types in EA.

Approach
- *Define a rock*
- *Identify the major rock types in East Africa i.e. igneous, sedimentary and metamorphic*
- *Describe how each rock type is formed*
- *State the characteristics of each type; give example areas where they are found.*

7(a) Differentiate between igneous and metamorphic rocks.

(b) Explain the importance of rocks to EA.

Approach

- *Define igneous and metamorphic rocks*
- *Explain the processes of formation for each type,*
- *State the major categories and examples of each rock type.*
- *In part (b) explain the positive and negative importance of rocks*

8(a) Differentiate between igneous rocks and sedimentary rocks.
(b) Explain the processes responsible for the formation of igneous rocks in EA.

WEATHERING

Introduction:
Weathering is an exogenic process which refers to ***the physical or mechanical fracturing or breakdown and chemical decomposition or decay or rotting of rocks 'in situ' (without any movement involved) by natural agents at or near the earth surface***. **Weathering** is the first stage in the **denudation** (wearing away) of the landscape. Other forms of denudation are *erosion, mass wasting and transportation*. These are different from weathering because they involve washing away and movement of weathered materials.

The end product of weathering is the formation of layers of weathered rocks known as **Debris/Regolith.** The action of weathering is dependent upon the removal of weathered layers by agents of erosion, notably wind, water and ice. If the debris/regolith is not removed, it may act as a protective layer to the underlying rock, thus preventing further weathering to take place.

Weathering processes combined with erosion and re-deposition are extremely useful in shaping landforms on the earth surface. Weathering also contributes to the formation of soil by providing mineral particles like sand, silt, and clay.

[*From the academic point of view, weathering is an important group of processes that once again illustrates the interactions among Earth's systems. But there are other good reasons to study weathering. One reason is so that we can develop construction materials that are more resistant to physical and chemical changes, or develop more effective methods to protect them from the elements. Another reason is that weathering is an essential part of the rock cycle. When **parent material** - that is, rocks and minerals exposed to weathering – breaks down into smaller pieces or perhaps dissolves, this weathered material may be eroded from the weathering site and transported elsewhere, by running water or wind, and deposited as sediment, the raw materials for sedimentary rocks. In addition to providing the raw materials for sedimentary rocks, weathering is responsible for the origin of soils. Needless to say, we depend on soils directly or indirectly for our existence. Another reason to study weathering is that it accounts for the origin or concentration of some natural resources, the ore of aluminum, for instance. Weathering is also responsible for many clay deposits that are used in ceramics and the manufacture of paper, and weathering coupled with erosion and deposition yields deposits of tin, gold, and diamonds.*]

Several agents facilitate weathering processes; they include atmospheric gases such as oxygen, carbon dioxide, and water vapor, biotic agents like man, plants and animals.

Two important classifications of weathering processes exist – physical and chemical weathering. Biological weathering is at times considered independently although it can be included in the above categories since biological processes can either be physical or chemical.

CHEMICAL WEATHERING/DECAY/ROTTING/DECOMPOSITION

This refers to the decomposition or decay or rotting of rocks in situ at or near the earth surface thru various chemical reactions. The chemical reactions take place between rock minerals, water and certain atmospheric gases, namely oxygen and carbon dioxide. The chemical nature of the rock is thus changed by transforming the original mineral compounds into new secondary compounds that are easily removed or dissolved or decomposed, i.e. new compounds are formed.

Chemical weathering processes operate more rapidly under the following conditions;
- Hot temperatures to accelerate the rate of chemical reactions
- Heavy rainfall and high humidity to avail water to enable chemical reactions

Thus chemical weathering is most effective in the warm, moist climates of the equatorial and tropical zones. Examples of such areas include Mabira forest, Northern shores of Lake Victoria, Kalangala Islands, among others.

With chemical weathering rocks may increase in volume, density and mass, rock material may become more mobile, rock texture or color may change with certain minerals added or subtracted and finally new rocks and minerals are formed. The main chemical processes include carbonation, hydrolysis, hydration, solution, reduction and chelation.

Carbonation – In this process carbon dioxide in the atmosphere mixes with rain water to form weak carbonic acid, and then reacts with certain minerals in rocks such as calcium carbonate, weakening and changing them into calcium bicarbonate that is readily removed in solution. This process is important in weathering calcareous rocks like limestone, marble and dolomite.

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

Calcium Carbonate + Carbonic Acid → Calcium bicarbonate (Calcium hydrogen carbonate)

This process is common in areas with limestone such as Tororo, Hima (Kasese), Nyakasura and the coastal areas of East Africa at Bamburi and Kilifi. Such weathering has led to the formation of karst landforms.

Hydration - In this process certain rock minerals absorb water and expand causing internal stress, finally fracturing and decomposing. New compounds formed are readily removed in solution. For instance, hematite absorbs water and is changed into limonite while calcium sulphate is turned into gypsum.

$$2Fe_2O_3 + 3HOH \longrightarrow 2Fe_2O_3 .3H2O$$

(Hematite) (Red) → (Limonite) (Yellow)

$$CaSO_4 + 2H_2O \longrightarrow CaSO_4.2H_2O \text{ (Gypsum)}$$

(Anhydrite calcium sulphate)

Hydrolysis – In this process hydrogen ions in water (OH- and H+) react with certain metal ions in rock minerals to produce new chemical compounds hence decay of the rock. For example feldspar is broken down into soft clay that is readily washed away. This process is common in the broad valleys of Buganda such as Kajjansi; and at Taita in Kenya. Hydrolysis often occurs with carbonation.

Oxidation – It involves the addition of oxygen to mineral elements. Oxygen dissolved in water reacts with mineral elements in rocks forming oxides that are weak and easily decompose. For instance rocks containing iron are affected by oxidation forming reddish brown iron oxide (rust) that crumbles easily into smaller particles and is thus removed, loosening and weakening the rock structure. Laterites along the valleys of Buganda such as Nakigalala along Entebbe road were formed when ferrous rocks were oxidized.

$$4Fe^{+3} + 3O_2 \longrightarrow 2Fe_2O_3$$

Iron + Oxygen → Iron oxide

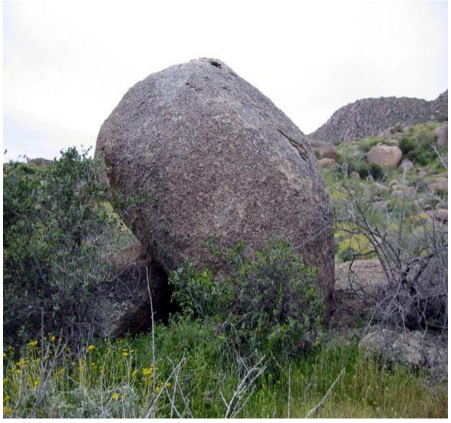
Reduction – It involves the removal of oxygen ions from rocks and replaced with hydrogen ions in water logged or swampy areas where water is stagnant and deoxygenated. It's common in swampy areas such as Kajjansi, Athi, among others. There is usually a change in soil colour to grey, blue or green.

$$2Fe_2O_3 \text{ (Hematite)} - O_2 \longrightarrow 4FeO \text{ (Ferrous oxide)}$$

Solution – Here some soluble rock particles are directly dissolved in water and weathered or removed in solution. The rock no longer remains solid and form holes, rills or rough surface and finally decomposes. This process mainly affects rock salts, sodium chloride, calcium chloride, magnesium chloride and calcium sulphate. This process is common in areas of Northern Kenya such as Marsabit & Samburu; areas around Lake Katwe and Lake Magadi.

Chelation - Decaying remains of dead plants in soil may form organic acids when dissolved in water causing chemical weathering when they react with rock minerals. Also plant roots extract minerals from rocks causing chemical changes. Furthermore plant roots release mineral nutrients into rocks thus causing chemical decay. Plants, such as the lichens on bare rocks, contribute to the decomposition of rocks by absorbing chemical elements from the rocks as food and also produce organic acids. Chelation is therefore a process which widely operates in an environment of dense vegetative cover.

Spheroidal weathering – Some rocks may absorb water along joints loosening and decaying the rock layer. As the process continues the outer shell of the rock swells or expands, decays and crumbles thus creating rounded boulders. It's also known as ***concentric or spherical weathering***. It mainly affects jointed rocks and occurs underground before the rock is exposed.




FACTORS AFFECTING CHEMICAL WEATHERING

1. **Nature of the parent rock:**
Mineral composition of the parent rock: some rocks like those having calcium carbonate react with carbonic acids which are due to combining of rain water with carbon-dioxide in the atmosphere to produce calcium bi carbonate by a process known as carbonation e.g. at Nyakasura. The calcium-bicarbonate can easily be dissolved in water.

Some rocks have minerals like feldspar which when mixed with water decompose to produce other mineral compounds like potassium hydroxide and aminocilic acids through the process of hydrolysis. However, in the absence of water, feldspar is a very hard element to weathering.

Some rocks have mineral compounds which react with oxygen in the presence of water to form new compounds or oxides through the process of oxidation e.g. ferrous rocks (rocks rich in iron compounds) are turned into brown or red ferric compounds or laterite soils.

Some rocks have minerals that can easily dissolve in water and the solution is carried away leading to the decomposition of the rocks through a process of solution e.g. limestone rocks, rock salts etc.

Jointing of the rock: the presence of joints or cracks increase the surface area for chemical reactions to take place and also allow water to penetrate to the deeper layers of the rocks to chemically weather the rock.

Permeability of the rock: when a rock is permeable, it allows water to penetrate and weather the deeper rock layers through the processes like carbonation, hydration and hydrolysis etc.

2. **Climate**:
The nature of climate experienced in area determines the type of weathering as indicated below;
Rainfall or precipitation provides the water needed for chemical weathering to take place. Many areas in East Africa receive heavy rainfall amounts almost year throughout (equatorial climate). Other areas like the savannah regions receive moderate rainfall and hot temperatures and such humid conditions are conducive for chemical weathering to take place for most of the year.
Areas having hot temperatures for most of the year have physical weathering as the most dominant weathering process. However, most of the humid areas in East Africa have hot

temperatures of over 20^0 C which increase the rate of chemical reactions thus promoting chemical weathering.

3. **Relief**:
Chemical weathering is more dominant on gentle slopes and low lying areas as water accumulates and percolates to chemically weather the rock than on steep slopes. However, erosion on the steep slopes exposes the rocks to chemical weathering.

4. **Drainage**:
Leaching occurs on flat lands because of poor drainage i.e. rock minerals are dissolved and taken away in solution to deeper layers of the soil profile. This leaves behind residual soils which are rich in iron, magnesium, and calcium compounds. The iron compounds are oxidized in the process of oxidization to form laterite soils.

Poorly drained areas like flat plains have a high dominance of chemical weathering inform of hydrolysis, hydration, reduction and solution which help to decompose the rock. This is because of the stagnant water in valleys and other low lying areas.

5. **Living organisms**:
Man's influence; man may influence chemical weathering through a number of ways e.g.

a. Emission of industrial gases in the atmosphere which increases acidity in rainy water which accelerates the rate of chemical weathering processes of carbonation.
b. Dumping of industrial or domestic or agricultural influence on land or water which directly react or increase the activity in the environment thus increasing the rate of chemical weathering by carbonation etc.
c. Man carries out activities that directly involve the breakdown of rocks e.g. mining, quarrying, road and other activities like agriculture which expose the underlying rocks to chemical weathering processes. Also irrigation avails water that increases chemical weathering processes like hydration, hydrolysis and solution.

Vegetation: the dead decaying organic matter produce humic acids that assist in rock decomposition. These humic acids react with minerals in the rocks and eventually decompose.

Plant roots release mineral substances into the rock while extracting other mineral substances from the rock in a process known as chelation. This weakens the rock and it eventually breaks up.

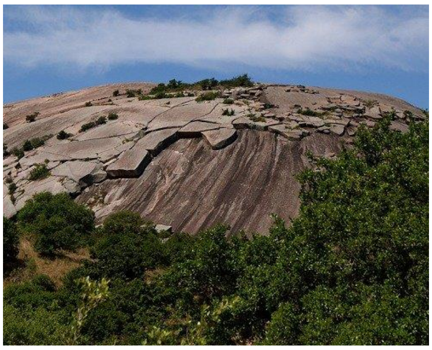
Other living organisms like animals secrete acids that chemically decompose the rocks e.g. uric acids. Barrowing animals make holes through the soil e.g. moles, termites etc. and through these holes water penetrates to the deeper layers of rocks which aids chemical weathering through processes like solution, hydration, hydrolysis, carbonation etc.

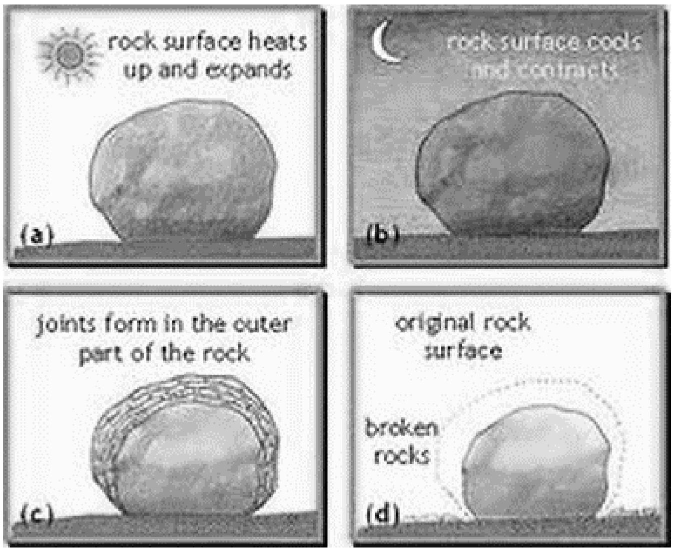
6. **Time**:
It takes time for the rock to undergo chemical weathering. The longer the time, the more the rock is chemically weathered and the shorter the time, the lesser the rock is chemically weathered.

PHYSICAL/MECHANICAL WEATHERING OR DISAGGREGATION

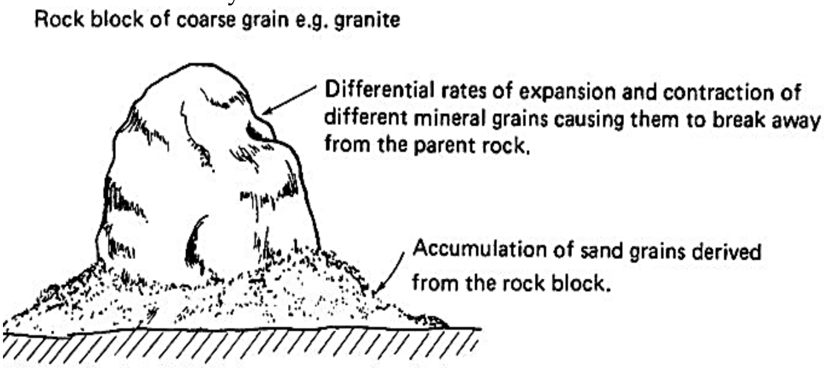
This involves the gradual physical or mechanical breakdown or fracturing of rocks 'in situ' without change in their chemical composition or set-up. Physical weathering occurs at or near the surface but under certain conditions it may occur at considerable depth. Physical weathering results in the breaking down of rock into successively smaller fragments and particles. This process is largely influenced by temperature changes, frost action and biotic factors like man, plants and animals. Physical weathering is more effective in areas which have: a little vegetation, a large diurnal range of temperature i.e. arid & semi-arid areas and temperatures fluctuating around 0^0 Celsius i.e. high mountain areas of Rwenzori, Kenya & Kilimanjaro. It is dominant in arid and semi-arid regions such as Karamoja, Turkanaland, Masailand, Lake Albert flats, Serengeti areas, Mubende and Nakasongola. The main processes of physical weathering include exfoliation, block disintegration, granular disintegration, frost action, pressure release and salt crystallization.

Exfoliation/Thermal Expansion/Onion Weathering - In arid & semi-arid areas with large daily or diurnal temperature ranges, rocks expand when heated during day and contract as they cool at night causing internal stress in the rock and eventually fracturing the rock. Rock being a poor conductor of heat, so the outside heats up more than the inside hence the surface expands more than the interior, producing stresses or strains that may cause fracturing or peeling off the outer rock layer. This forms ***exfoliation domes***. The fallen angular rock particles called screes collect at the bottom of the rock forming a ***talus or scree slope***. This process is dominant in arid and semi-arid areas such as Kumi, Nakasongola, Mubende, Kitgum, Songea, Kongwa and Serengeti.

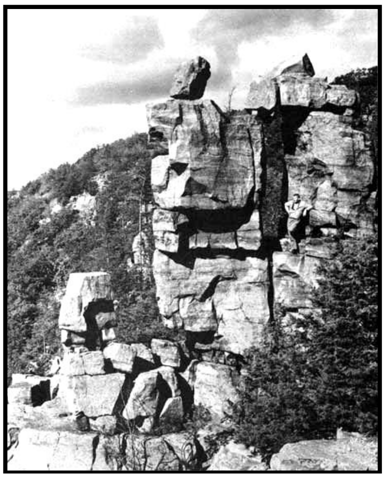


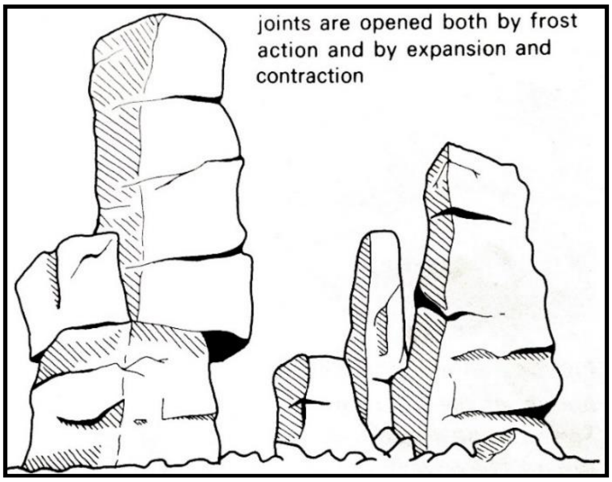


Granular Disintegration - This occurs in heterogeneous crystalline rocks i.e. rocks composed of different minerals and colors, especially igneous and metamorphic rocks. These minerals expand and contract at different rates when heated causing internal fracturing and gradual disintegration of the rock into separate small angular coarse grains. This is common in the Yatta plateau of Kenya and Chalbi desert in Northern Kenya.

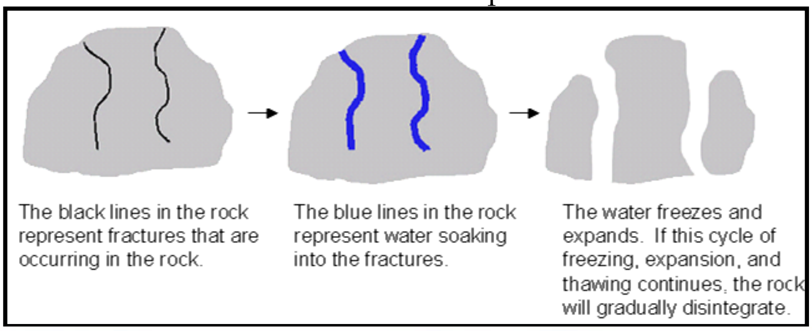


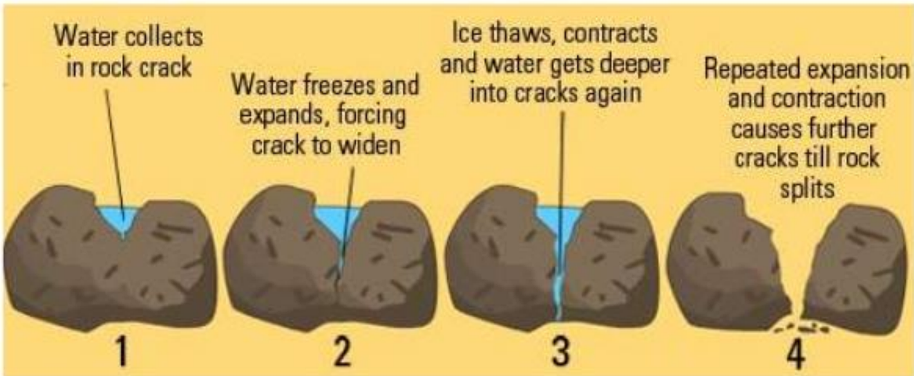
Block Disintegration – This process occurs in well-jointed rocks. Here hot temperatures successively heat up and expand rocks and contract on cooling, in the process rocks break up into large rectangular shaped blocks or boulders. It is common in granitic rocks and areas with large diurnal/daily temperature range. This process is can be seen in parts of Mubende, Nakasongola and in Soroti on Kachumbala hill.



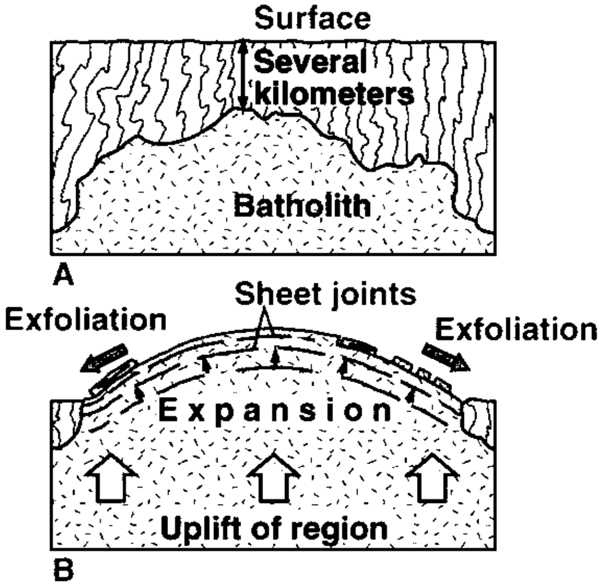


Freeze-thaw Action/Frost Action/Frost Shattering – This process occurs in mountainous areas and cold climates where there is alternate freezing and thawing/melting of ice such as Rwenzori, Kenya and Kilimanjaro mountains. This is the most effective form of physical weathering. During the day water fills the rock joints or cracks and at night water freezes. When water freezes it expands by about 9 percent in volume thus widening and deepening rock cracks and joints. Repeated freeze-thaw will eventually shatter the rock along the cracks or joints into angular pieces. The broken materials collect at the foot of the slope to form ***scree or talus slopes***.



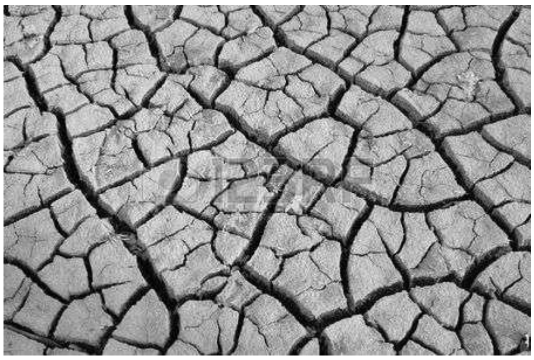


Pressure Release/Unloading/Dilatation - Most of the igneous and metamorphic rocks are formed at great depths in the crust under great heat and pressure, e.g. granite. When the overlying materials are removed by erosion and mass wasting, pressure on the underlying rocks is reduced, causing them to expand, arch and split or crack along the surface. Over a period of time, the outer layers of the rock break away in sheets. This process is common in the Nyika plateau and Machakos in Kenya; Arua and Nakasongola in Uganda; Mwanza and Iringa in Tanzania. And high mountain areas.



Salt Crystallization - Under some circumstances, saline solutions penetrate rock joints, evaporate, crystallize and expand causing fracturing or disintegration of rocks. In hot desert and semi-desert areas high evaporation, groundwater rises to the rock surface by capillary action and evaporates leaving behind tiny salt crystals which accumulate overtime leading to fracturing of rocks like sandstone apart, grain by grain. This can be seen in the rift valley areas of L. Magadi, L. Natron, L. Katwe, and Kasenyi.

Aridity shrinkage/Alternate wetting and drying - Some rocks such as clay absorb water during rainy seasons and expand or swell. When they dry water evaporates and they quickly contract or shrink. This alternate wetting and drying weakens the rocks and they begin to crack and the rock crumbles into fragments. Aridity shrinkage is common in swamps or areas with clay such as Masai-Mara plains in Kenya and Tanzania, Nakasongola and Tororo in Uganda.



Factors favouring physical weathering

a) **Hot and dry climate**

Hot temperatures during the day and cool night temperatures cause wide temperature fluctuations thus alternate expansion and contraction. This leads to breakdown of rocks through exfoliation, granular disintegration and block disintegration to form landforms like exfoliation domes and granitic tors. This explains why physical weathering is a dominant process is the semi-arid environments of East Africa.

b) **Short rains**

The presence of short rains in semi-arid areas facilitates the occurrence of aridity shrinkage. This is when porous rocks like clay tend to absorb water during the short rainy season and expand/swell. Later, when the dry season sets in they lose water, dry up and crack; this causes breakdown of rocks into smaller fragments.

c) **High altitude cold climatic conditions**

In high altitude areas like mountain Rwenzori, cold temperatures cause freezing of water in rock cracks/joints and when temperatures warm up during the day, the ice melts. Alternate freezing and thawing leads to breakdown of rocks in a process known as frost shattering.

d) **Limited/thin cloud cover**
The existence of a limited/thin cloud cover in semi-arid and desert areas exposes surface rocks to hot temperatures during the day leading to expansion and cold temperatures at night leading to rapid cooling and contraction of rocks, resulting into rock breakdown through exfoliation.

e) **Heterogeneous rocks**
Heterogeneous rocks expand and contract at different rates leading to the occurrence of granular disintegration.

f) **Jointed rocks**
Jointed rocks expand and contract along joints leading to block and granular disintegration. Frost action also is more efficient in well-jointed rocks of mountainous areas since the joints are widened by snow to cause eventual breakdown of rocks.

g) **Dark coloured rocks**
Dark coloured rocks like basalt absorb a lot of heat. This causes their expansion on hot days but later contract when temperatures fall. This alternate expansion and contraction of rocks causes their breakdown into progressively smaller particles through processes such as granular disintegration.

h) **Vegetation cover**
Plant roots grow deep into the rock joints, causing expansion of cracks and eventual breakdown of rocks into smaller particles.

i) **Role of animals**
Constant trampling of domesticated and wild animals on rocks causes development of joints into the rock system. Such movements stress and strain the rocks which eventually breakdown into smaller fragments. This partly explains why physical weathering is a dominant process in Nomadic Pastoral communities of the Sahel region and Semi-arid areas of East Africa.

j) **Human activities**
Human beings normally carry out a number of activities for survival. For instance in areas where mining, quarrying, cultivation and construction activities are carried out explosives, hammers, grinding machines are used to breakdown rocks into smaller particles required for constructional purposes.

BIOLOGICAL/ORGANIC WEATHERING

Animals, plants, and bacteria all participate in the mechanical and chemical decay of rocks. Movement of animals and insects in the ground such as worms, termites, reptiles and rodents, loosen and constantly mix partially weathered rock thus promoting weathering.

Also burrowing animals and insects increase access of gases like oxygen, and water to greater depths through cracks and holes created and thus promoting decay of rocks.

Burrowing animals and insects carry organic matter down from the surface hence promoting further decomposition of rocks.

The earthworms ingest (eat) soil and thus bring about physical and chemical changes in soil material.

Large animals with large hooves trample rock surfaces leading to physical break down of rock surfaces. Such animals include buffaloes, elephants, cattle, rhinos, and wildebeest among others.

The active growth roots of plants, especially large bushes and trees, can exert pressure strong enough to open and widen cracks or joints in rocks.

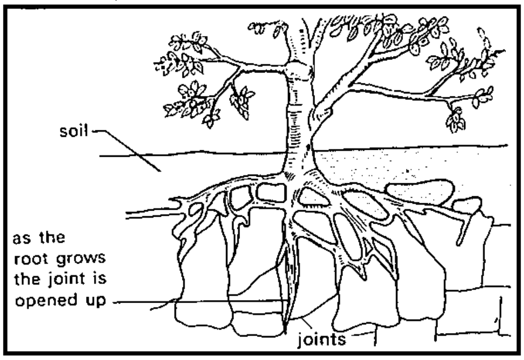
Furthermore, the cracks or joints provide a pathway for water, atmospheric gases and chemical infiltration hence further rock decay.

Plant roots release acids/chelating compounds (organic acids) that react with and decompose rocks.

Micro-organisms release soil acids as they digest organic matter, thus the acids rapidly decay rocks in wet climates.

Decaying/Decomposing remains of dead plants in soil may form organic acids which, when dissolved in water, cause chemical weathering.

Man through his activities such as mining, quarrying, building roads, and cultivating the land, exposes the rocks to other agents of weathering thus promoting physical and chemical weathering. This is known as ***Accelerated weathering***. In urban areas, sulfur and nitrogen oxides pollute the air. When these gases dissolve in rainwater, we get acid precipitation rich in sulfuric and nitric acids, which rapidly dissolves limestone and chemically weathers other types of building stones, stone sculptures, building decorations, and tombstones.



Trees put down roots through joints or cracks in the rock in order to find moisture. As the tree grows, the roots gradually prize the rock apart.

Algae and lichens produce chemicals that help break down the rock on which they live, so they can get the nutrients thev need.

The interdependence of chemical and physical weathering

All the three types of weathering are interdependent. Physical weathering may open up some areas through disintegration thus enabling chemical weathering processes to take place deeper within the rock.

Physical weathering is at its maximum in arid and semi-arid regions because of high diurnal or daily temperature ranges which create stress and strain within the rock while chemical weathering is at its maximum in humid areas due to the presence of water which facilitates chemical reactions.

In general, all three types of weathering operate together and are usually complementary although in a given area one type may be more dominant than the others. For instance since chemical weathering occurs on the surface of minerals, the water and acids that control chemical weathering require access to the surface. Physical weathering breaks the rock to provide that surface. Fracturing the rocks, as occurs during jointing, increases the surface area that can be exposed to weathering and also provides pathways for water to enter the rock. As chemical weathering proceeds, new softer minerals, like oxides or clay minerals, will create zones of weakness in rock that will allow for further physical weathering.

Differences Between Physical and Chemical Weathering

Physical weathering involves breakdown of rocks into smaller fragments without any change in the chemical composition or character of the rock, thus no new minerals are formed. Chemical weathering involves the breakdown of rocks and causes changes in rock composition. Thus new minerals are minerals or products are formed.

Physical weathering is mainly influenced by temperature changes hence it is common in arid and semi-arid areas with large daily temperature ranges. Chemical weathering is mainly influenced by water thus it is common in humid or tropical areas with high rainfall amounts throughout the year.

Physical weathering occurs in the upper layers of the crust, thus shallow. Chemical weathering occurs even in the deeper layers where percolating water can reach.

Physical weathering involves rapid disintegration of rocks. Chemical weathering involves slow decomposition of rocks (rotting).

Factors Influencing the Rate and Nature (Type & Character) of Weathering Processes

1. Nature of rock

(a) ***Mineral composition of the rock*** - The mineral composition of rock can greatly affect the rate and nature of weathering. Igneous and metamorphic rocks are susceptible to chemical weathering because they are formed under temperature and pressure conditions different from those operating at the earth surface. Thus they are not chemically stable and when they are exposed to elements at the surface such as water and air, ***chemical weathering*** processes such as carbonation set in at a ***fast rate***.

Sedimentary rocks are more stable because they are formed by the deposition of previously weathered material which has already undergone chemical change. As such they are weathered at a **slow rate** by ***chemical weathering***.

Rocks containing iron compounds and limestone or calcium carbonate are ***chemically weathered*** at a **fast rate** by oxidation and carbonation respectively.

Rocks with different minerals (heterogeneous) expand and contract at different rates when heated causing stress within the rock and eventually ***physical weathering*** at a **fast rate** by granular disintegration.

(b) ***Rock jointing*** – Jointing influences the rate of weathering because joints are avenues through which agents of weathering such as water and air, penetrate rocks. A well jointed rock will ***chemically weather*** at a **fast rate** than a massive rock containing no bedding planes, joints, or fractures because joints increase the probability of entry of water and air into the interior of a rock for chemical weathering to take place through processes like carbonation, oxidation and hydration. ***Physical weathering*** processes like frost action and thermal expansion occur **very fast** in rocks that are well jointed.

Similarly ***biological weathering*** will occur at a **fast rate** in jointed rocks since plant roots penetrate rocks through existing rock joints to weather rocks.

(c) ***Rock color*** – Dark colored rocks like granite, olivine and diorite absorb heat, expand quickly and with continued expansion and contraction crack or disintegrate at a **very fast rate** by ***block and granular disintegration***. Thus dark colored rocks weather faster than light colored rocks like quartz, under hot temperatures.

(d) ***Rock hardness*** – Hard rocks such as quartzite are more resistant to ***chemical weathering*** processes like ***carbonation*** and ***hydration***, hence the rate of weathering is **slow**. However soft rocks like clay are weathered at a **fast rate** by *chemical weathering* processes like ***oxidation***.

(e) ***Rock solubility*** – Rocks that are soluble in water such as rock salt weather at a **fast rate** in solution, thus rocks which are soluble in water are easily weathered by ***chemical weathering*** processes of solution.

(f) ***Rock permeability*** – Permeable rocks allow penetration of water into the rock mass thus a **fast rate** of *chemical weathering*, for example, sandstone and limestone allow water to percolate through them, in the process water dissolves and removes materials through chemical weathering processes like carbonation to occur at a **fast rate**. Impermeable rocks do not allow water to percolate them thus do not weather easily.

(g) ***Rock texture*** – Rocks with a rough texture easily allow water to collect on their surfaces thus *chemical weathering* processes like hydration can take place at a **fast rate**.

(h) ***Nature of cementing materials*** – Some rocks have cementing materials that are resistant to weathering, for example, quartz cemented by silica is one of the most resistant to weathering. On the other hand, some sandstones with iron and calcite (calcium carbonate) cements are easily weathered chemically by oxidation and carbonation processes respectively.

2. Climate

This is by far the most important factor influencing the rate and nature of weathering. Climate variations result in different rates of weathering. Rainfall and temperature are the major climate elements that affect the rate and nature of weathering.

In equatorial and humid climates with heavy rainfall (about 1500mm and above throughout the year) and hot temperatures, *chemical decomposition* occurs at a **fast rate**. The heavy rainfall avails water which acts a medium for chemical reactions while the hot temperatures speed up chemical reactions. This results in the formation of a thick layer of weathered rock (regolith) which protects the underlying rocks from direct heating hence limiting physical weathering. Chemical weathering is more dominant in hot and wet areas such as the northern shores of Lake Victoria, e.g. Jinja, Mukono and Wakiso. Also the dense vegetation in equatorial regions protects rocks from direct sunlight hence limiting physical weathering.

In areas with savanna climate with alternate wet and dry seasons, *chemical weathering* is **dominant** during the wet season when humidity is high through processes like solution while *physical weathering* is **dominant** during the dry season due the hot temperatures, high evaporation rates and sparse vegetation through processes like salt crystallization and exfoliation. This is evident in areas of Nakasongola, Mubende and Lake Albert flats,

In arid and semi-arid areas with low rainfall, long dry season, very hot temperatures (above 30^{0}C), large daily temperature range, high evaporation and little or no vegetation, *physical weathering* is **dominant**. During day temperatures become too hot and at night temperatures may fall below 12^{0}C causing rapid expansion and contraction of rocks resulting in processes such as thermal expansion and block disintegration. Salt weathering due high evaporation rates is also encouraged as moisture seeping into rocks carries dissolved salts into rocks thus weakening rocks. This is common in areas like Turkana & Chalbi desert in Kenya, Moroto, Kotido, Kaabong, Nakapiripiriti and Ankole-Masaka dry corridor in Uganda.

In high mountain tops where temperatures go below 0^{0}C such as Mt. Rwenzori and Mt. Kenya, *physical weathering* processes such as frost action occur at a **fast rate**. Chemical weathering is limited by the low temperatures and relative absence of liquid water.

4. Relief
The rate at which weathering takes place is related to the speed at which the weathered material (regolith) is removed. On steep slopes ***physical weathering*** occurs at a **faster rate** due to the high rate of removal of weathered material by erosion, mass wasting & transportation, which exposes underlying rocks to weathering processes. The steeps slopes and bare rock surfaces in high mountains such as Mt. Rwenzori, Kenya and Kilimanjaro, are very susceptible to ***physical weathering*** processes such as frost shattering.

In lowlands/valleys, the parent rock may be protected by thick layers of soil and deposited weathered material thus **slow rate** of weathering processes. However the presence of organic acids from thick vegetation and the increased accumulation & infiltration of water promote f**aster rates** of ***chemical weathering*** in low lying areas and gentle slopes.

In addition, rainfall totals tend to be higher in upland areas and temperatures colder - again **increasing rates** of ***physical weathering*** such as freeze-thaw.

3. Living organisms (Plants & Animals)
Plants, especially trees facilitate weathering by the action of plant roots which grow into rocks and expand joints/cracks, thus causing ***physical weathering***. However dense vegetation may hinder effective ***physical weathering*** since the plants act as a protective layer slowing down the removal of weathered materials.

Plants also through ***chemical weathering*** process of **chelation** lead to decay of rock where by plant roots extract minerals from rocks and at the same time release minerals into rocks thus changing the chemical nature of rocks.

When living organisms die they decompose into humus and organic matter. When water is added it forms organic acids that decomposes rocks by ***chemical weathering***.

The movement of animals and insects in the ground, such as, rodents, termites and earth worms, through burrowing loosen rock particles thus causing ***physical weathering***. The burrows created act as avenues for water and air to reach rock mineral particles thus enabling ***chemical weathering*** to take place at a **fast rate**.

Man has accelerated weathering through numerous activities such as mining, quarrying, blasting rocks with explosives, road construction, releasing gases into the atmosphere, dumping chemicals, using fertilizers, spraying with pesticides and herbicides. As a result man has facilitated ***physical*** and ***chemical weathering*** to take place at a **fast rate**.

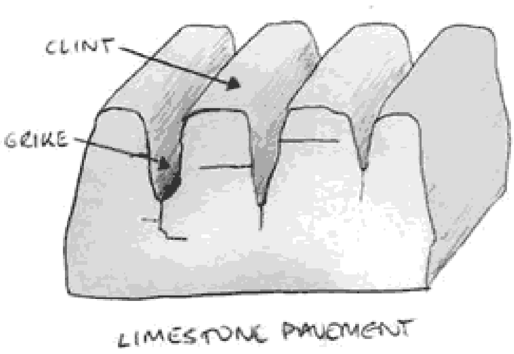
5. Time
This describes the duration taken by environmental factors to affect rocks. The longer the duration/time of exposure of rocks to weathering processes, the more pronounced the break down or decay of rocks. This is due to the fact that weathering is a very long and slow process.

LANDFORMS RESULTING FROM WEATHERING PROCESSES

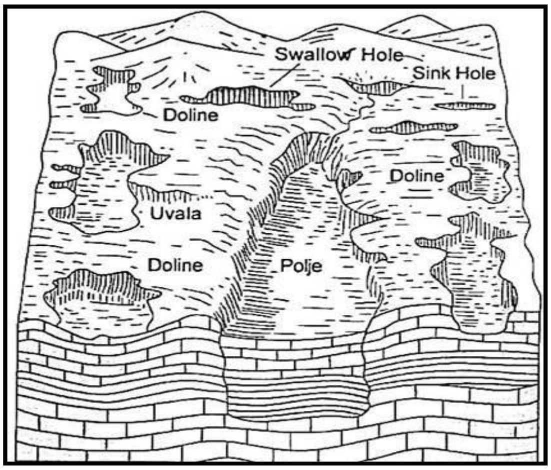
Weathering leads to the formation of various landforms as noted below;

1. **Karst Landforms:**
Karst landforms develop in limestone & dolomite rocks. These rocks are very soluble in water containing carbon dioxide thus forming very distinctive types of landscape known as 'karst'. When rain water combines with carbon dioxide it forms carbonic acid and turns the insoluble calcium carbonate into a soluble bi-carbonate (calcium carbonate or calcium magnesium carbonate) and can be readily carried away by groundwater in solution. The landforms include;

(a) **Grykes (Grikes) and Clints or Limestone Pavement** – This is a bare rock surface covered or marked by numerous wide irregular grooves divided by narrow ridges. When a weak carbonic acid dissolves limestone along its joints or cracks, deep narrow grooves or ditch-like depressions known as ***grikes*** are formed separated by round or flat-topped ridges or blocks of undissolved or insoluble rocks called ***clints***. Together they resemble something like large separate paving stones hence the name '***limestone pavement***.' They are common at Tanga in Tanzania. (*differential chemical weathering of limestone rocks*)

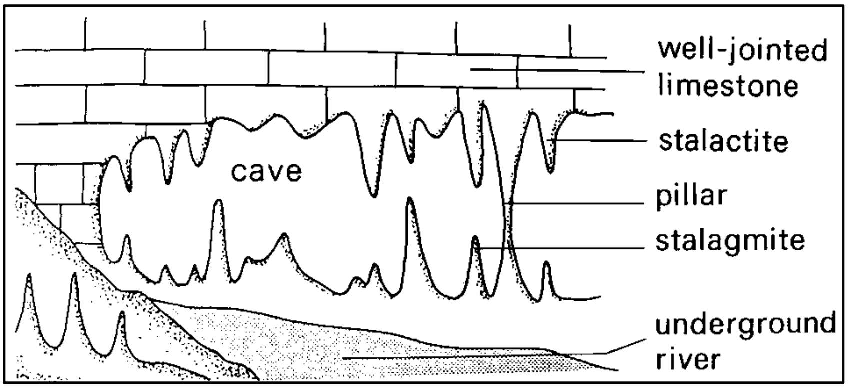


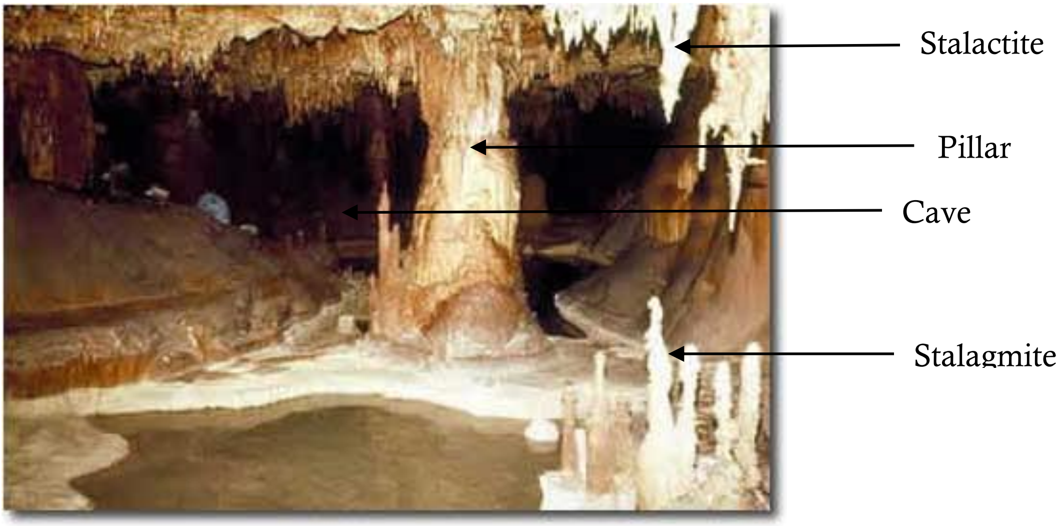
(b) **Swallow Hole or Sink Hole –** This is a closed deep hole on the earth surface with nearly vertical sides leading to an underground cave system. It can be cylindrical, conical, bowl-shaped or dish-shaped. It is formed when carbonic acid dissolves limestone along cracks or joints or grikes gradually widening or enlarging them to form a small basin called a ***sink hole***. Examples occur along the East African coast and in the Mahafaly plateau, Madagascar.



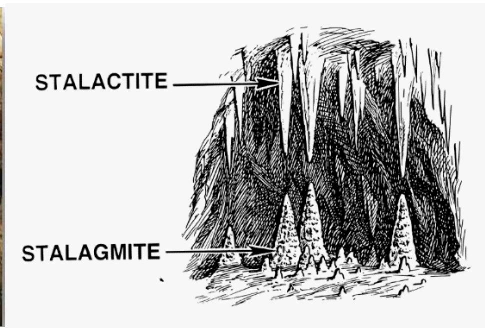
(c) **Doline –** This is a shallow depression or hollow with gently sloping sides and circular or oval in plan. ***It is formed when underground water dissolves limestone along major joints forming a small basin, which is gradually enlarged. It can also be formed when several sink holes join to form a large opening or depression***. Likewise several dolines may merge to form a larger closed depression called ***Auvala*** or ***Uvala***. Several dolines and uvalas can be found on the Mahafaly plateau in SW Madagascar.

(d) **Limestone Caves** or **Underground Caverns** – This is a natural underground opening or chamber large enough for a human to enter. It is formed by solution when ground water with dissolved carbon dioxide dissolves limestone along joints and bedding planes forming an underground cavity/chamber. The cavities are further enlarged by mechanical or stream erosion by underground streams and occasional roof collapse. Examples include the Amabere ga Nyinamwiru at Nyakasura in Fort Portal (Kabarole), Tororo in Uganda; Tanga in Tanzania; Cango caves in South Africa; Hoyo, Matupi & Salanga caves in the DRC.

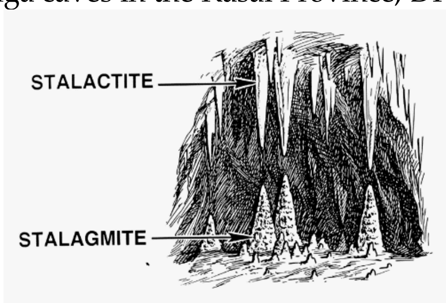




(e) **Stalactites** – This is a sharp, slender column or mass or fingure-like projection of calcium carbonate (calcite) hanging from the cave roof. It is formed when a weak solution of carbonic acid dissolves limestone in the cave. When the water partially evaporates on the cave roof it leaves behind deposits of calcium carbonate that harden to form a long, slender needle-shaped projection hanging down from the cave roof. Examples can be found at Amabere ga Nyinamwiru at Nyakasura in Fort Portal.



(f) **Stalagmites** – This is a column or mass of crystalline calcium carbonate (calcite) that rises from the floor of a limestone cave. It is formed when water containing calcium carbonate falls from the cave roof to the floor evaporates leaving behind deposits of calcite that build up to form a long, slender fingure-like projection on the cave floor called a stalagmite. Examples are at Amabere ga Nyinamwiru at Nyakasura in Fort Portal and Salanga caves in the Kasai Province, DRC.

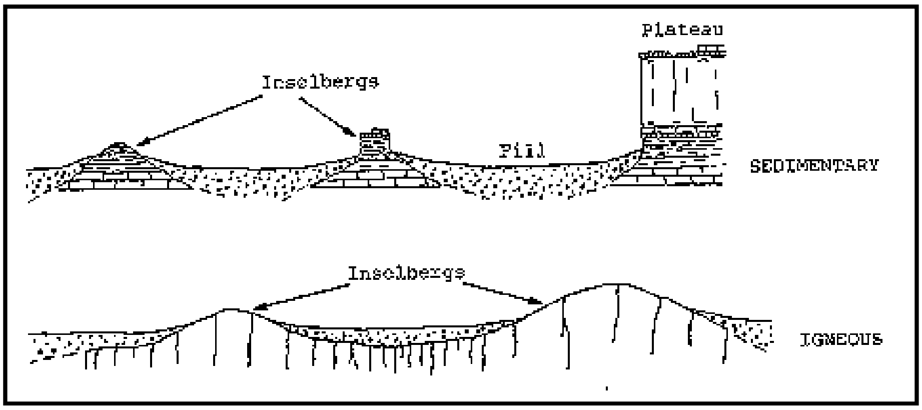


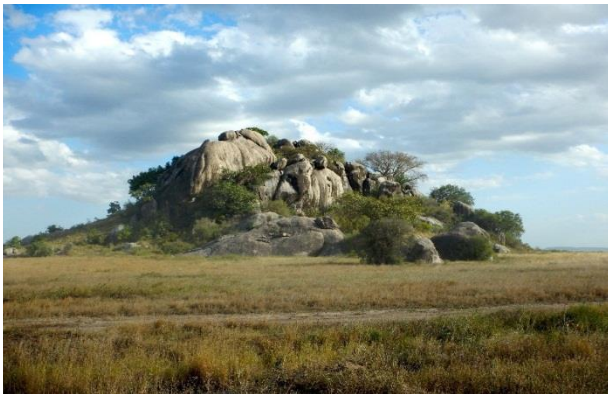
(g) **Pillar** or **Column** – This is formed in an underground cave when stalactites and stalagmites continue to grow towards each and eventually join/converge forming limestone pillars or columns or the stalagmite grows upwards until it reaches the ceiling. Examples are in the caves of Nyakasura, Fort Portal and Tanga in Tanzania.

(h) **Limestone gorge** – This is a deep, steep-sided, narrow valley or depression formed when the roof of an underground cave or tunnel collapses. The gorge can also develop when a river cuts/incises (vertical erosion) across and down into limestone region. Example can be found at *Kyambura gorge in QENP, at Tanga in Tanzania and in central Madagascar*.

2. **Inselbergs**

This is an isolated or prominent steep-sided hill of resistant rock, such as granite, rising above the gently sloping ground. Some inselbergs consist of a pile of massive boulders. They are formed when a resistant rock is exposed at the surface by weathering processes, especially exfoliation leaving behind a residual hill. ***Volcanic*** *processes may give rise to a body of* ***rock*** *resistant to* ***erosion****, like a batholith, surrounded by a body of softer rock such as* ***limestone*** *which is easily eroded away to form a* ***plain*** *while the hard rock is left behind as an isolated mountain. They're also formed due to fast subsurface chemical weathering leading to removal of soft weathered rocks leaving isolated hard rocks/residual hills/inselbergs*. Inselbergs are common in arid and semi-arid areas like Nakasongola, Mubende, Soroti, Tororo in Uganda, Voi in Kenya and Sukuma land in Tanzania. Examples include ***Lugala Rock, Mlimwa (Lion Rock), Tega & Imagi in Tanzania, the Namuli mountains of Mozambique, Kufena Hill near Zaria, Dutsin Zuma, SW of Abuja & Ogun Hills (Ado Rock) in Nigeria, Brandberg mountains in Namibia, Phingwe, Nsunje & Banda inselbergs in Malawi and Ayers or Uluru rock in Australia*.**

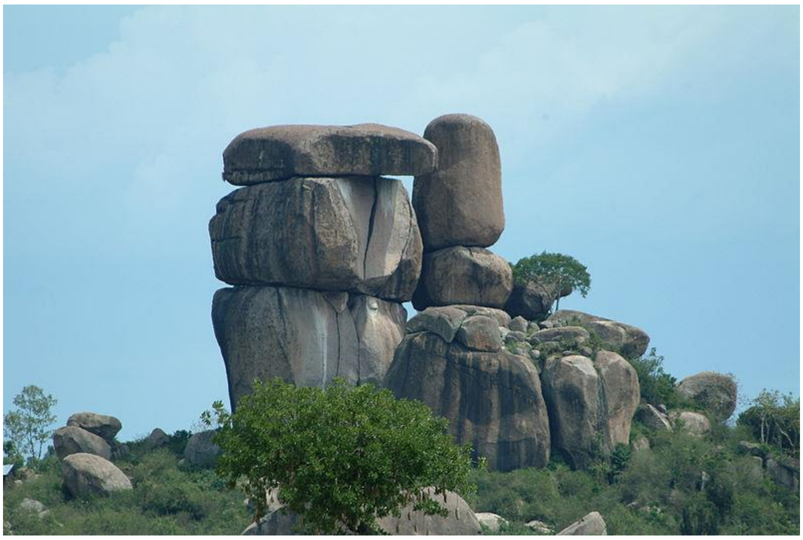





Pride Rock, Serengeti – Tanzania   Voi – Kenya

Types of Inselbergs

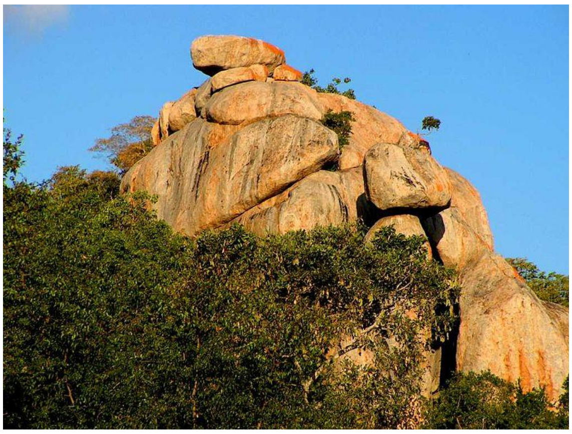
(a) **Tors –** This is a large residual mass or rock outcrop of weathered boulders often of granitic rocks which have their base in the bed rock and are surrounded by weathered debris. Tors are formed on exposed jointed granite rocks by physical weathering process called **block disintegration**. Expansion and contraction of rocks due to wide temperature changes in hot and dry environments, causes widening of rock joints in granite; with time when the process is repetitive rocks breakdown into blocks of rocks called **granitic tors**. They may occur on hills and these are called ***Skyline tors*** or in a depression or hillside and these are called ***Subskyline tors***. Examples are Karegyeya tors in Rukungiri South Western Uganda; Kit-Mikayi tor near Kisumu, Kenya; Bongo Rocks in Ghana.

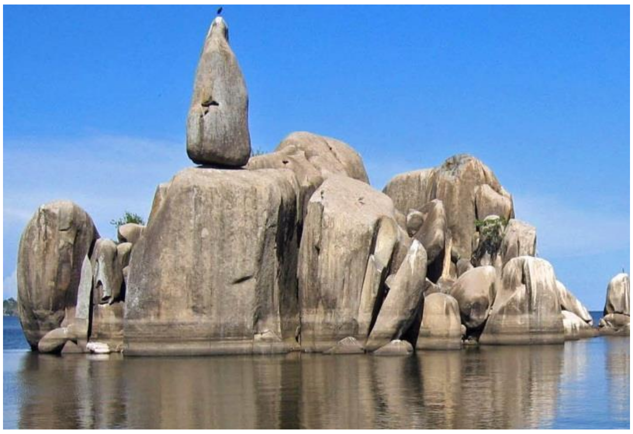


Kit-Mikayi Tor near Kisumu, Kenya

(b) **Castle Kopje** – These are inselbergs that that have undergone little weathering. They are steep sided massive crystalline boulders that appear cube-like or blocky and are jointed. Examples include Bismarck rock on the shores of L. Victoria at Mwanza (Tanzania), Dolwe Islands in L.

Victoria, Lugala Rock, NW of Dodoma in Tanzania, in the Maragoli Hills Kisumu, Kenya. Others can be found *north of Koriga in Nigeria; and near Funsi in Ghana.*



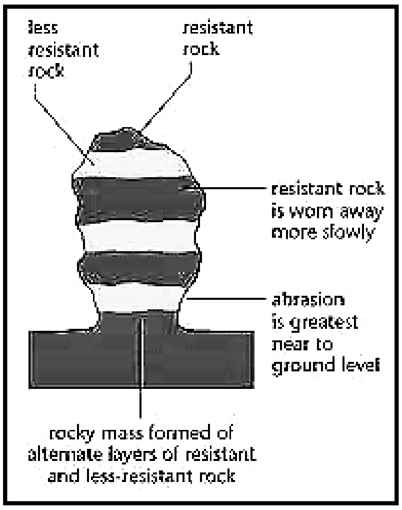


Kopje in Serengeti National Park, Tanzania Bismarck Rock, Mwanza, Tanzania

(c) **Bonhardts** - This is a domed inselberg usually formed from a granitic intrusion and it has undergone little weathering [***is a dome-shaped, steep-sided, bald rock outcropping***]. Sometimes it is called a steep-sided rocky hill. They are formed by the increased removal of regolith leaving isolated hills. Bornhardts are seen in humid and semi-arid regions. Examples include ***Uhambingetu (Wambegetu) NE of Iringa, Tz.; Ogun Hills (Ado Rock) & Zuma Rock in Nigeria; Nyanoa & Abura Abura in southern Ghana between Nsawam & Cape Coast; Mbewa, Simvwa & Mtoko in eastern Zambia; Klien Spitzkopje in the central Namib Desert, Namibia.*** [Exfoliation dome]

Bornhardts, Matopos Zimbabwe

3. **Rock Pedestals/Mushroom Rock** – They are rocks with alternate soft and hard layers. The soft layers are worn away by weathering while the hard layers remain protruding laterally to form tower like structures of various shapes. They are common in arid regions such as Karamoja in NE Uganda and the mountains of central Sahara.



4. **Lateritic Duricrusts** (Laterites) – This is a hard crust made of laterite formed at or just below the ground surface as a result of oxidation. Laterites are a compound of highly weathered rock

minerals rich in iron oxide, aluminium oxide and silica found in areas of heavy rainfall. Silica is leached leaving behind an orange or reddish brown residue on the earth surface known as ***lateritic duricrust***. When further weathering occurs it is broken down into laterites of lateritic soils. These are common on hills in Buganda region, Uganda.

IMPORTANCE OF WEATHERING

Rock disintegration by weathering provides raw material in the form of regolith for the development of soil. Weathering provides the inorganic parts (weathered rock particles) which form the skeleton of the soil which is developed by other soil forming processes. Soil indirectly supports all animal forms of life in the form of vegetation. (Promotes soil formation)

Weathering breaks rocks thus exposing valuable minerals. During the prolonged period of time, weathering processes expose concentrations of valuable mineral ores of iron, manganese, tin, aluminium, diamonds, and uranium etc.

Lateritic duricrusts that have been widely exposed by erosion and are not too deeply dissected can provide good, hard surfaces for gravel or murram. The material is often used as building blocks and as a base and subgrade for roads.

Weathering leads to the formation of new landforms such as exfoliation domes, caves, tors, among others which attract tourists and generate foreign exchange.

Weathering is important because it transforms the solid bedrock into small, decomposed fragments and prepares those fragments for removal by the agents of erosion.

Revision Questions:
1(a) Distinguish between physical and chemical weathering.
(b) Describe the factors which have favored chemical weathering in EA.
2. Describe the weathering processes taking place in the Lake Victoria basin of EA.
3. Examine the influence of chemical weathering on rock structures in EA.
4. To what extent does rate and character of weathering depend on the nature of the rock?
5. "Physical weathering dominates in arid regions." Discuss.
6. Account for the dominance of physical weathering in the semi-arid areas of EA.
Approach:
- Define PW
- Identify areas where PW is dominant & mention x-tics of such areas
- Describe PW processes dominant in such areas
- Explain reasons for dominance of PW in such areas
7. Describe the landforms resulting from chemical weathering in EA.
8(a) What is chemical weathering?
(b) With reference to specific examples from EA, examine the influence of chemical weathering on landform formation.

MASS WASTING OR MASS MOVEMENTS

Mass wasting refers to the spontaneous (unplanned, voluntary) creeping, flowing, sliding or falling of rock and weathered materials downhill or downslope under the influence of gravity. The movement may be gradual or sudden, depending on the gradient of the slope, the weight of the weathered debris and whether there is any lubricating moisture or water. The major factor that helps to overcome any resistance to movement is water. Water facilitates movement by increasing the weight of weathered materials along the slope and lubricating the surface which reduces friction or cohesion between the rock particles, weathered materials and the solid rock. A water saturated mass moves down more easily than a dry one because water both increases the weight of the mass and also reduces the cohesion of the materials in the mass. Mass wasting is also known as ***slope failure***.

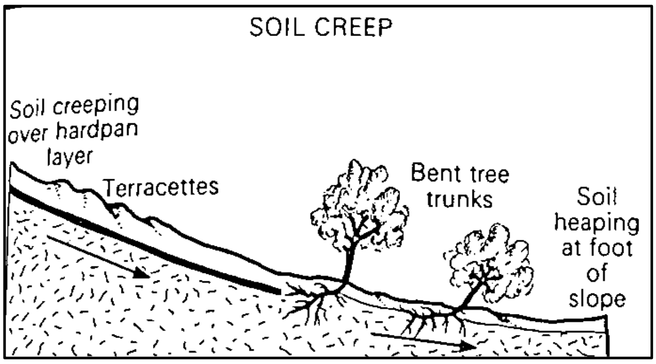
Mass wasting is different from erosion in a sense that, in soil erosion water physically transports away the soil particles **BUT** in mass wasting water does not wash away the material but assists the material to slide under the influence of gravity.

Mass wasting is common in mountainous areas or highlands such as Mt. Elgon, Kenya highlands, Mt. Kilimanjaro, Kigezi highlands, Mt. Rwenzori, Southern Tanzania highlands, to mention but a few.

Types of Mass Movements
There are two broad categories of mass movements namely; **slow movements** and **rapid or fast movements**. The rate of movement depends on the steepness of the slope, the nature and weight of the material, and the amount of water in the material.

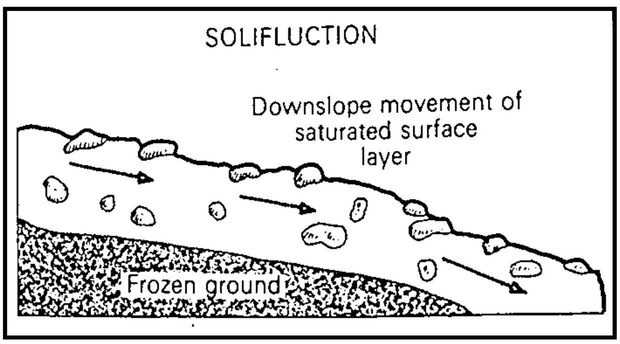
A. Slow Movements:
These advance at an imperceptible or invisible or slow rate and are usually detectable only by the effects of their movement, such as tilted trees and power poles or cracked foundations. They include;

1. **Soil Creep** – This is the ***very slow*** movement of soil and fine particles (regolith) on a ***very gentle slope*** under the influence of gravity. This is the most common and widespread form of mass wasting. Any process that disturbs the stability of soil and weathered rock will trigger soil creep, e.g. rainfall, earthquakes or tremors, movement of grazing animals & heavy vehicles, burrowing of animals in the soil, up and down hill ploughing. Also alternate wetting and drying or heating and cooling may cause soil creep. The addition of water to a dry sediment lubricates soil particles and enables them to slide over each other. Soil creep is difficult to detect because it is very slow and usually hidden by vegetation cover. It is usually detected by the bending of tree trunks, fencing and telephone poles in the direction of soil creep and road cracks. Soil creep is common on slopes of Kololo hill, Nakasongola, etc.

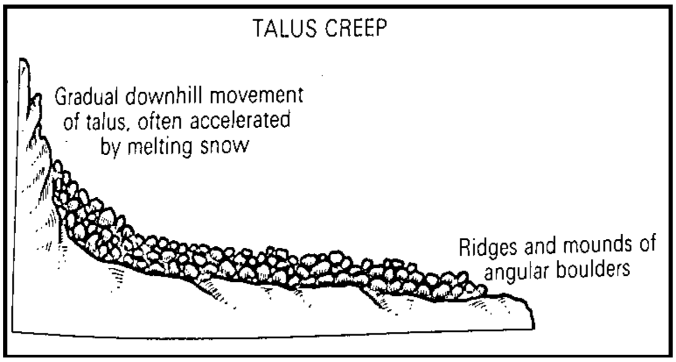


2. **Solifluction or Sludging** – This occurs in tundra or glaciated regions or highlands. It involves the ***slow*** downslope movement of saturated surface soil, gravel and weathered rocks over an underlying frozen ground or sub-soil (**permafrost**) on a ***moderate or gentle slope*** under the influence of gravity. It takes place on gentle slopes in glaciated mountains such as Kenya, Kilimanjaro and Rwenzori where freeze and thaw occurs. Thawing or melting of ice provides water which cause saturation of gravel and weathered materials on gentle slope, and lubrication causing them to slide down slowly over the permafrost or frozen ground. Solifluction produces distinctive lobes on hill slopes.

Solifluction lobes on a mountain slope

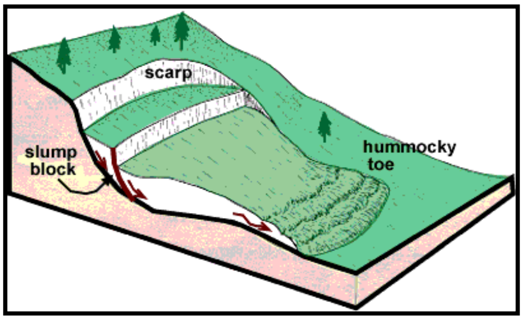


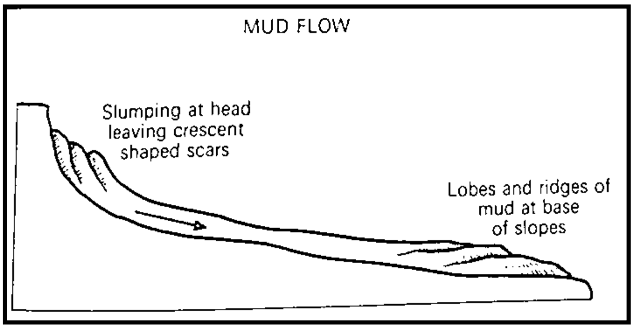
3. **Talus Creep** – This involves the ***slow*** or ***gradual*** downhill movement of angular rock wastes or particles of different sizes (talus) on a ***moderate slope*** under the influence of gravity. It occurs as a result of frost weathering which produces rock wastes of all sizes. When ice or snow melts the particles are saturated, lubricated and hence move down as a mass under the influence of gravity. Talus creep is common in glaciated mountains like Mt. Kenya and Rwenzori.



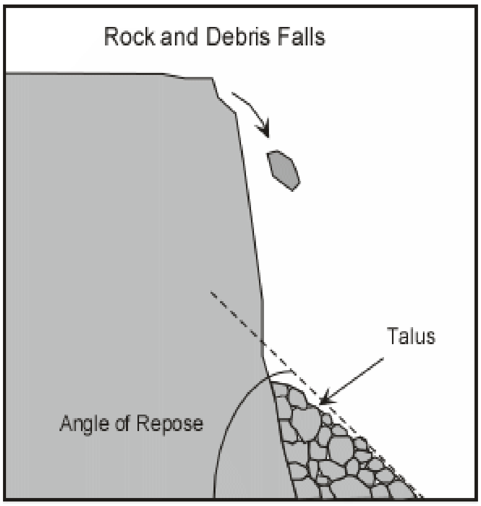
B. Rapid or Fast Movements:
These involve a visible movement of loosened rocks and soil or debris on a steep slope under the influence of gravity, e.g. along a cliff face, valley side or an embankment. Such movements usually occur quite suddenly or rapidly, and the material moves very quickly downslope. Rapid mass movements are potentially dangerous and frequently result in loss of life and property damage. It should be noted that all forms of mass movements, ranging from fast to very fast are collectively known as **Landslides**. They include;

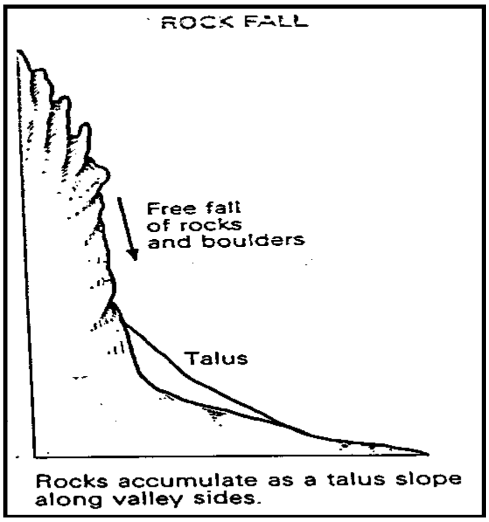
1. **Mudflow or Earth or Soil Flow** – This involves the **fast or rapid** downhill movement of super-saturated (semi-liquid) mud, gravel and boulders on a **moderate to steep slope** under the influence of gravity. Mudflows are the most fluid and move most rapid. Mudflows are common in arid and semi-arid areas with little or no vegetation where they are triggered by heavy rains that quickly saturate the soil, turning it into a raging flow of mud that floods or drowns everything in its path, e.g. Karamoja. Mudflows can also occur in mountain regions and on slopes covered by volcanic ash such as Mt. Elgon & Mt. Muhavura, SW Uganda. Mudflows can also result from volcanic eruptions that cause melting of snow or ice on the slopes of volcanoes, or draining of crater lakes on volcanoes. Volcanic mudflows are often referred to as ***lahars***.



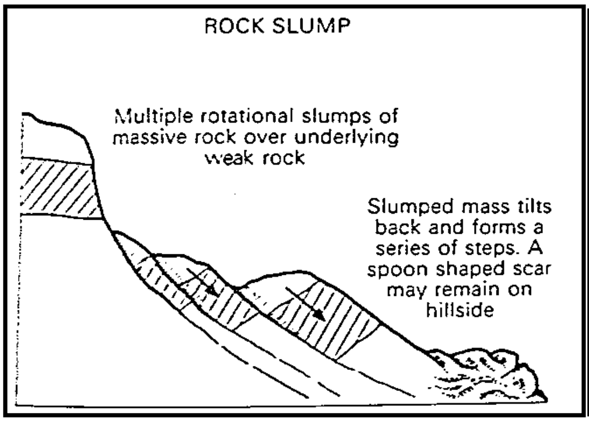


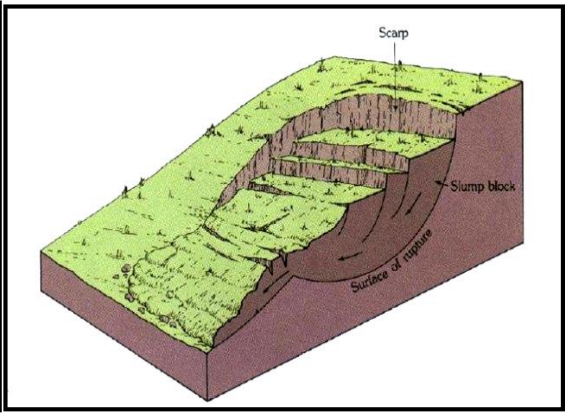
2. **Rock fall** – This is the process by which individual rocks or boulders fall freely **very fast** on a **very steep or vertical slope** such as a cliff face, under the influence of gravity. This is the fastest of all mass movements and destructive to land use down the valley. The rocks may be loosened by frost weathering. It is common in mountainous areas with jointed rocks, e.g. Mt. Elgon, Rwenzori & Kenya and along sea coasts and lake shores. The broken rocks (talus) collect at the base of the cliff or slope in a mound called a ***talus slope.***



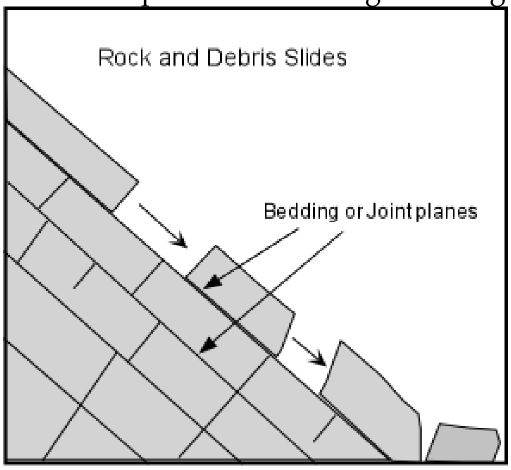


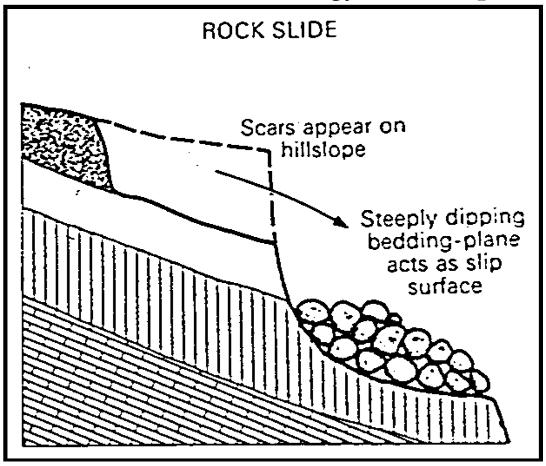
3. **Rock Slump or Rotational Slide** – This involves the **fast** downward and outward movement of rock or unconsolidated material on an **over steepened** or **curved slope**, e.g. scarps or escarpments and road cuttings, under the influence of gravity. Large blocks of material move suddenly downward and outward along a curved plane in a backward rotation. Slumps usually occur where large massive rocks are overlying weak ones such as clay; undercutting of steep slopes which removes supporting material causing slope failure, e.g. during road construction; heavy rains or earthquakes can also trigger slumps. Slumping produces a scarp or cliff at the top of the slope. It is common in the rift valley areas of Bunyaruguru in western Uganda and along sea coasts and lake shores.





4. **Rock Slide or Translational Slides** – This involves the **fast or rapid** movement of large masses of rock and debris over a **very steep** or **over steepened slope** under the influence of gravity. The blocks tend to break up into smaller pieces as they slide move downslope a pre-existing surface, such as a bedding plane or joint surface. Piles of talus are common at the base of a rock slide or debris slide. Rock slides can be triggered by earth movements such as earthquakes and vulcanicity; heavy moving vehicles and heavy rainfall which causes saturation of materials on a slope. Rock slide is pronounced in highland regions like Kabale, Bundibugyo and Kapchorwa.





5. **Avalanches** – This is a sudden or **rapid** or **very fast** downhill movement of debris embedded in ice or glaciers on a **steep slope** under the influence of gravity. They typically occur in mountainous areas such as Mt. Rwenzori and Mt. Kenya. It is a fast movement and is usually influenced by;

- very cold temperatures which support glacial formation
- heavy precipitation inform of snow
- presence of steep slopes

N.B: Diagrams in Colin Buckle Pg. 70.

FACTORS THAT AFFECT THE RATE AND NATURE OF MASS MOVEMENTS

1. **Nature of material**. Where weathered layers are thinly bedded mass wasting will be very fast because thin beds increase the tendency since there are more bedding planes over which movement can occur. Also if the rocks underlying a slope dip in the same direction as the slope, movements like rock slide are likely to occur than if the rocks are horizontal or dip in the opposite direction. When the rocks dip in the same direction as the slope, water can percolate along the various planes and decrease the cohesiveness and friction between adjacent rock layers. This is particularly true when clay layers are present because clay becomes slippery when wet. Also where the weathered later is steeply dipping mass wasting will be rapid.

2. **Extent of saturation**. The amount of water in rock or soil influences slope stability. Large quantities of water from melting snow or heavy rainfall greatly increase the likelihood of slope failure. Water decrease friction between grains thus reducing cohesion and also increases the weight of rock thus causing mass wasting. For example, slopes composed of dry clay are usually quite stable, but when wetted they quickly lose cohesiveness and internal friction and become an unstable slurry. Thus the ***more saturated the material, the more likely it is to move***.

3. **Slope Angle or Steepness**. The steeper the slope, the faster the rate of movement. Therefore steep slopes are more likely to experience fast movements than gentle ones. Landslides such as rock fall, rock slide and avalanches occur on steepened slopes in the highland areas of East Africa. Over steepening of the slope may be due to undercutting by wave or stream erosion, road construction and excavations in mountainous areas.

4. **Climate**. This includes amount & nature of rainfall, annual & daily temperature ranges. Heavy rainfall or alternate freezing and thawing encourage movement. Prolonged heavy rainfall infiltrates & soaks weathered debris (regolith) increasing weight of slope material, reduces internal friction and cohesion resulting in fast movements such as mudslides. In high mountains, temperature changes enable alternate freezing and thawing leading to movements such as solifluction, talus creep, rock fall and avalanche in glaciated mountains such as Rwenzori, Kenya and Kilimanjaro.

5. **Weathering.** Mass wasting is more likely to occur in loose or poorly consolidated slope material than in solid bedrock. As soon as solid rock is exposed at the earth's surface, weathering begins to disintegrate and decompose it, thereby reducing its shear strength and increasing its susceptibility to mass wasting. In areas where weathering occurs at a fast rate, such as the tropics, mass movements are present.

6. **Nature of rock**. Jointed rocks are easily affected by movements. Joints allow water to filter through them increasing the weight of the rock mass and leading to movements such as rock slump and slide. Also where massive permeable rocks overlying impermeable weak rocks on a steep slope are saturated by heavy rainfall get lubricated and overloaded thus fast movements like rock slide & slump may occur.

7. **Overloading or Debris Accumulation**. Overloading is almost always the result of human activity and typically results from dumping, filling, or piling up of material. The additional weight created by overloading increases the water pressure within the material thereby weakening the

slope material. If enough water is absorbed or the material is affected by earth quakes movement is likely to occur.

8. **Vegetation**. Vegetation has a binding effect on slopes. The roots of the vegetation help to bind or hold soil and sediment along the slope. The removal of vegetation by either natural or human activity is a major cause of many mass movements such as mud flow and landslides on steep slopes such as the Kigezi highlands and Mt. Elgon.

9. **Animals**. Burrowing animals such as rodents enable deep weathering which reduces the cohesion between rock particles, especially on steep slopes. Thus this leads to slope failure and mass movements.

10. **Human activities**. Man's activities such as mining & quarrying, building, herding animals, cultivation, road construction, among others affect the stability of surface layers resulting in various movements.

11. **Endogenic processes**. Strong vibrations from earthquakes and volcanic eruptions may trigger large and widespread fast movements like avalanches, rock slide & slump. Also tectonic movements like faulting create steep slopes, cliffs and escarpments that encourage rock slide and rock fall.

CAUSES OF MASS MOVEMENTS

(a) Removal of vegetation through deforestation, overstocking and overgrazing. Tree roots help to bind soil particles along a slope. If the trees are removed the binding effect will be lost, soils become exposed to heavy rainfall and this results in landslides occurring. This is common in highland areas such as Kigezi and Mt. Elgon that have suffered from landslides due to loss of vegetation cover.

(b) Occurrence of natural calamities such as earthquakes, earth tremors, volcanic eruptions and flooding along unstable slopes have led to mass movements. Such events loosen rock particles and trigger off mass movements. For example in 1966 an earthquake led to landslides in Bundibugyo district.

(c) Mining and quarrying along steep slopes leaves the upper slopes unstable which leads to mass movements such as slumping and rock fall. Also the use of explosives during mining operations which produces tremors result in movements such as rock fall and slump. For example stone quarrying in Muyenga, Mukono, limestone and vermiculite in Mbale, murrum on hill tops in Buganda, wolfram in Kabale, Cobalt in Kasese, Diamond in Shinyanga, Gold e.t.c

(d) Cultivation and grazing along steep slopes increases the likelihood of slope failure hence mass movements occurring. Cultivation may lead to loss of natural vegetation while animals moving along steep slopes may loosen rocks, sending them crashing down slope.

(e) Undercutting over steepened slopes during construction of roads, railway lines and on building sites; wave and river erosion has led to mass movements such as rock falls and slumping. For example along sea & lakes shores, river banks and highland areas.

(f) Heavy vibrations by heavy mobile machinery like lorries, buses, tractors and trailers moving through highlands areas cause vibrations which disturb unconsolidated slope material resulting in movements such as rock fall, slide & slump and soil creep on gentle slopes.

(g) Frost action. Water can flow into even the narrowest of rock fractures. If the temperature then drops below freezing, ice crystals will form, expanding in volume by 9 %. This is a very powerful force that can wedge apart rocks, often causing them to fall from steep slopes in mountains. Also the melted ice acts as a lubricant thus making it possible for loose, unconsolidated rock debris to slide downslope under the influence of gravity.

Effects of Mass Movements

Mass wasting is associated with positive and negative effects.

- Soil creep and mud flow cause severe loss of top fertile soil resulting into low crop productivity/ yields for example in Kigezi, Manafwa, Sironko, Kapchorwa, Mbale and Rwampara hills in Mbarara.

- Landslides lead to massive loss of human life and livestock for example cattle, goats and birds. For example, the 2006/7 El-Nino caused landslides that destroyed homesteads in Kisuro village in Kapchorwa, Maziba and Ndorwa counties in Kabale, Bushanja and Nyarubuye in Kisoro.

- Destruction of valuable asserts such as houses, house hold items and agricultural plantations/ gardens. For example the 2006/7 El-Nino caused landslides that destroyed banana and coffee plantations, cotton, Irish potatoes etc. in Kabale, Manafwa, Sironko, Bubulo in Mbale, Kasese and Bundyibugyo.

- Soil creep and landslides destroy transport and communication lines making communication very difficult, for example 2006/7 El-Nino caused landslides that destroyed Kisoro-Katuna road, Fort Portal-Bundibugyo road, Kapchorwa-Bukwa road e.t.c. Most bridges, railway and telephone lines were destroyed for example Siron-Ngagata road, Siron, Powut and Silanwa bridges in Kapchorwa, Kigarama-Kivu road, Rwakihirwa Bridge in Kabale, Nalugungu-Elgon road, Simu corner-Kaserem road in Sironko e.t.c

- Mass wasting across a river valley blocks the valley forcing the river to pond back its water leading to the formation of temporary reservoir or a permanent lake for example Lake Bujjuku in mountain Rwenzori and Lake Mbaka in southern Tanzania.

- Deposition of materials by Landslides and soil creep produce fertile soils down slope in valleys and low lying areas encourage crop cultivation for example banana, potatoes, yams and vegetables in Kabale , Sironko etc., coffee on the slopes of mountain Elgon, Kenya and Kilimanjaro.

- Mass wasting inform of slumping, rock slides and soil creep expose underlying minerals making mining easy and cheap for example limestone in Sukuru hills, diamond in Mwandui Tanzania, gold in Bushenyi etc.

- Mass wasting facilitates soil formation by removing overlying materials and exposing fresh rocks to agents of weathering for example in highlands such as Kigezi e.t.c

- Mass wasting is a source of education material and research for example causes of mass wasting, mitigation measures etc. for example in Bududa and Bundibugyo

- Mass wasting contributes to landform development by creating beautiful scenery such as terracetes on Ankole hills, scars created by slumping and straight slopes in Kabale and Rukungiri.

- Mass wasting aid soil erosion by transporting weathered and unconsolidated materials down slope in form of mudflows, slides, soil creeps and falls. For example in Kigezi, mountain Elgon slopes, Nyanza province in Kenya, Kondoa and Ukambari in Tanzania.

- Mass wasting causes destruction of forest vegetation in highland areas, for example on mountain Elgon and Kigezi leading to loss of forest resources.

- Landslides lead to displacement and resettlement of people while destruction of crops often results into famine, starvation and sometimes death for example in Kasese, Kigezi, Bulucheke and Bundyibugyo.

- Landslides increase government expenditure inform of relief emergence and resettlement of people.

- Landslides inform of Soil creep, slumping and mud slides increase silting of drainage systems such as culverts and destruction of transport network. In addition it increases maintenance costs inform of dredging.

- Landslides such as mudflow and slumping lead to contamination of water sources and loss of marine organisms for example lake Mutanda (24 km^2), Murehe (4 km^2), Kyahifi (1 km^2) and Kayumbo (2 km^2) in Kisoro.

- Landslides affect education through increased absenteeism of both children and teachers because of impassable muddy roads and blocking of roads by landslides for example in Kigezi, Bududa, Bulucheke e.t.c. for example the 2006/7 El-Nino caused landslides that blocked roads and disorganized End of year Exam programme Kabale and Kisoro because roads were blocked hence scouts and Examination papers could not reach examination centers in time.

Measures to reduce the occurrence of Mass movements

1. Planting trees along steep slopes to increase cohesion in rock particles. This has been done in Kigezi highlands where eucalyptus trees have been planted along slopes.

2. Constructing a retaining wall along the bottom of the slope to support the upper part of a slope, stopping or at least slowing mass wasting.

3. Draping or covering a heavy metal net over the slope to trap loosened rocks. Screen mesh draped over a steep slope keeps rocks loosened by an earthquake from bouncing onto the road at the base of the slope. This is a relatively cheap and effective method to protect the roadway.

4. Rocks routinely fall or bounce down the slope, to prevent them from moving onto the road and into traffic, steel mesh fencing and screen catch and trap rocks before they can do any harm. This is a very effective and relatively inexpensive method of reducing the effect of mass wasting from an over-steepened slope.

5. Selective cutting can reduce the forest, but still leave enough mature trees to anchor the slope and protect sediment from rainfall and runoff. Enough large trees can remain to anchor and protect the slope from severe mass wasting. However removal of vegetation along steep slopes should be prohibited by law.

6. Excessive water in a slope adds weight and reduces shear strength within the slope itself. To counter these affects you can either prevent rain or snowmelt from percolating into slope sediment with plastic sheets or tarps, or improve surface drainage so that water flows rapidly off the slope, reducing the potential for water to percolate underground into slope sediment and rock. Large pipes are sank into the slope to readily drain away surface runoff from rainfall before it can percolate underground. (Drainage pipes could be inserted into the slope to more easily allow water to get out and avoid increases in fluid pressure, the possibility of liquefaction, or increased weight due to the addition of water.)

   Plastic sheets can be deployed on top of a slope to prevent water from flowing on the slope and from percolating into the slope material. The sheets are staked, strapped or weighted down to keep them in position.

7. Setting up flood control channels can be set up to divert mudflows.

8. Rock bolts can be used to anchor or hold in unstable rocks, especially on a highly fractured Slope to hold the slope together and prevent failure.

9. Steep slopes can be sprayed or covered with concrete to prevent rock falls.

10. Over steepened slopes could be graded to reduce the slope to the natural angle of repose.

11. Conduct slope stability studies to know where to place roads, developments and utility lines.

Revision Questions:
1. To what extent has climate influenced the nature of mass wasting in EA?
2. Examine the causes and effects of mass wasting in EA.
3. To what extent has relief contributed to the occurrence of landslides in the highland areas of EA?
4. Account for the occurrence of landslides in EA.
5(a) With reference to specific areas in East Africa, examine the causes of mass movements.
(b) Outline the measures being taken to control the problem of mass movements in the identified areas in (a) above.
6. Account for the occurrence of large-scale mass wasting in the highland areas of EA.

LANDFORM EVOLUTION IN EAST AFRICA

Landforms are distinctive configurations of the land surface. They include mountains, hills, valleys, plains and plateaus. The study of these landforms including their history and processes of formation is termed ***Geomorphology***. It should be noted that landform evolution is a slow and continuous process.

There are two broad categories of forces that bring about landform evolution;

1. **Endogenetic or Endogenic Forces**
These originate from the earth's interior. They include **earth movements (diastrophism)** and **tectonism**. Earth movements include crustal warping, faulting, earth quakes and folding while tectonic movements (tectonism) include crustal warping, faulting, folding and vulcanicity. Earth movements comprise of vertical & lateral forces. **Vertical forces** operate up & down causing the crustal rocks to fault or fold. They include compressional and uplift forces. Features produced include *plateaus*, *block mountains*, *basins*, among others. **Lateral forces** operate sideways causing crustal blocks to fold. They include tension & compression forces. Features produced include *fold mountains*, *block mountains*, *rift valleys*, among others. Endogenic (Tectonic) processes usually lead to increase in elevation and relief.

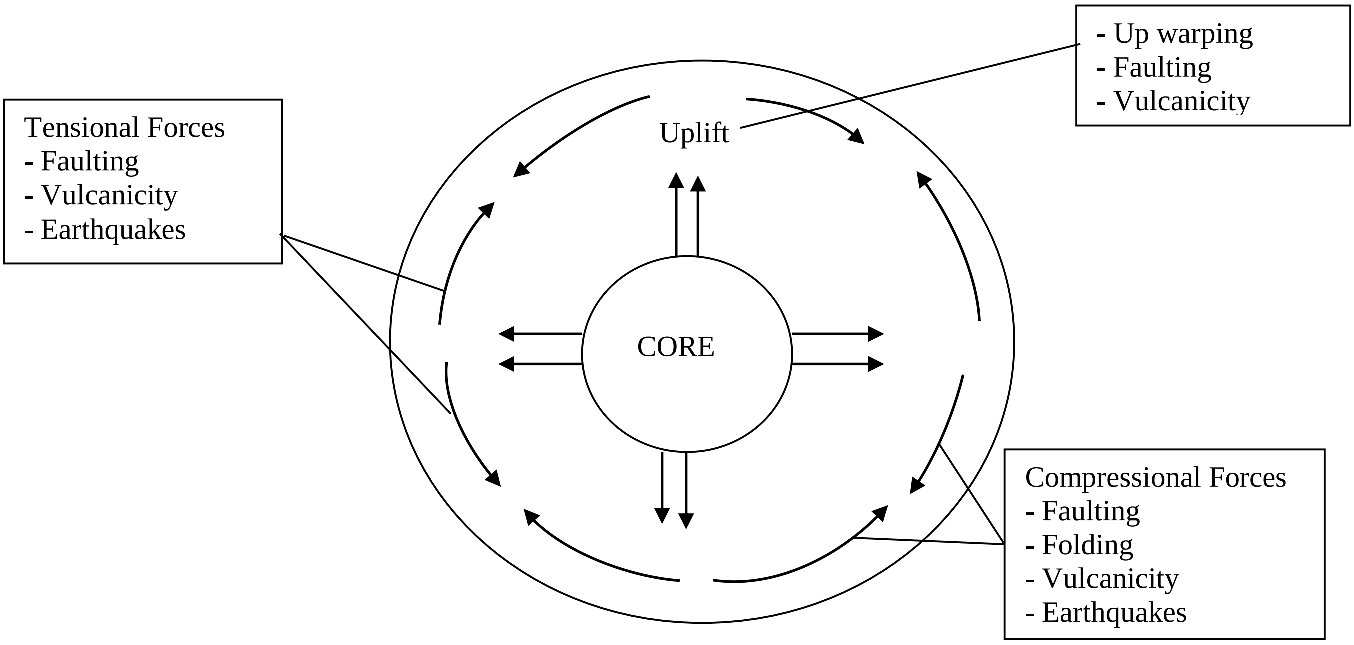
2. **Exogenetic or Exogenic Forces**
These forces operate at or on the earth surface. They include;
(a) **Denudation or Degradation forces** such as weathering, erosion, glaciation and mass wasting.
(b) **Deposition or Aggradation forces** which are able to destroy landforms resulting from endogenic processes or forces such as faulting, producing new structures called ***residual features*** such as inselbergs.

EARTH MOVEMENTS:
The term **earth movements** refers to ***all crustal disturbances of endogenic origin***. The origin of earth movements is the large scale convectional currents in the upper mantle. The hot temperatures in the earth's interior created by radioactive decay and geo-chemical reactions generate convective currents that rise upwards towards the crust and exert a push force causing ***epeirogenic uplift*** (slow large scale uplift of the crust). On reaching the upper layers of the mantle, the currents spread out and flow laterally in opposite directions thus stretching or dragging the overlying crust in the direction of flow. This causes the crust to fracture and get displaced due to the generated **tensional forces** or **stress**. This fracturing is termed **faulting**. When convective currents move towards each other or meet, **compressional forces** are generated. These push crustal plates towards each other resulting in **folding**. The faults or lines of weakness created may lead to the escape of hot magma from the mantle hence facilitating **vulcanicity**. As the convective currents sink back into the mantle they pull the overlying crust downwards in a process called **down warping**. This creates down warped basins.

In addition, when rocks facture they release pressure which had accumulated in them for a long time. This sudden change in pressure creates shock waves within the crust causing earthquakes or tremors.

Crustal warping may occur where convective currents are subducted (sunk) into the mantle thus exerting a pull force on the dense simatic crust hence the crust sags.

When rocks fracture, they release pressure which had accumulated in them for a long time. This sudden change results into shock waves within the crust causing **earth tremors** normally known as **earthquakes.**



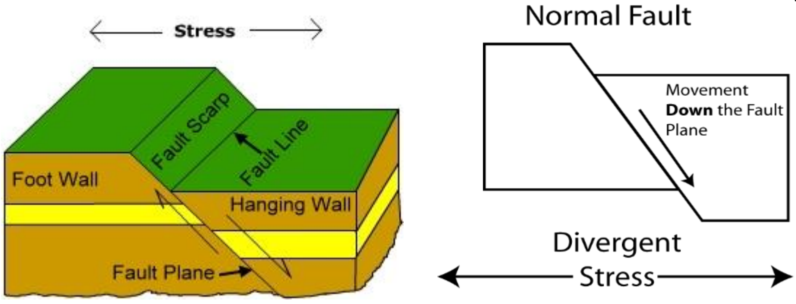
FAULTING

***Faulting refers to the breaking, fracturing or cracking of rocks within the earth crust by relative displacement of rocks on either side of a fault or fracture*. Or** *the fracturing, breaking and displacement of rocks on either side of a fracture*. Because of friction and the rigidity of the rock, the rocks cannot glide or flow past each other. Rather, when movements occur stress builds up in rocks resulting in fracturing. Faulting occurs in old rocks that are hard and brittle.

Faulting is caused by either **compressional or tensional forces**. Faulting leads to uplift, subsidence or depression and horizontal displacement of crustal rocks. Heat in the mantle generated by radioactive and geochemical reactions leads to formation of convective currents. As the currents move towards the crust they may converge creating **compressional forces** thus reverse faulting or diverge forming **tension forces** thus normal faulting. Thus as the convective currents move the crustal blocks away or towards each other fracturing of rocks occurs.

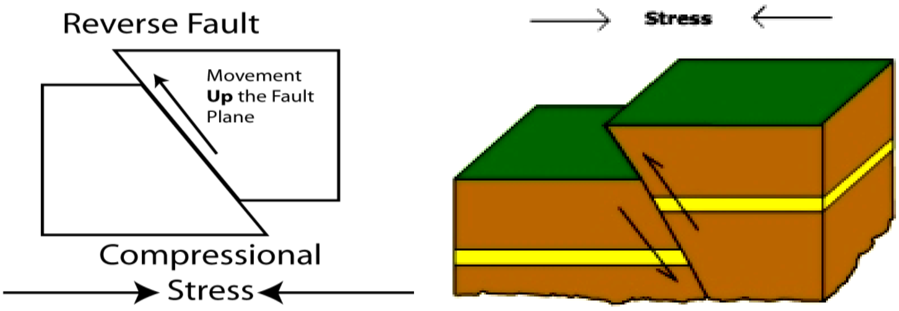
Types of faults:

(a) **Normal Fault** – It is formed when crustal rocks are stretched by **tension forces** leading to the hanging wall to drop down relative to the other block. They develop at a divergent plate boundary. Examples can be seen in the eastern arm of the East African rift valley.

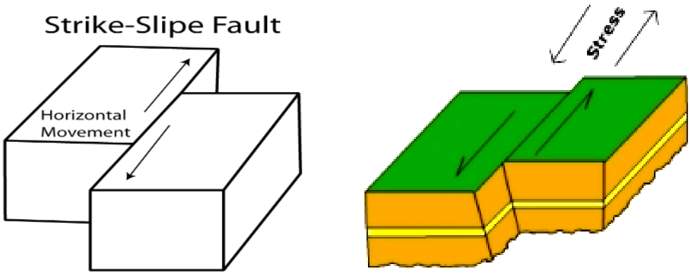


(b) **Reversed Fault** – It is formed when the hanging wall moves up in relation to the other. Compressional forces cause one block to be pushed up and over the other block. They develop at a convergent plate boundary. Examples are in the western arm of the East African rift valley.

Together, normal and reverse faults are called dip-slip faults, because the movement on them occurs along the dip direction—either down or up, respectively.



(c) **Strike-Slip or Tear or Transform Fault** – It is formed when the rocks move sideways or past each other. The forces creating these faults are **lateral or horizontal**, carrying the sides past each other. Examples are the Aswa valley in Northern Uganda.

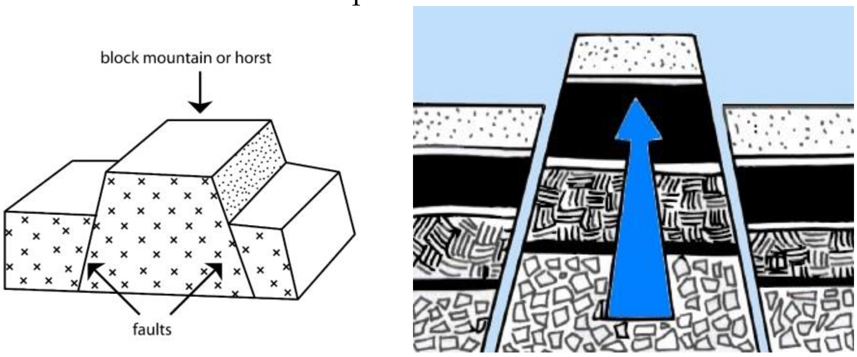


The Influence of Faulting on Landform Development in East Africa

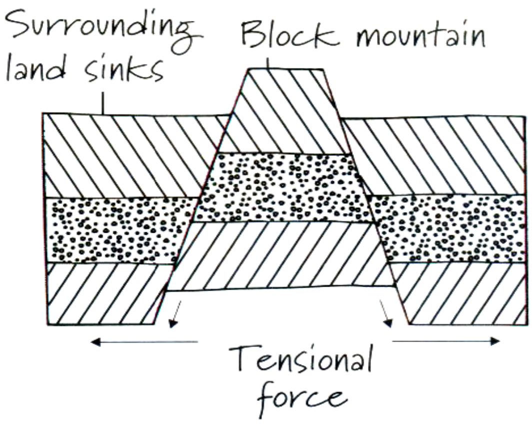
Direct effects of faulting

1. **Block Mountain or Horst** – This is ***an upland bounded or bordered by faults on one or both sides***. It has a level summit and stands above the surrounding landscape as a result of being raised up or uplifted by earth movements along faults. It is formed by either vertical or horizontal movements of the earth. Such movements are normally caused by tensional or compressional forces where faults or cracks develop. For a horst to form, the block of the crust may have moved in the following ways;

(a) **Differential Uplift** – In this case, tensional or compressional forces cause block faulting over a wide area. This is followed by general uplift of the faulted region due to rising convective currents. However the uplift is not uniform thus the central blocks rise faster than the side or outer blocks. The middle block forms the peak of the horst.



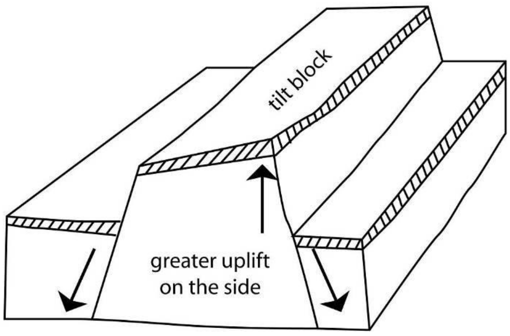
(b) **Differential Subsidence** – Tensional or compressional forces result in formation of multiple parallel fault lines. This is followed by gradual or relative sinking of the faulted region due to sinking convective currents and pull of gravity. However the sinking is not uniform and the central or middle blocks remain at a higher elevation as the peak of the horst.



(c) Block mountain may also be formed when the two outer blocks remain stable while the middle block is uplifted.

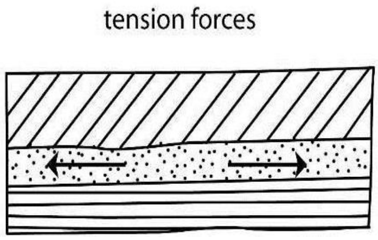
Examples of Block Mountains in East Africa include ***Mt. Rwenzori in Uganda, Mathews Ranges, Nyiru and Ndotos in Northern Kenya, Usambara, Mahenge, Ufipa, Rungwe, Pare and Chikweta mountains in Tanzania***. Others are Danakil Alps, Ethiopia; Karas mountains, Namibia.

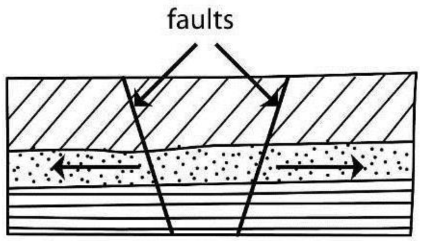
2. **Tilt Block** – It is ***an upland of angular ridges and depressions which are inclined on one side such that the land falls from a higher to lower elevation***. Tilt blocks are formed when layers of the earth crust are subjected to compressional forces causing parallel faulting, this is followed by uplift and tilting of one side of faulted blocks higher than the other side. Examples include ***Usambara tilt blocks in Tanzania; west Kenya tilt block***, this rises to about 1900 meters towards Lake Victoria. A combination of several tilt blocks forms a ***tilt-block landscape***, for example the Afar triangle in Ethiopia.



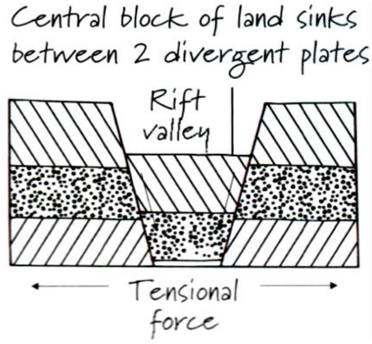
3. **Rift Valley** - This is ***an elongated trough or depression bordered or bound by two in-facing escarpments or fault-scarps***. The East valley Africa rift system extends southwards from the Red sea, through Ethiopia and East Africa to Malawi covering a distance of about 5600km. It is divided into four sections; the Ethiopian rift from the Afar triangle south to Lake Turkana; the Eastern rift in Kenya and Tanzania; the Western rift from Lake Albert to Lake Tanganyika; and the Malawi rift bounding Lake Malawi and the Shire valley. The origin of the East African rift valley is still a matter of debate involving many theories related to radioactive and geochemical processes in the earth's core generating heat & convective currents to bring about tensional, compressional, and vertical displacement forces which lead to displacement of the crust along fault lines. The major theories include;

(a) **Tensional Force Theory** – Theory was proposed by J.W Gregory. In the earth's interior heat generated by radioactive and geochemical reactions produces convective currents. As the convective currents rise towards the crust they cool and spread out dragging along the overlying crust hence forming tensional forces. The tensional movements led to the formation of normal faults in crustal blocks. As the tension widened the fractures blocks of the crust sank down or subside along parallel faults to produce a rift valley. Weathering, erosion & mass wasting modified the steep sides of the rift valley. This theory has been used to explain the formation of the ***eastern rift valley in Kenya***.

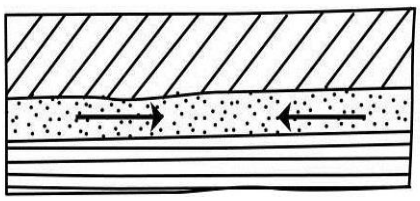


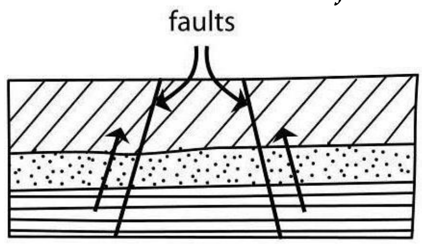


Tension forces act on crustal block Normal faults develop

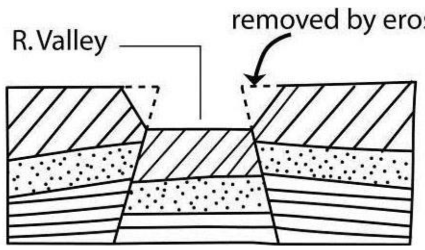


(b) **Compressional Force Theory** – Theory was proposed by E.J Wayland. Heat in the earth's interior by radioactivity & geochemical reactions results in convective currents. As the currents rise up to the crust they converge creating compressional forces that drag crustal blocks towards each other. This results in formation of reversed fault lines. With increased compression the outer block or crust overrides or 'rides' up and partially over the central block or crust thus producing a rift valley. The over-lying sides of the rift valley are later removed by erosion. This theory explains the formation of the ***western rift valley in Uganda***.





Compressional forces act on crust Reverse faults develop in the crust

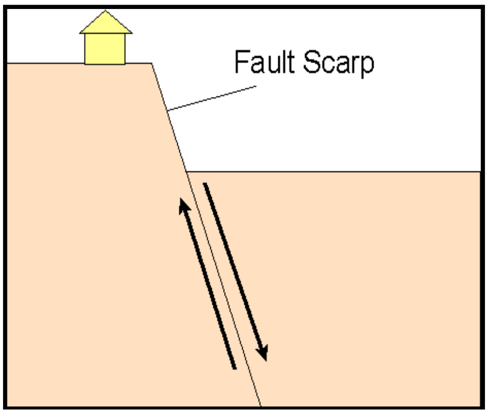


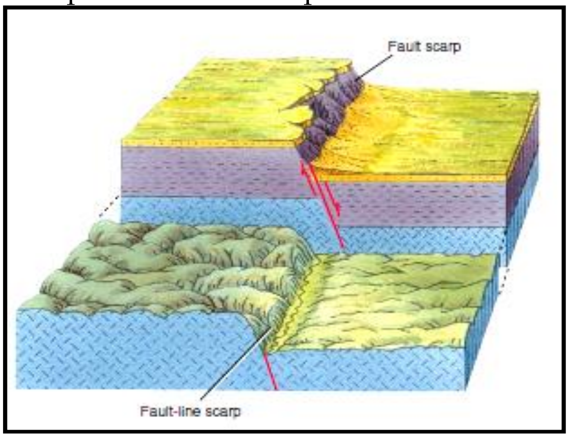
(c) **Differential Uplift Theory** – Theory was proposed by Dixie and Troup. In this theory, normal faulting led to the formation of several parallel fault lines. This was followed by the gradual or relative uplift of the faulted region. However the side blocks rose much faster than the central blocks. The central blocks then lagged behind forming a rift valley. Examples are seen around the ***Kedong scarp in the eastern rift, south west of Nairobi***.

(d) **Differential Subsidence** – In this theory normal faulting due to divergent convective currents in the mantle led to the formation of several parallel fault lines. As the convective currents sink back into the mantle they crustal blocks the crustal blocks sink or subside at different rates and the middle block sink faster than the outer blocks thus forming a rift valley.

Secondary faulting on the rift valley floor has produced numerous grabens that have been filled with water to form rift valley lakes and they vary in size, depth and salinity. Examples of the salty lakes are Lakes Natron, Magadi, Tanganyika, Albert, George, Edward, Turkana, Malawi, among others.

4. **Fault Scarp or Escarpment** – This is the ***inward facing slope of the rift valley where land falls from a higher level to a lower level***. It is usually very steep. It is formed by relative vertical displacement along a fault line such that one block along the fault is thrust upwards while the other is thrust downwards to create a steep cliff-like slope between them. Example in East Africa include ***Nandi, Elgeyo, Marakwet, Kikuyu, Mau, Laikipia, Kedong, Nyando, Keiyo, Nyandarua (or Aberdare) (Kenya); Butiaba, Kichwamba, Bunyaruguru (Uganda); Ufipa, Chunya, Manyara and Kungu (Tanzania)***. Others are Ethiopian scarp & Bamenda scarp in Cameroon.



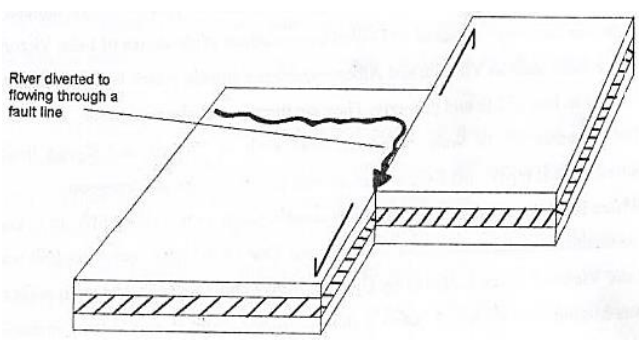


Fault scarp (above) and Fault-line scarp (below)

Indirect effects of faulting

5. **Fault-line Scarp** – This is ***a steep slope which develops along an ancient fault scarp due to differential erosion of hard and soft rocks on either side of the fault***. It is different from a fault scarp because the fault scarp is created by fault movement while a fault-line scarp is due to differential erosion. Besides the fault-line scarp has a **gentle slope** separating the zone of hard rock from the zone of soft rock unlike the fault scarp that has a **steep slope**. When erosion along the fault line is so intense, a shallow valley is formed separating the two blocks. A fault line scarp is therefore a residual landform which develops during and after the modification of the original fault scarp by denudational forces like erosion. Examples in East Africa include ***Kilosa-Msolwa southwest of Morogoro in Tanzania and Mutiro fault-line scarp east of Kitui hills in Kenya***.

6. **Fault-Guided Valley** - This is a valley following a pre-existing fault line. It is formed from a flowing river that moves with a fault, erodes the weak rocks in the fault. Examples include ***River Aswa flowing through the Aswa valley in Northern Uganda (Gulu), River Kerio flowing through the Elgeyo and Tungen faults and the Ewaso-Ngiro river flowing in the Nkrumah fault in Kenya***.



Influence of Faulting On Drainage

In most parts of East Africa, faulting has had a significant influence on the drainage as noted below;

(a) Vertical faulting across a river profile may create a waterfall, for example *Sipi falls in Eastern Uganda*.

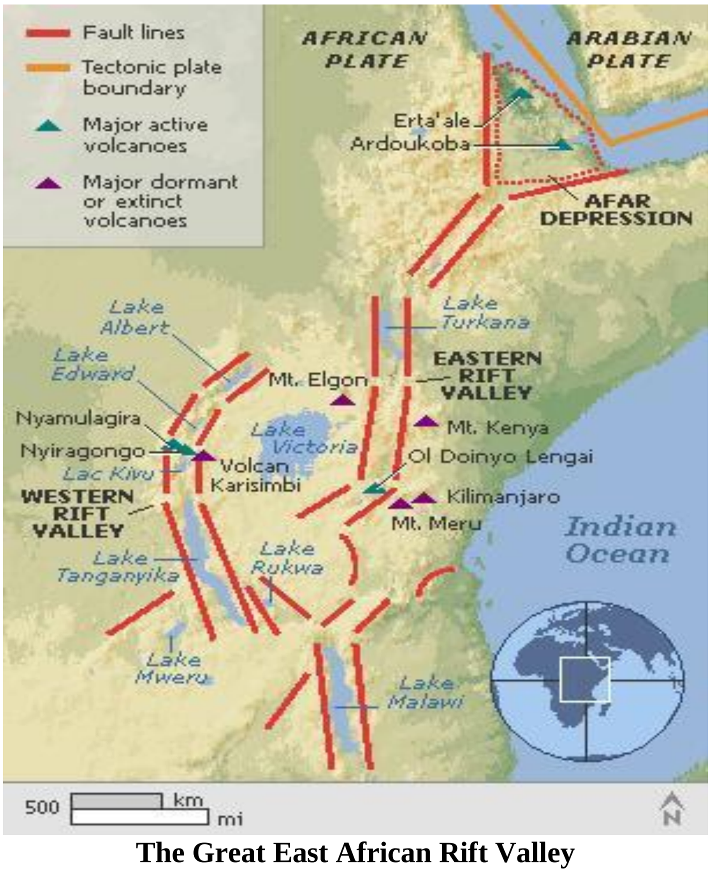
(b) Tear faulting or horizontal displacement across a river will cause the river to be off-set at the point where it crosses the fault.

Importance of Faulting

- Faulting has resulted into the formation of high mountains in East Africa. For example the Rwenzori in western Uganda, the southern highlands and the Usambara mountains in Tanzania and the Mathew ranges in Kenya. These are the most productive areas, where both cash crops and subsistence crops are grown.
- These highlands receive abundant and reliable rainfall.
- Rift valley lakes for example Lakes Tanganyika, Turkana, Naivasha and Baringo are fishing grounds.
- Some of these lakes have fresh water which can be used for irrigation and also for domestic purposes and industrial use.
- L. Magadi contains vast deposits of soda ash, which is one of the most important minerals in Kenya.
- Faulting presents impressive scenery which can be used for tourism. For example L. Nakuru has millions of colorful flamingos and other birds.
- Some highlands have been made into National parks and game reserves e.g. the slopes of the Nyandarua and Rwenzori mountains. These parks attract many tourists.
- Faulting can also cause the formation of waterfalls such as the Karuma falls, Murchison falls.

Problems Caused By Faulting

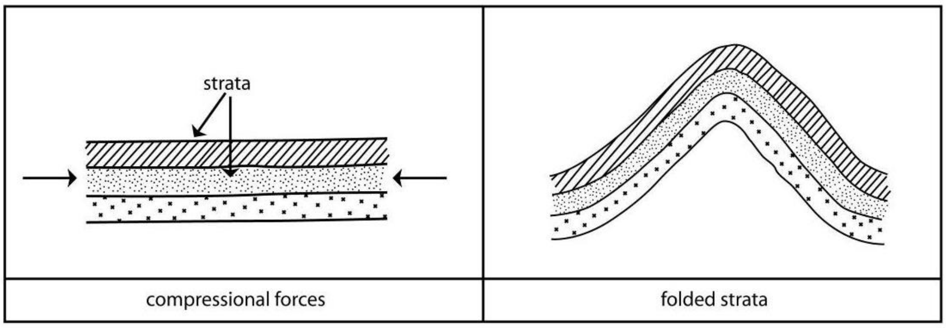
- Escarpments and mountains hinder transport development.
- Rift valleys are very hot and only suitable for grazing because they are in the rain shadow unless irrigation is practiced as with the case of Mubuku.
- There is severe soil erosion and mass wasting on the steep slopes which result in the destruction of soil surface, crops and at times people's property. For instance on the Rwenzori mountains.
- It is difficult to settle on the steep areas on the rift valley escarpments.

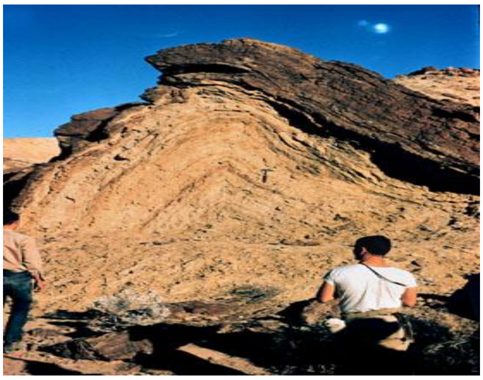


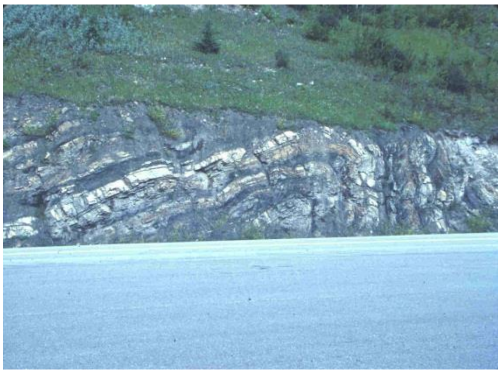
The Great East African Rift Valley

FOLDING

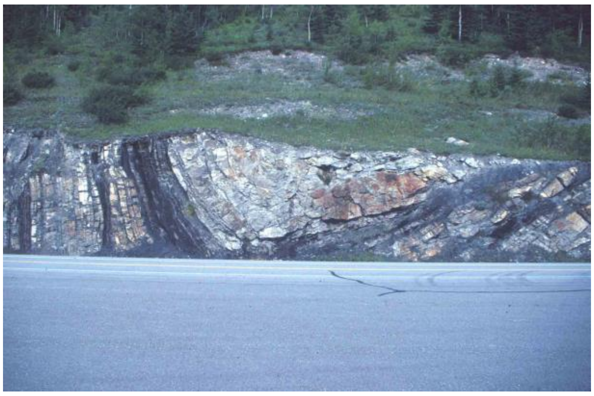
Folding is a ***process through which young rocks are bent hence developing undulating structures***. Folding results from tremendous **lateral forces of compression** that develop when tectonic plates of the crust move towards each other. Folding is common in young sedimentary rocks that are relatively soft and compressible. Folding produces ***anticlines*** (up folds) and ***synclines*** (down folds).



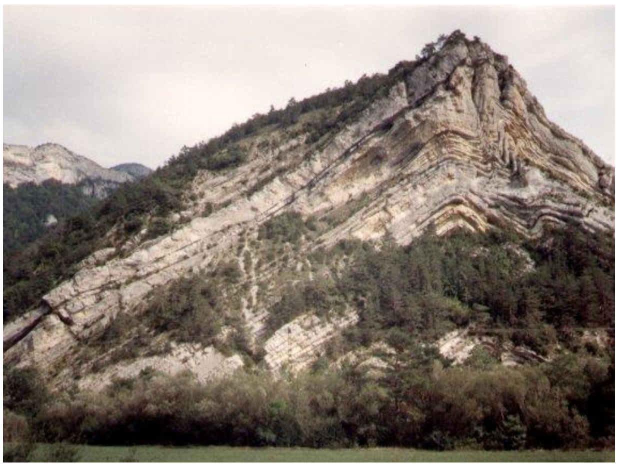




Anticlines



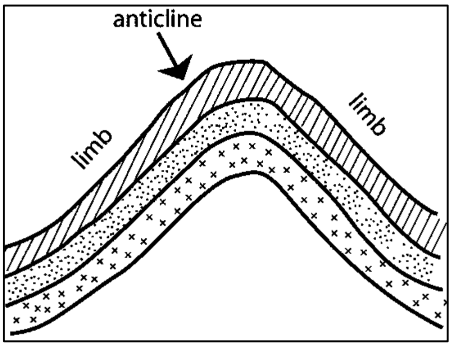
Synclines



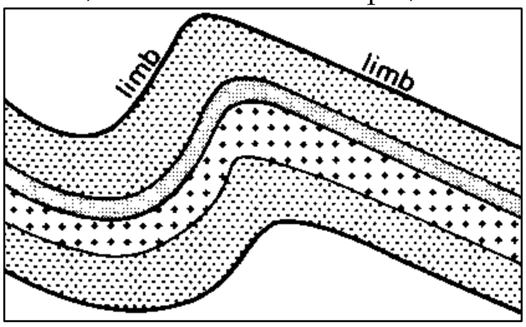
Folded landscape

Types of Folds:

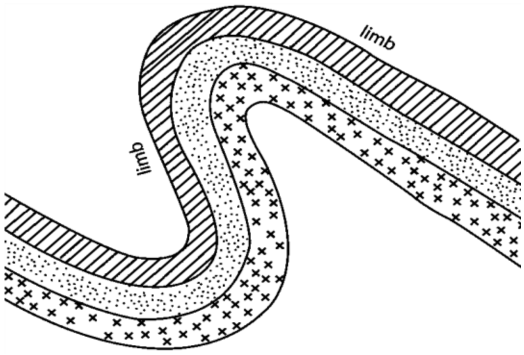
1. **Symmetrical or Simple Fold** – This type of fold has two limbs of uniform or equal steepness. It results when two compressional forces moving towards each other are of equal strength.



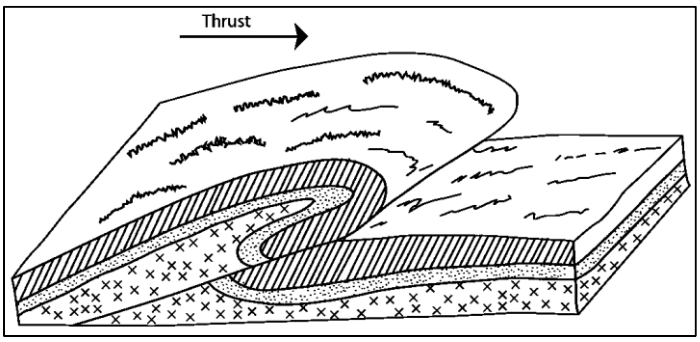
2. **Asymmetrical Fold** – This fold has one limb steeper than the other. It results when compression is greater on one side than the other, thus one crest is steeper, i.e. the crest is not uniform.



3. **Over Fold or Recumbent Fold** – This fold has one limb (crest) over the other limb. It is formed when the degree of compression is very high due to intense pressure, i.e. one opposing force is very much greater than the other.



4. **Overthrust Fold or Thrust Fault** – This is formed when pressure is very great such that a fracture occurs in the over-riding fold or crest and one limb is pushed forward over the other limb.



CRUSTAL WARPING

This is ***crustal instability involving large scale or regional uplift (upwarp) and subsidence (down warp) of the earth crust***. Warping is different from folding in a way that when folding occurs in a small area rolling hills develop due to bending of young rocks BUT if a large area is folded a chain of inter-linking fold mountains is formed. Besides warping usually occurs in old rocks.

In East Africa, the process of warping has been effective. Faulting in conjunction with warping has led to the formation of an enclosed basin and eventually a lake was formed by drainage reversal and back ponding of rivers into the enclosed basin. The formation of lakes Victoria and Kyoga was due to this process whereby streams that flowed westwards into the Congo basin like Kagera, Kafu and Katonga reversed their flow and collected in the down warped basin. The thrust in western Uganda was followed by a light uplift in the east forcing rivers like Nzoia to pond back into the Victoria basin.

Today much of Lake Kyoga is a vast shallow depression of papyrus swamps. Its peculiar shape is due to river Kafu being forced to flow back into its own valley and tributaries. Thus it's important to note that crustal warping across a river valley will gradually force the river to reverse direction if it is unable to maintain its original position.

REVISION QUESTIONS
1. To what extent has the process of faulting been responsible for landform development in EA?
2. Account for formation of the East African rift valley.
3. Assess the influence of faulting on landform evolution in EA.
4(a) Distinguish between a tilt block and a horst.
(b) Describe the processes responsible for the formation of block mountains in EA.
5. Examine the influence of tectonic movements on the formation of highlands in EA.
6(a) Distinguish between normal faults and reversed faults.
(b) Account for the formation of the East African rift valley.
7. Examine the influence of faulting on the development of relief landforms in EA.

VULCANICITY/ VULCANISM

Vulcanicity is the total process through which gases and molten rock (magma) from the earth's interior are intruded into the earth crust or extruded onto the earth surface. The magma originates from the upper plastic mantle called **asthenosphere** in the interior of the earth. This magma is kept in a semi-solid or semi-plastic or semi-molten state by the hot temperatures (over 4500^0 C) in the mantle. This heat is **generated by geochemical and geophysical** reactions as well as **radioactivity** due to decomposition of uranium in the earth's interior which releases a lot of heat that keeps the rocks in a molten state. Additional heat is generated by **friction along plate boundaries** due to faulting and other crustal movements. The heat results in the formation of **convective currents** which drive molten rock towards the crust. The molten rock rises to the surface through **cracks/faults/lines of weakness** created in the crust by **faulting**. The molten rock rises due to the lower pressure at the surface along fissures in the crust. When magma is poured onto the earth surface it loses its gases and is turned into **lava**.

Lava varies considerably in its chemical composition, particularly in its silica content. The silica content determines the degree of mobility and this also party explains the different types or shapes of volcanoes and nature of eruption whether explosive or quiet. ***Basic lava*** is very fluid and mobile with a poor silica content, thus it is able to flow long distances before solidifying. It forms gently sloping cones, lava plateaus and plains. ***Acidic lava*** is very viscous and immobile with high or rich silica content. It solidifies quickly and eruptions are violent or explosive. It forms steep landforms such as volcanic neck and plug. ***Intermediate lava*** is fairly viscous with moderate silica content, thus it is unable to flow far before solidifying. Intermediate and acidic lavas are usually associated with explosive eruptions due their viscosity.

Type	% of silica	Degree of mobility	Rock type
Acidic (Felsic)	Greater than 66%	Very viscous and immobile. Solidifies rapidly at high temperatures	Rhyolite, Granite
Intermediate	52 - 66%	Fairly viscous, unable to flow far before solidifying	Trachyte, Gabbro
Basic (Mafic)	45 - 52%	Very fluid and mobile, able	Basalt,

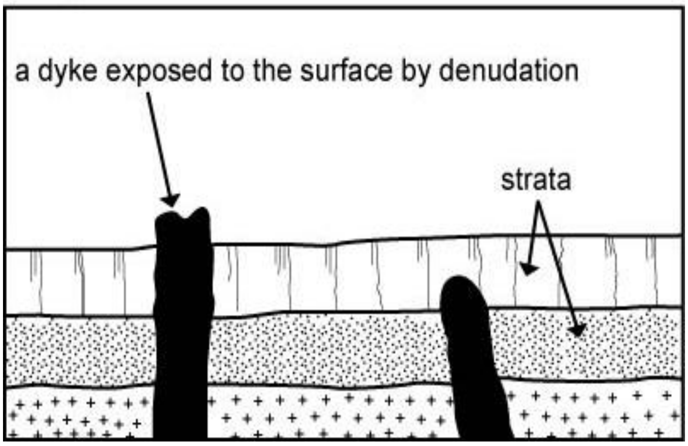
		to flow long distances before solidifying	Peridotite

The result of the various processes of vulcanicity is the development of two major types of features, i.e. extrusive and intrusive landforms.

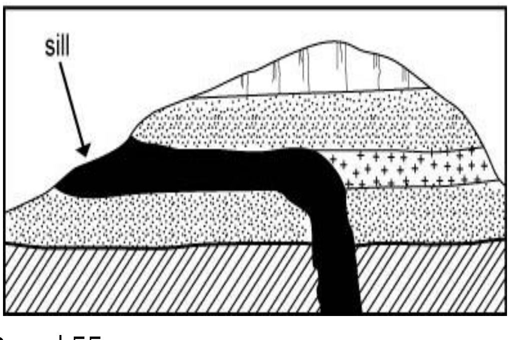
INTRUSIVE LANDFORMS

This is the process by ***which molten magma from the earth's interior is intruded into the earth crust and cools or solidifies before reaching the surface***. Landforms resulting from intrusive vulcanicity lie below the earth surface but may later be exposed to the surface by denudational processes such as erosion, weathering and mass wasting to form important features in the landscape. The major intrusive features include;

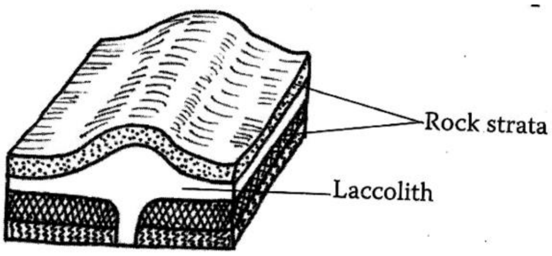
1. **Dyke** – This is a ***vertical or steeply inclined rock sheet intruded into or cut across rock layers or strata***. It is formed when magma solidifies within a vertical fissure or fault or crack in the earth crust before reaching the surface. Its thickness varies from a few centimeters to hundreds of metres. Dykes are said to be discordant with the surrounding rock layers or strata. They can occur singly or in large groups (swarms). Examples occur in ***south Nyanza, Thika district (Kenya) and Rungwa, east of Kisumu***.
When the dyke is eroded it may form a wall-like **ridge** if it's more **resistant** than the adjacent or surrounding rocks, such as ***Isingiro ridges in western Uganda; in Busia & Rungwa complex***, **BUT** if it's **less resistant** than the adjacent rocks it will form a shallow **trench** such as those in ***west of Lake Turkana, Kenya***. Sometimes dykes give rise to waterfalls or rapids. (Bunnett Pg. 43; Buckle Pg. 53)

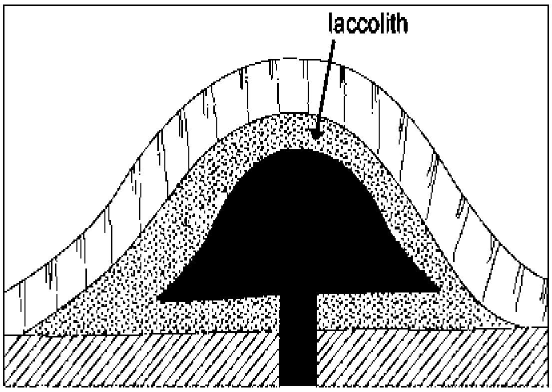


2. **Sill** – This is a ***horizontal or tabular sheet of magma intruded along a bedding plane***. Its thickness varies from a few centimeters to thousands of meters. A sill is formed when magma rises from the interior and spreads horizontally along the bedding plane before solidifying. Sills form from ***basic magma*** which is very fluid and mobile thus it's able to flow far before solidifying. They are concordant (consistent) with the adjacent rocks. They may occur singly or in groups. When sills are **hard** compared to the surrounding rock they may be exposed by erosion to form **escarpments** or **cliffs** & flat topped hills called buttes, e.g. ***Three Sisters in Cape Province of South Africa*** while if they occur across a river bed they may form **waterfalls** and **rapids**. Examples are ***Thika and Thompson falls in Kenya, Ssezibwa falls and Bujagali in Uganda***.



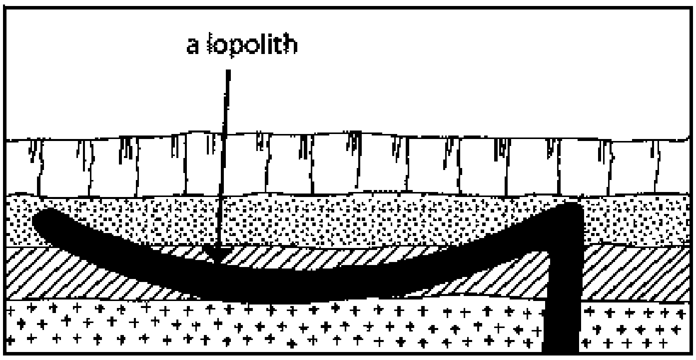
3. **Laccolith** – This is a ***dome-shaped intrusion with a more or less flat base***. It is formed when viscous magma which is unable to flow far rises and solidifies within the crust and accumulates in a large mass, pushing up the overlying rock layers to form a dome or mushroom-like feature with a generally flat base. When exposed a resistant laccolith may form an **upland**. Examples are at ***Kitui Hills, Voi in Kenya***.



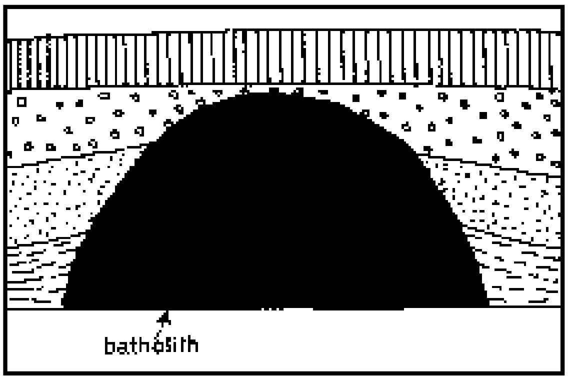


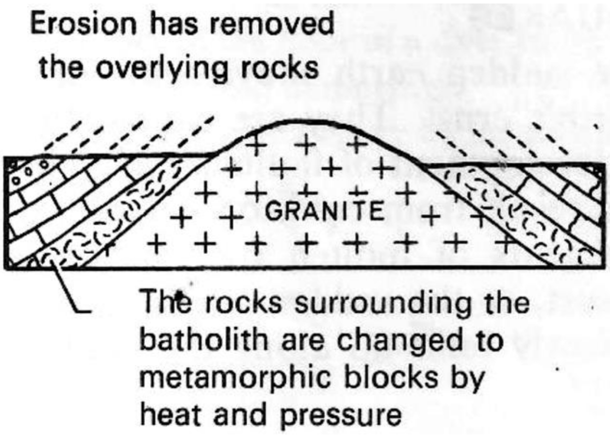
Laccolith exposed by erosion of overlying strata in Montana

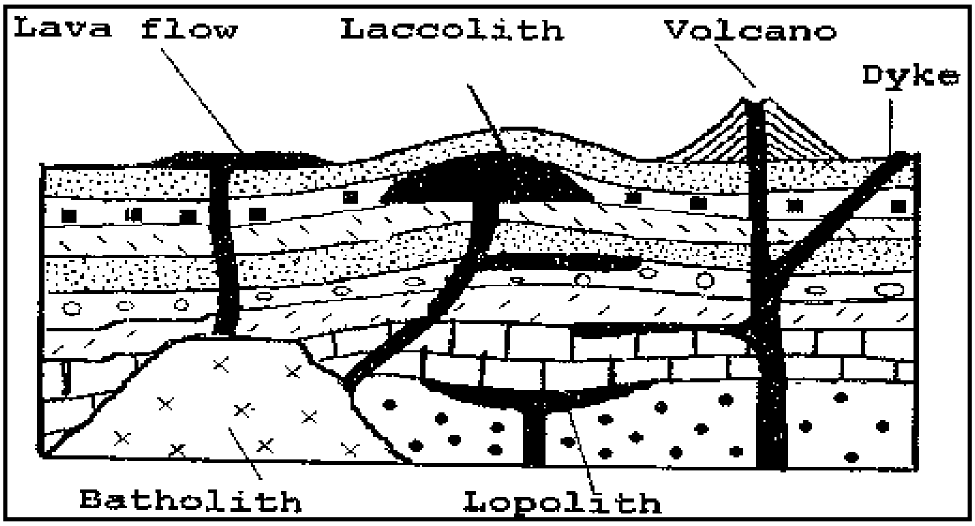
4. **Lopolith** – This is a very large saucer-shaped intrusion of viscous magma. It is formed when viscous magma is intruded into the crust and spreads horizontally. The increased weight of the overlying crust may cause sinking of magma giving it a saucer shape. When exposed by denudational forces the upturned edges of the lopolith may form **steep out-facing scarps** while the depression may form a **shallow basin**. Examples include the ***Rubanda arenas in Ankole*** while other lopoliths are found *north of Harare in Zimbabwe*.



5. **Batholith** – This is a ***very large dome shaped body or mass of igneous rock (generally granite) formed at great depth by the intrusion and solidification of viscous magma***. This is the largest intrusive volcanic landform. It is formed by large-scale intrusion of viscous magma deep in the earth crust which cools and solidifies slowly. When exposed at the surface by prolonged denudation resistant batholiths may form massive rock **uplands**. These resistant hill outcrops stand out as inselbergs or residual hills surrounded by soft low lying plain. Examples include the ***Tanganyika batholith which outcrops between Mwanza and Iringa, Mubende (Ssingo) batholiths and Parabong hills (Acholi) in Uganda***. Others include *Chaillu Massif in Gabon; Sinda batholith, east Zambia; Cape Coast batholith, Ghana*.





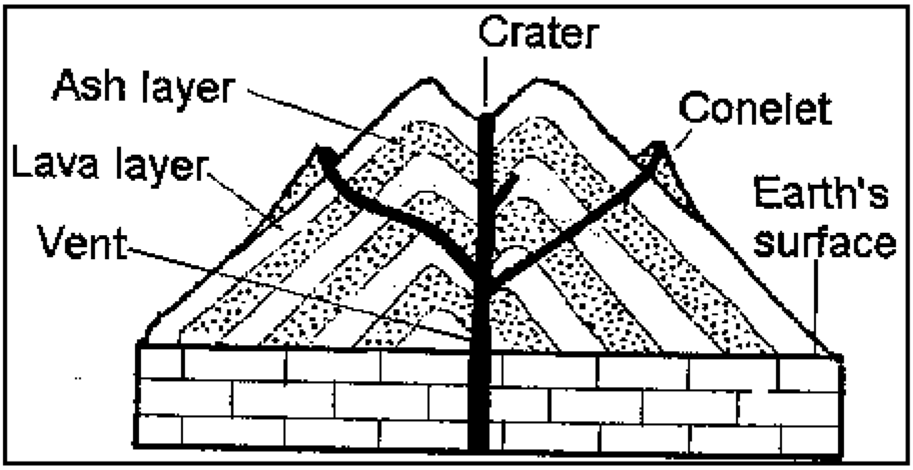


EXTRUSIVE VOLCANICITY

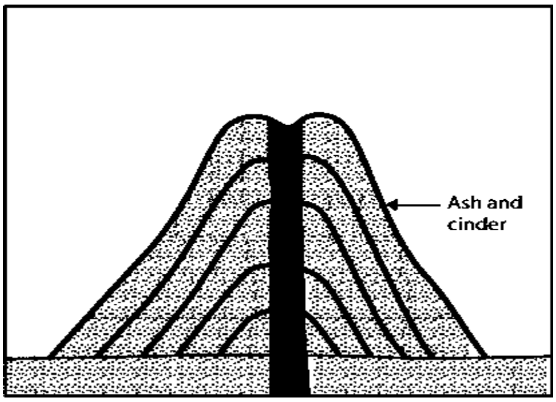
This is the ***process by which molten magma from the earth's interior is ejected and deposited onto the earth surface through a central vent or fissure***. When eruption occurs, magma is ejected in form of ash, stones and blocks as well as gases. These fragmental materials are known as ***pyroclasts***. The features formed take various shapes depending on the type of lava which forms them.

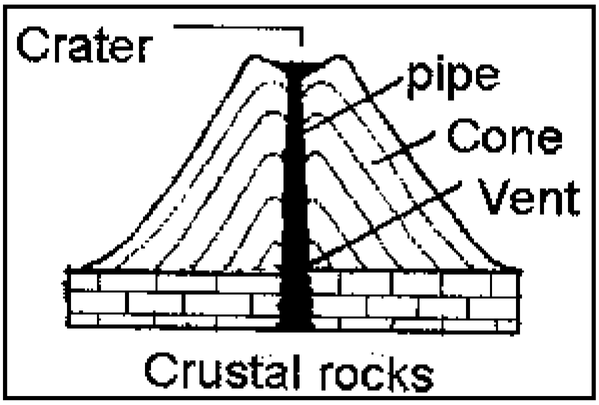
LANDFORMS RESULTING FROM EXTRUSIVE VOLCANCITY

1. **Composite Cone or Strato Volcano** – This is usually ***a large cone with fairly steep sides consisting of alternate layers of ash and lava ejected through a central vent over a long period of time***. It is formed by alternate **violent and non-violent eruptions** releasing a lot of ash and lava which pile up around the vent. The violent cycle creates a layer of ash while the non-violent cycle creates a layer of lava. When the cycle of ash and lava is repeated over and over in alternating layers, a composite volcano is formed. The **acidic lava** released is very viscous hence cools and hardens before spreading. A later violent explosion may blow off the top of the volcanic cone forming a large crater. Secondary or parasitic cones may develop on the sides when the main vent is blocked by solidified magma. Examples include ***Mt. Muhavura, Mgahinga, Meru, Kenya, Kilimanjaro, Ol Doinyo Lengai and Nyiragongo (DRC); Mt. Cameroon***.

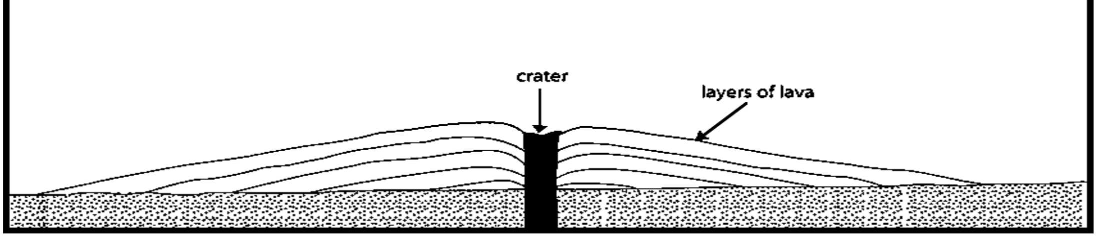


2. **Ash and Cinder Cones (Scoria Cone)** – This is a ***small steep sided volcano composed of ash and cinder layers***. It is formed when **acidic magma** is **violently or explosively ejected** creating many fragments (pyroclasts) of varying sizes, the smallest being ash. The fragments are later laid down in alternate layers of ash and cinder which accumulate and gradually build a conical hill with steep sides and a bowl-shaped crater at the top. They frequently occur in groups and are usually small, less than 200m in height. Examples include ***Suswa, Menegai; Nabuyatom, Abili Agituk, Murniau, Likaiyu and Teleki hills south of Lake Turkana; Mathanioni and Sambu in Kibwezi area of Kenya; Longonot, Sarabwe and Fileko, in Tanzania; Muganza, Sagitwe, Busoka, Bitale and Bisalo in Kisoro, SW Uganda and Chuyulu hills in Uganda***; Kitsimbanyi, north of Nyamlagira in DRC.





3. **Shield Dome or Basalt Dome or Volcano (Basic Lava Cone)** – This is a ***large, flat topped gently sloping convex dome***. It's usually low in height relative to its large base. It is formed during a **quiet or non-violent eruption** when **very fluid** basaltic or **basic lava** flowing from one vent or several fissures spreads out over a large area before solidifying to form a very large lava cone or dome with gentle slopes. They are named for their large size and low profile, resembling a *warrior's shield*. Usually a large shallow steep sided crater is found on the basalt top. Examples include ***Nyamlagira (DRC); Mt. Marsabit in northern Kenya, Tukuyu in southern Tanzania; Erta Ale, Mat 'Ala & Alayta in the Afar Triangle, Ethiopia***.

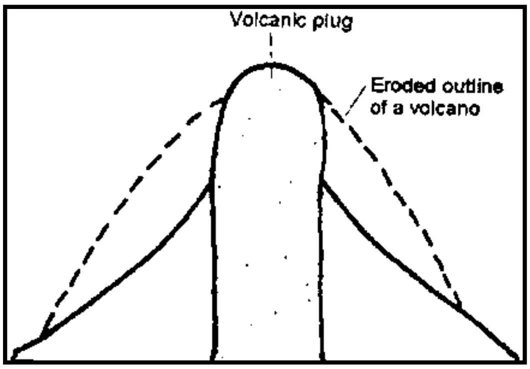


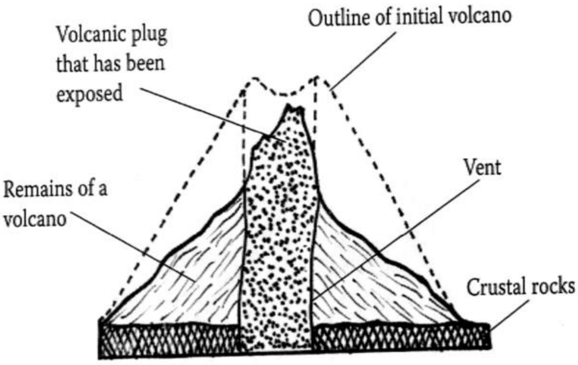
4. **Volcanic Plug or Neck** – This is a ***cylindrical mass of solidified lava in the vent of a volcano exposed by erosion of the surrounding cone***. It is formed when **very viscous acid magma** solidifies within the vent or pipe of an extinct volcano. After prolonged denudation of the volcano cone a distinctive upstanding landform is exposed. Examples include ***Tororo rock in Eastern Uganda,***

Alekileki on Mt. Napak, in Uganda; Batian and Nelion peaks on Mt. Kenya; Mawenzi, Mt. Kilimanjaro; *Wase Rock, south Jos in Nigeria.*

Tororo Rock, Eastern Uganda

Volcanic Plug on Mt. Napak





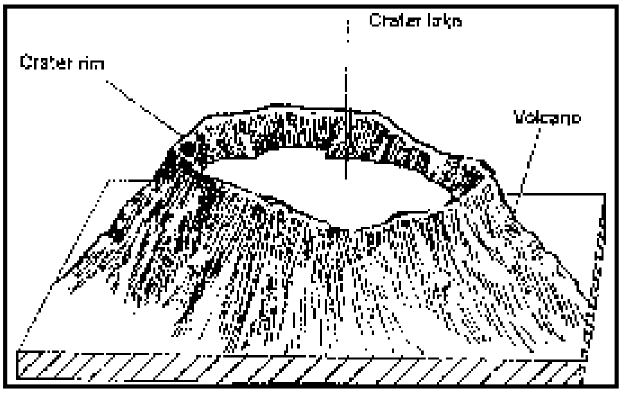
5. **Explosion Crater or Ring Crater** – This is ***a circular, shallow, flat-floored depression surrounded by a low rim of pyroclasts and local rock***. The craters are usually less than 50 meters high and often found in groups. Their formation is mainly based on **two** theories;

The **1st theory** notes that they are formed when a vent is blown through the local rock by a series of violent gas explosions. Fragments are deposited around the rim or edge of the crater created.

The **2nd theory** notes that as magma is poured onto the earth surface, a chasm or empty space is left beneath the volcano. Due to the weight of the overlying material (volcanic neck), the neck collapses into the chasm creating a depression.

When the depression extends to the water table it may be filled with water to form a **crater lake**. Examples include ***Lakes Katwe, Nyungu, Kyamwiga, Nyamusingire, and Nyamunuka in western Uganda around Lakes George and Edward; Lake Nkugute in Queen Elizabeth National Park; Ndali - Kasenda craters near Fort Portal and Kibale Forest; Lake Kyaninga crater lake in Fort Portal; Ghama & Ndobot craters, Tanzania;*** *Bishoftu & Hora craters, Ethiopia.*

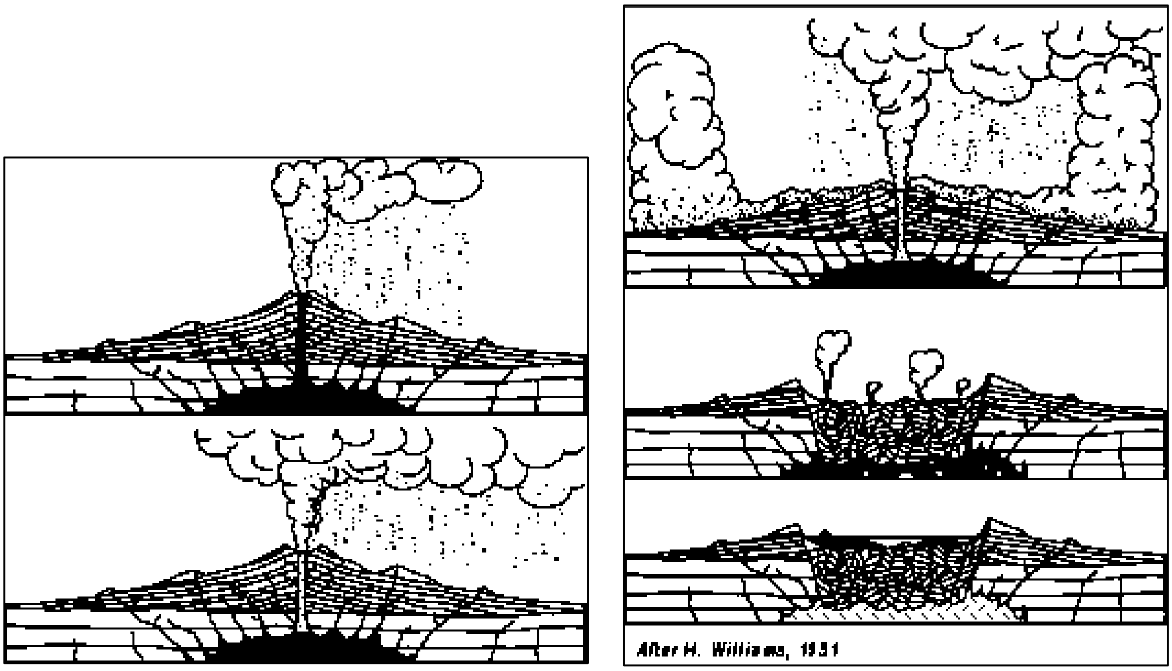
Crater Lake in Western Uganda



6. **Caldera** – This is a ***large, circular depression found on top of a volcano***. They usually exceed 1km in diameter. Their formation is based on two theories.
The **1st theory** noted that they are formed when a **violent eruption** blows off the volcano top and disintegrates into a mass of rocks and ashes, leaving behind a large circular depression.

The **2nd theory** notes that the caldera is formed by a process known as ***cauldron subsidence***. After a major eruption, the supply of magma is depleted or exhausted creating a large empty space (chasm) beneath the volcano. Due to the massive weight of the volcanic cone above, faults develop and in time the whole cone collapses into the chasm below creating a large depression called a caldera. Examples of calderas include ***Ngorongoro and L. Ngozi calderas in Tanzania; Longonot; on Mt. Menegai, Suswa and Meru in Kenya; on Mt. Elgon, Napak and Kadam in Uganda***. When a caldera is filled with water it forms a caldera lake such as ***Lake Shala, Ethiopia; Lake Bosumtwi, Ghana***.

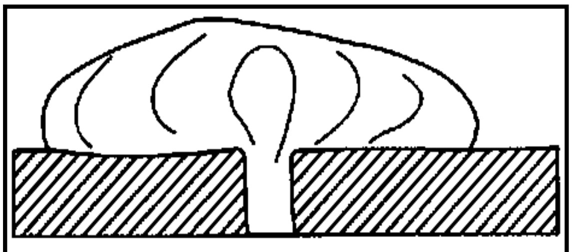
Panorama View of Ngorongoro Crater

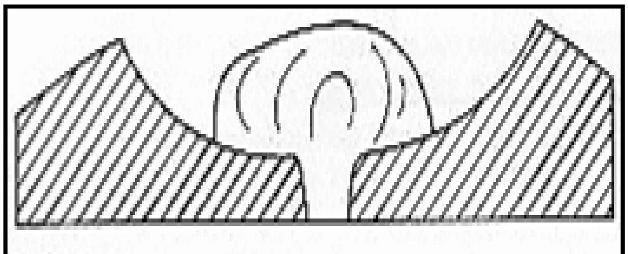


Cauldron Subsidence

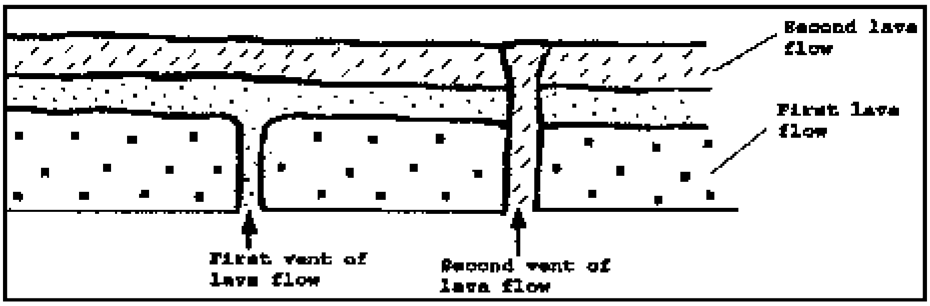
7. **Cumulo Dome or Acid Lava Dome** – This is a ***steep sided convex dome of acid lava***. It is formed when **viscous acidic lava**, which does not flow far, piles up around the vent and hardens quickly on the outside. Later eruptions are unable to reach the surface may force the overlying layers outwards. The dome usually has no visible crater. Examples include ***Mt. Ntumbi east of Mbeya, Tanzania***.

Cumulo domes which form inside craters or calderas are called ***Tholoids***, for example in the caldera of ***Mt. Rungwe in Tanzania***.

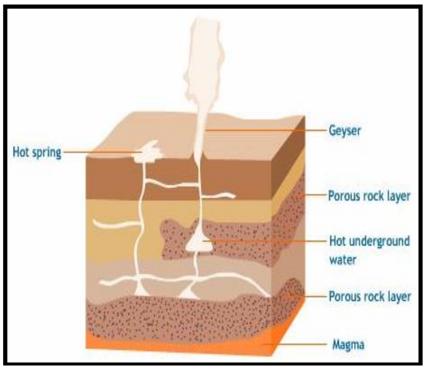

a. Cumulo-dome or mamelon

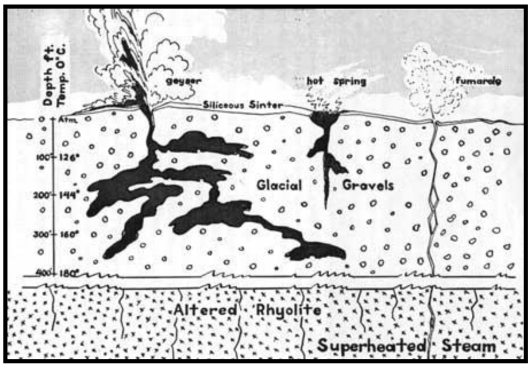

b. Tholoid

8. **Lava Plain or Plateau or Field or Bed** – This is an ***upland with a generally level summit made of successive layers of lava***. It is formed when **basic lava** which is very fluid or mobile, flows out from several fissures or cracks in the crust and spreads out over a wide area before solidifying. Repeated non-violent eruptions lead to the building of a thick and high plateau, completely covering the original landscape. Examples include ***Laikipia, Yata, Kapiti and Simbara plateaus in Kenya; Kisoro plains in south west Uganda***.



9. **Hot springs and Geysers** – A ***geyser is a spring of hot water and steam ejected into the atmosphere with great force or explosively at irregular intervals***. A ***hot spring is a spring or stream of hot water coming out of the ground with water temperatures above its surroundings***. Both features are caused by surface water gradually seeping down through the ground until it meets rocks super-heated by magma. The geothermally heated water then rises back toward the surface by convection through porous and fractured rocks. If the water becomes so hot that it builds steam pressure and erupts in a jet above the surface of the earth, it is called a ***geyser***. If the ***water only reaches the surface in the form of steam and other gases***, it is called a ***fumarole*** e.g. on *Mt. Kilimanjaro around Kibo's crater*. If its water only flowing out then it forms a ***hot spring***. If the water is mixed with mud and clay, it is called a ***mud pot***. Examples of hot springs include ***Kitagata in Sheema, Sempaya and Buranga in Bundibugyo, Kisizi in Rukungiri, Ihimba south of Kabale, at Panyimur, Nebbi District; Maji ya Moto near Nakuru in Kenya***.





Kitagata Hot spring

Sempaya Hot spring

Significance of Vulcanicity

1. Volcanic mountains and lava plateau provide fertile volcanic soils which support agriculture, e.g. Arabic coffee is grown on mountain Elgon, Mufumbiro, Kenya and Kilimanjaro, coffee earns the country foreign currency and provides employment, and other crops grown include wheat, tea, pyrethrum, maize, bananas, vegetables, and Irish potatoes.

2. The highland areas are densely settled. This is due to the fertile soils and cool climate, e.g. Bugishu, Kigezi, Kenya and Kilimanjaro highlands. In addition some of these areas have large towns like Kabale, Mbale, Moshi, and Nairobi. This has led to development of commercial activities.

3. The volcanic features especially mountains are tourist attractions. They provide sporting activities like mountain climbing. They generate income in form of foreign exchange and provide employment to local people.

4. Volcanic mountains influence climate, lead to formation of geographic or relief rainfall which is important for agriculture. Some mountains are ice capped. They are a source of many rivers, which provide water for domestic use and generate hydroelectric power.

5. There are forest reserves on the slopes of mountains like Elgon, Mufumbiro Kenya, and Kilimanjaro which are valuable source of timber and firewood. The forests also act as wildlife conservation areas e.g. Bwindi impenetrable forests, has the largest population of gorillas, which promote tourism.

6. Lava or magma is rich in minerals e.g. Tororo rock volcanic plug is a source of limestone for the cement industry. Iron,tin uranium are found in the Mufumbiro ranges; Lake Katwe which is an explosion crater is a centre for salt mining. The Kimberlite rock in Tanzania is centre for gold and diamond mining. Minerals provide revenue and employment.

7. Hot springs or Geysers are potential source of geothermal power (electricity).in Kenya, the Ol karia Geothermal Power Station near Lake Naivasha in Kenya, generates electricity.

8. There is fishing in lava-damned lakes, which provides food and employment.

9. The intrusive features Batholiths, dyke, sills, laccoliths and lappoliths once exposed to the surface as inselbergs have the following advantages;

- Good sites for quarrying. They are sources of stones used for construction.
- Sills and Dykes once crossed by rivers create waterfalls which are good for hydro power generation.
- They are tourist attractions.

Negative

- Volcanic features especially mountains are communication barriers due to steepness.
- It is very expensive and risky to construct roads and railways in the hilly areas.
- Volcanic eruption leads to loss of lives and property e.g. Mt. Nyiragongo erupted on 22nd May, 2021.
- Heavy rainfall and steepness lead to soil erosion, mass wasting and landslides which are common in Kigezi and Elgon areas.
- Mountains act as barriers to rainfall especially on the leeward side (rain shadow areas) this causes aridity.
- Intrusive features like sills and dykes form waterfalls and rapids which hinder navigation of rivers.
- Where there are Inselbergs and Batholiths make agriculture practicing difficult.

REVISION QUESTIONS:

1. Account for the development of extrusive volcanic landforms in EA.
2. Examine the relationship between the nature of material ejected and the resultant landforms in EA.
3. To what extent does the nature of materials ejected influence the formation of volcanic relief landforms?
4. Examine the influence of intrusive vulcanicity on the development of relief landforms in EA.
5. Explain the processes responsible for eth formation of intrusive volcanic landforms in EA.
6. Examine the influence of vulcanicity on drainage in EA.
7. Examine the influence of extrusive vulcanicity on the development of relief landforms in EA.

GLACIATION

A glacier is a large mass of accumulated/compacted mass of ice in motion under the influence of gravity. Glaciers form in areas of permanent snow, both at high latitudes and at high elevations at any latitude. Permanent glaciers exist in all continents except in Australia. The altitude or elevation at which permanent glaciers exist or occur above sea level is known as the ***snowline***. The snowline varies from place to place, for instance in the tropics it is above 4000m a.s.l while at the poles it can fall as low as 0m a.s.l. In East Africa glacial activity is limited to Mt. Rwenzori, Mt. Kenya and Mt. Kilimanjaro.

Formation of Glaciers

When the temperature of air falls below 0^0 C, some of its water vapor condenses and freezes into ice crystals or snow. When enough snow accumulates **(accumulation)** for a long time it transforms into ice in a process called ***alimentation***. With time new layers of snow bury and compress the previous layers (***compression***) forcing the snow to re-crystallize forming very small grains. **Compaction** squeezes air between the grains causing the snow to slowly compact and forming a solid impermeable glacier. The increasing weight causes the snow crystals under the surface to become compact and transform into a granular mass called **névé** or ***firn*** (***firnification***). With time, larger ice crystals become so compressed that any air pockets between them are very tiny hence forming a large solid block of ice, known as a **glacier**. The glacier then moves downslope. For most glaciers, this process takes over a hundred years.

Ice Movement

Ice may move through one of these three processes:

1. **Plastic Flowage**: Ice has plastic qualities and may flow en-masse like a viscous liquid
2. **Basal Slip**: Melt water at base of glacier reduces friction by lubricating the surface and allowing the glacier to slide across its bed.
3. **Internal Shearing**: Movement similar to rock faulting involving differential sliding along planes.

Glaciers like rivers perform a triple function or erosion, transportation and deposition, in the process creating several landforms.

GLACIAL EROSION

Although glaciers lack the velocity and turbulence of rivers, they are effective agents of erosion. This is because in the process of their slow movement, they melt, freeze and grind obstacles which are later carried away with them. Glaciers erode through three major ways;

(a) **Plucking** – This is ***a quarrying and tearing process by which underlying rock fragments frozen into the base of the ice are pulled away as a glacier moves***. Glacial plucking is most effective on well-jointed rocks.

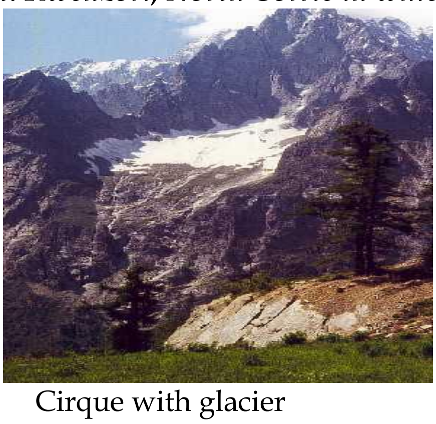
(b) **Abrasion** – This is ***a grinding process in which stones and boulders frozen into the glacier are dragged over the underlying rocks polishing and scratching the surface of the glacial valley***. Visible characteristics of glacial abrasion are ***glacial striations.***

(c) **Basal Sapping (Free-thaw)** – During day time temperatures allow water to melt, and at night the water freezes again. As the water freezes it expands and causes the cracks to widen. This cycle continues, each time widening or enlarging the cracks and hollows by a tiny amount. Eventually this continuous process causes rocks to break up. [***This is the rotational slipping of ice which involves alternate freezing and thawing of water in cracks leading to gradual enlargement of cracks***.]

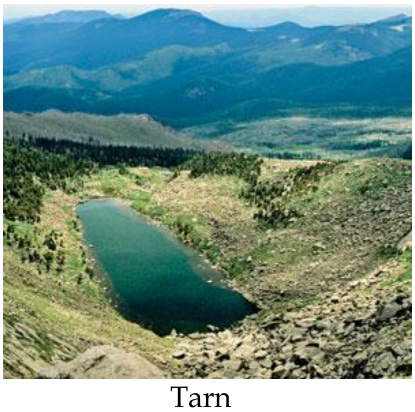
Glacial erosion depends on the following factors;
- Rock resistance. Erosion is greater where rocks are weak.
- The speed of the glacier. Erosion increases with the speed or velocity of the glacier.
- The thickness and weight of ice. Erosion increases with the weight of the glacier.
- Availability of rock debris or moraine as a tool to erode the surface. Erosion is greater where there is a large supply of debris.

Landforms Resulting From Glacial Erosion

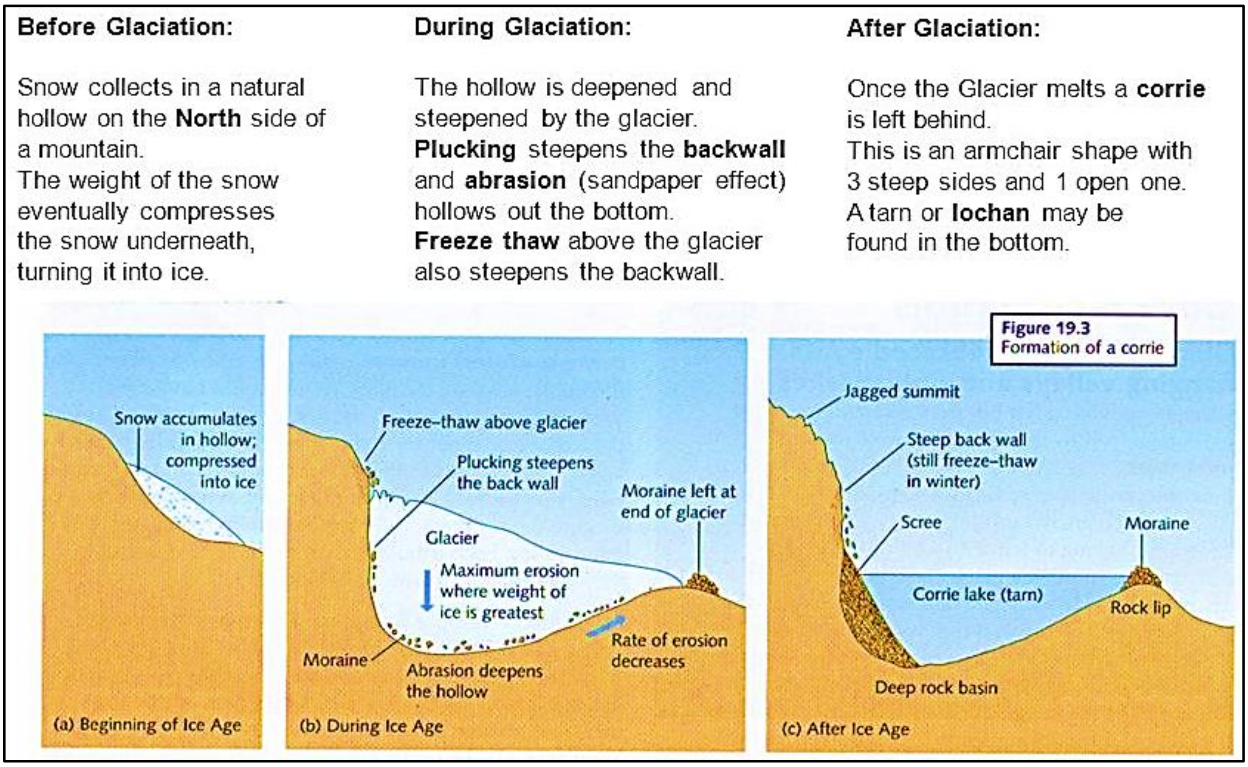
1. **Cirque or Corrie or Cwm** – This is ***a semi-circular, steep-sided rock basin cut into the mountain side***. Cirques develop from a **nivation or pre-glacial hollow** where ice accumulates. ***Basal sapping*** through frost shattering as well as **plucking** help to **steepen** the back wall of the hollow in a process known as ***back-wall recession***. At the same time the resulting rock debris embedded within the glacier is used to **deepen** the depression through **glacial abrasion**. When ice melts, water accumulates to form a lake known as a ***tarn***. Examples include ***Teleki, Hut, Tyndall, Hidden, Hanging, Simba, Hobley and Hall tarns on Mt. Kenya; Lac Catherine, Gris, du Speke, Vert, Noir and Blanc on Mt. Rwenzori; North Corrie in which lies Mawenzi Tarn on Mt. Kilimanjaro***.



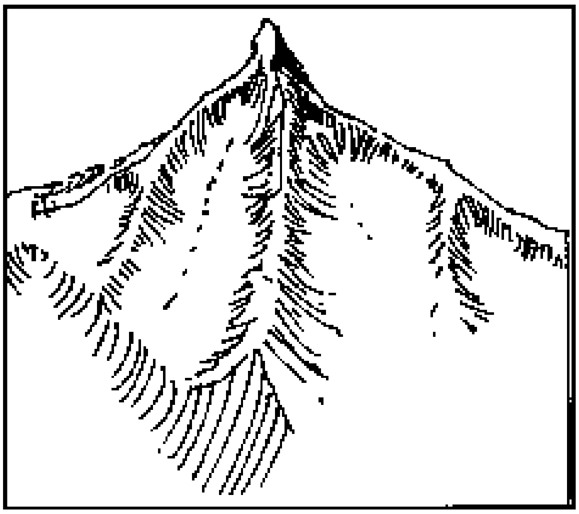
Cirque with glacier



Tarn

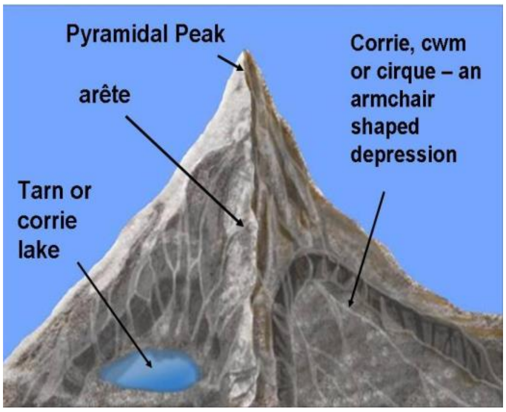


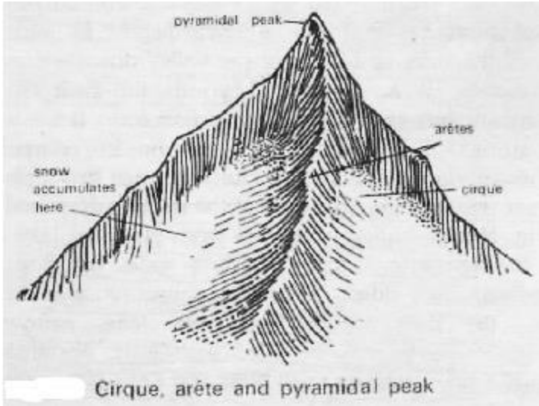
2. **Arête or Ridge** – This is ***a narrow, steep-sided or knife-like rocky ridge separating two cirques***. It is formed by the backwall recession of two adjacent cirques by **plucking** leading to the formation of a sharp knife-like ridge separating two cirques. The edge is then sharpened by frost shattering while the slope on either side of the arête is steepened through mass wasting and the erosion of exposed rock. Examples can be seen on ***Mt. Rwenzori where an arête radiates eastwards to Mugusu valley while another radiates southwards to Bujuku valley; on Mt. Kenya there is a large arête extending south from Nelion peak***. [*When two corries cut back on opposite sides of a mountain*]



Mount Rwenzori - Alexandra Peak

3. **Pyramidal peak or Horn** – This is ***a steep-sided, sharp-pointed jagged peak surrounded by cirques with a radiating system of arêtes***. It is formed at the junction of arêtes by the backwall recession due to **glacial plucking** of two or more cirques on all sides of a mountain. **Frost action** sharpens the peaks. Examples include ***Magherita Peak on Mt. Stanley, Alexandria Peak and Albert Peak on Mt. Rwenzori; Point Piggott, Pt. John, Pt. Tilman, Pt. Lenana, Pt. Midget, Nelion, Batian, Corydon, Shipton, Tilman, Grigg & Sommerfelt Peaks on Mt. Kenya***.





Cirque, arête and pyramidal peak

4. **Glacial Trough or U-Shaped Valley** – This is ***a broad, flat-floored, steep-sided valley with a roughly U-shaped cross profile***. Glacial troughs are formed when a glacier develops and travels along a former river valley, transforming it into a U-shaped valley through the glacial plucking and abrasion. This widens, deepens, straightens and polishes the former river valley into a glacial trough. When the ice recedes or thaws, the valley remains, often littered with small boulders that were transported within the ice. Examples include ***Bujuku, Mubuku, Bugusu, Kamusoso and Lusilube valleys on Mt. Rwenzori; Mackinder, Gorges, Teleki, Hobley and Hausberg valleys on Mt. Kenya; Karanga & South East valleys on Mt. Kilimanjaro***.

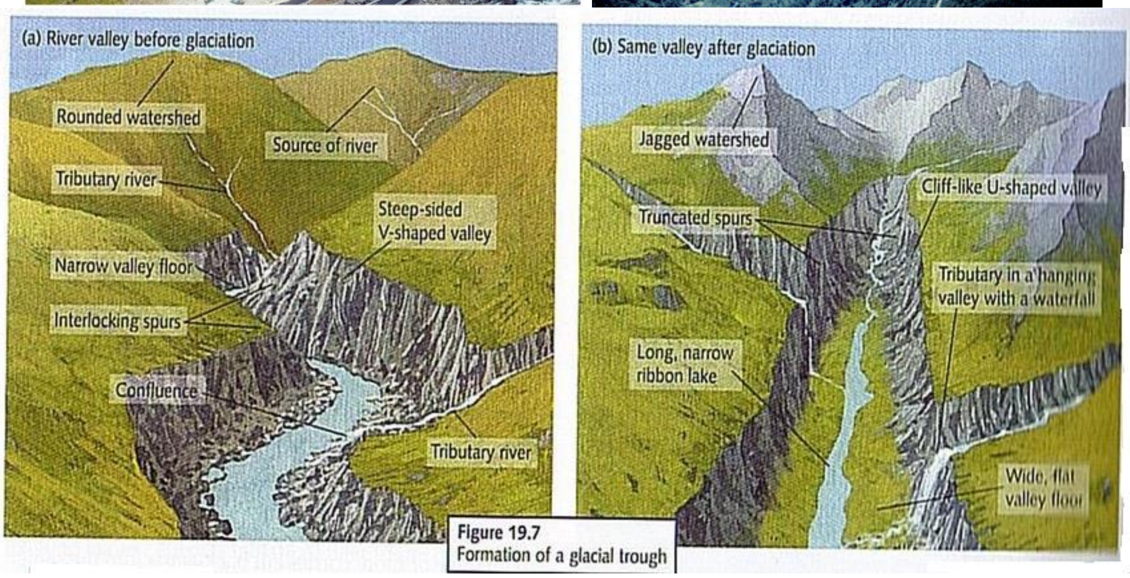
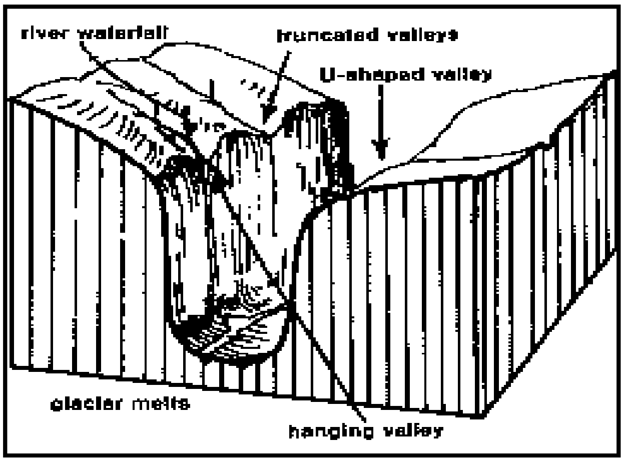


Figure 19.7
Formation of a glacial trough

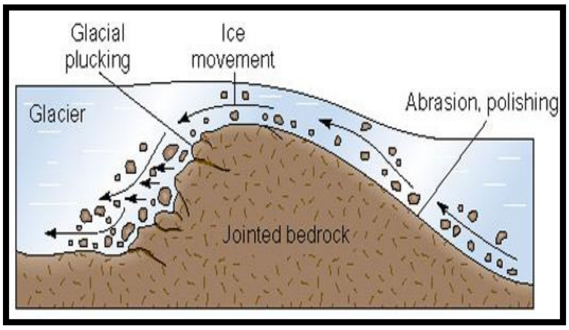
5. **Hanging Valley** – This is ***a tributary valley of a glacial trough that descends steeply into the main valley***. Hanging valleys appear at a higher level thus they're said to be hanging. They normally contain fewer glaciers with less erosive power hence the bed of the hanging valley is less deepened. They are formed when a tributary glacier flows into a main glacier of larger volume. The main glacier erodes much more rapidly by **plucking** and **abrasion** forming a deep U-shaped valley with nearly vertical sides while the tributary glacier, with a smaller volume of ice, makes a shallower U-shaped valley that appears to be 'hanging' above the main valley. Often water from the hanging valley descends over the steep edge of the valley forming waterfalls. Hanging valleys

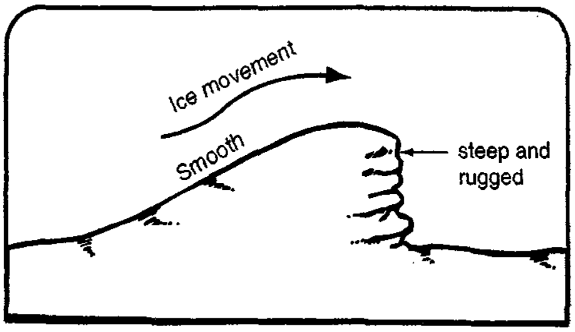
are also the product of varying rates of erosion of the main valley and the tributary valleys. The tributary valleys are eroded and deepened by glaciers at a slower rate than that of the main valley floor forming a hanging valley. Examples include the ***Nithi River is joined by one of its tributaries called Little Nithi from a hanging valley via the Vivienne falls on Mt. Kenya; Speke valley hangs over the Lusilube trough and Vert valley hangs above Kamusoso valley on Mt. Rwenzori***.



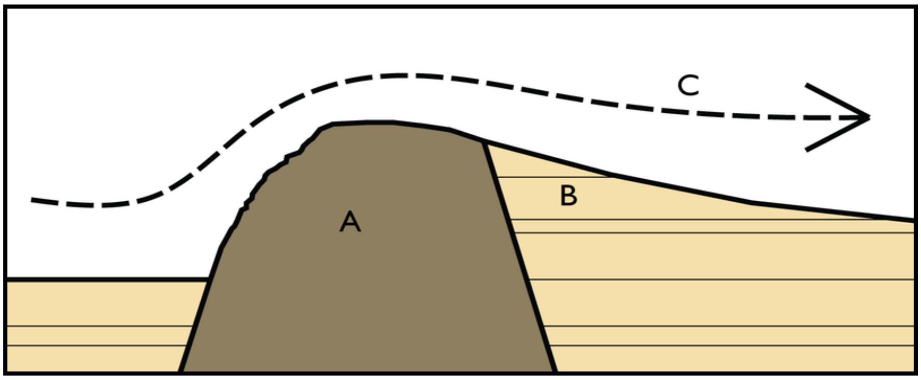
6. **Roche Moutonnée** (Sheepback) – This is ***an ice-smoothened resistant rock rising above the plain***. It is formed when the upstream side of the rock (***stoss***) is polished or smoothened by **glacial abrasion** while the downstream or leeward side (***lee***) is steepened, made irregular and rough by **glacial plucking**. Examples can be seen in the ***Mubuku valley on Mt. Rwenzori; Gorges valley on Mt. Kenya and on the slopes south of Mawenzi on Mt. Kilimanjaro***.

Roche Moutonnée in Wales





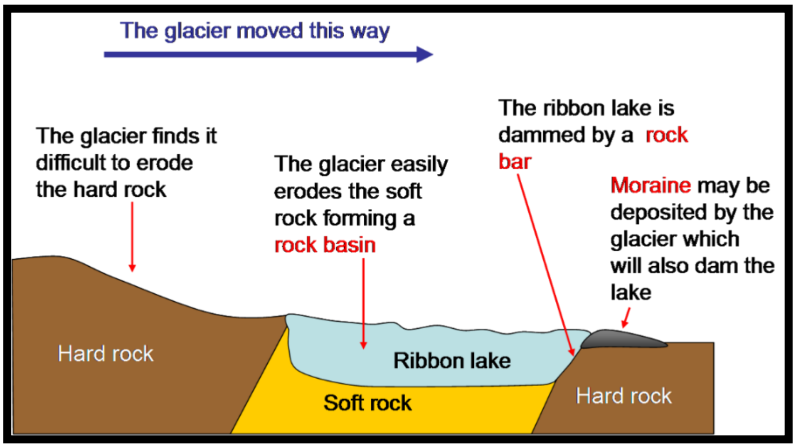
7. **Crag and Tail** – This is ***an elongated outcrop of resistant rock***. It is common in areas affected by volcanic activity. It is formed when a resistant rock outcrop of granite or a volcanic plug obstructs glacier movement. The glacier erodes the surrounding softer material, leaving the rocky block protruding above the surrounding terrain. The result is a rock mass of hard rock called a **crag** protecting an elongated **tail** of weaker rocks on the leeward side. Examples can be traced ***on the saddle between Kibo and Mawenzi peaks of Mt. Kilimanjaro***.



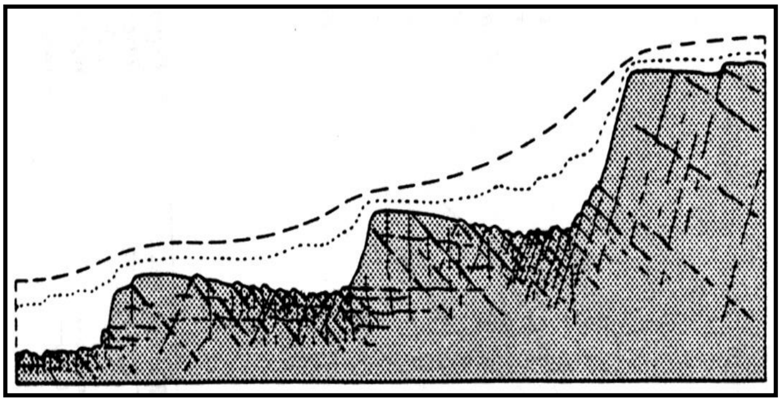
A – Crag of hard volcanic rock; B – Tail of softer rock; C – Direction of ice movement

Crag and Tail

8. **Rock Basins –** This is ***an irregular depression in the floor of a U-shaped valley***. They are formed by unequal glacial erosion of the bed rock due to varying ice thickness and variation in rock resistance. Where the thickness of ice is great and rocks are soft/weak then erosion will also be great thus forming rock basins. When the glaciers melt rock basins may be filled with water to form lakes known as **Rock Basin or Ribbon lakes**, e.g. ***Lake Michaelson in the Gorges Valley, Lake Hohnel & Carr Lakes on Mt. Kenya; Lac Noir & Lac Vert in the upper Kamusoso Valley on Mt. Rwenzori***.

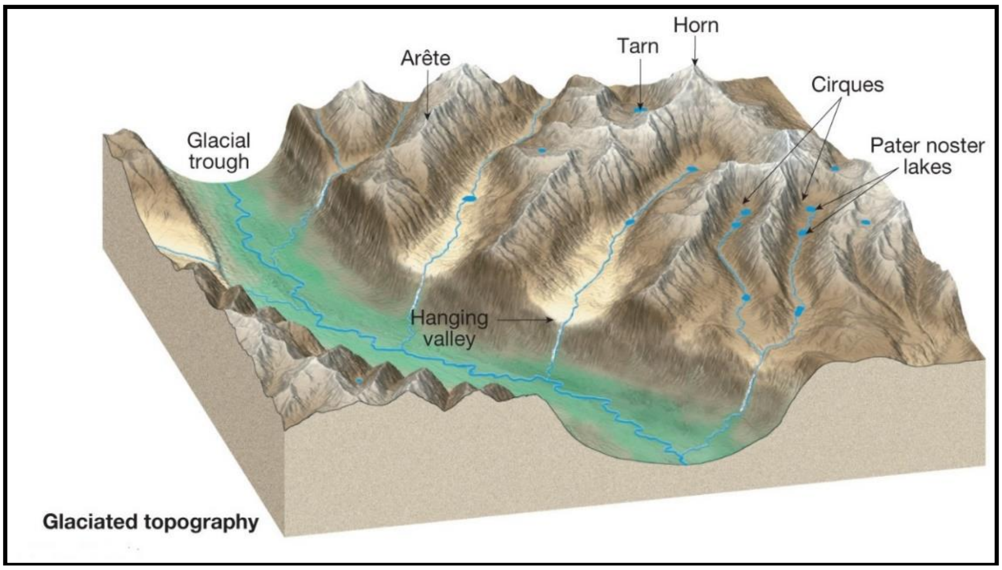


9. **Rock Steps** – These are knick points or rock projections formed where hard rocks alternate with soft rocks. When glaciers flow over alternate hard and soft rocks there is unequal or uneven glacial erosion of the bed rock. The soft rocks are eroded while hard rocks resist erosion. This uneven vertical erosion results in the formation of rock steps by the hard rocks. Examples are found on ***Mt. Kenya in the upper part of the Gorges valley as far down as the Vivienne falls is divided into a series of rock steps; in the Bujuku & Mubuku valleys on Mt. Rwenzori***. [*A series of rock steps are formed due to different degrees of resistance to glacial erosion of bedrocks.*]



Rock Steps

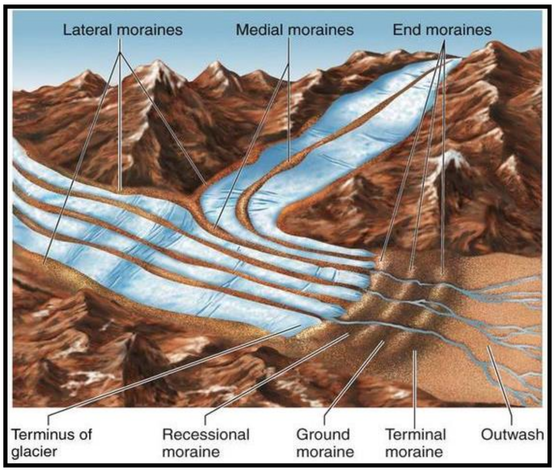
9. **Ice Eroded Plain** – This is ***an extensive area once covered by an ice sheet which smoothed off the original landforms to give a rounded topography***. Weak rocks were scratched or smoothened and rock basins covered, creating an almost clean swept original covering of weathered rocks. As the glacier is eroding, the eroded material is transported and later deposited as glacial drift thus forming an ice eroded plain. On such a plain several features such as roche moutonnée and crag and tail are found. Examples can be found in the ***Mubuku valley on Mt. Rwenzori and Gorges valley on Mt. Kenya***.

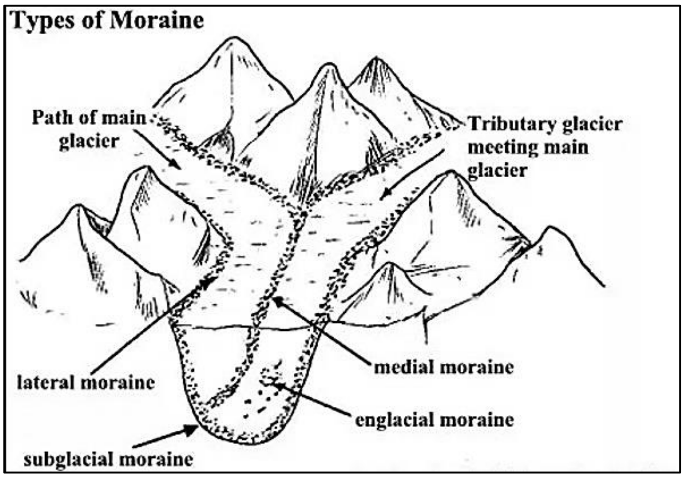


GLACIAL DEPOSITION

Glaciers move from highlands to lowlands, as they flow they carry along all sorts of debris falls onto the glacier through mechanical weathering of the valley walls. This debris is carried by the glacier for many kilometers and only deposited as the ice melts. Glaciers deposit materials ranging from sand, gravel, clay and boulders. These deposited materials are known as ***Moraine*** or ***Till*** and are laid down in a lowland area called a ***Till plain***.

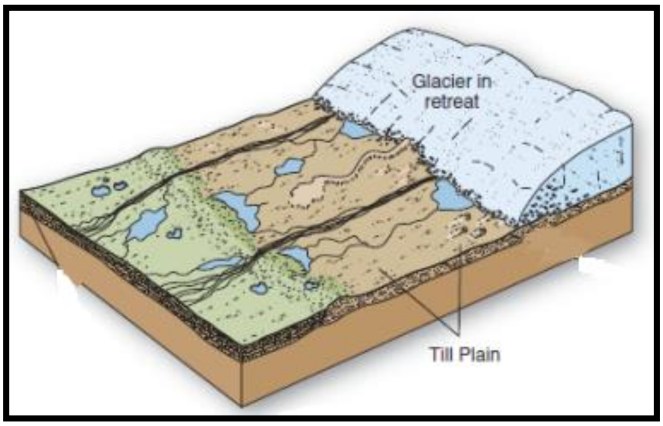
Moraine is classified according to where it is deposited. Moraine or till that is deposited along the sides or edges of the glacier is called **Lateral Moraine**. Till that forms at the front or snout of the glacier is called **Terminal or End Moraine**. Till that is deposited over the valley floor is called **Ground Moraine**. If two glaciers join their inner lateral moraines join together to form **Medial Moraine**. **Recessional moraines** form at the end of the glacier so they are found across the valley, not along it. They form where a retreating glacier remained stationary for sufficient time to produce a mound of material. **Supraglacial moraine** is material carried on top of the ice e.g. that falling on to the ice from weathering of surrounding slopes or that is windblown. **Englacial moraine** is material carried within the glacier itself. **Subglacial moraine** is material carried along in the base of the glacier. Much of this is likely to have been derived from glacial erosion, however some may have been englacial material that has gradually worked its way down through the ice. Surface melt water streams that flow down crevasses may also provide material which becomes subglacial.





When moraine is deposited it forms various landforms such as till plain, drumlin, esker, kettle, erratic and kames.

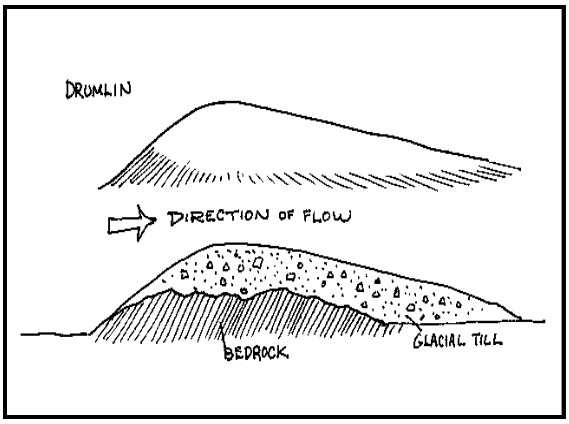
1. **Till Plain or Moraine Plain or Boulder Plain** - This is ***an extensive flat plain of unstratified or unsorted glacial till or deposits such as clay, rock fragments & boulders***. It is formed when a sheet of ice becomes detached from the main body of a glacier and melts in place, depositing the sediments it carried. It is composed of unstratified or unsorted material or till. Examples can be seen in the ***Mubuku and Bujuku valleys on Mt. Rwenzori***.



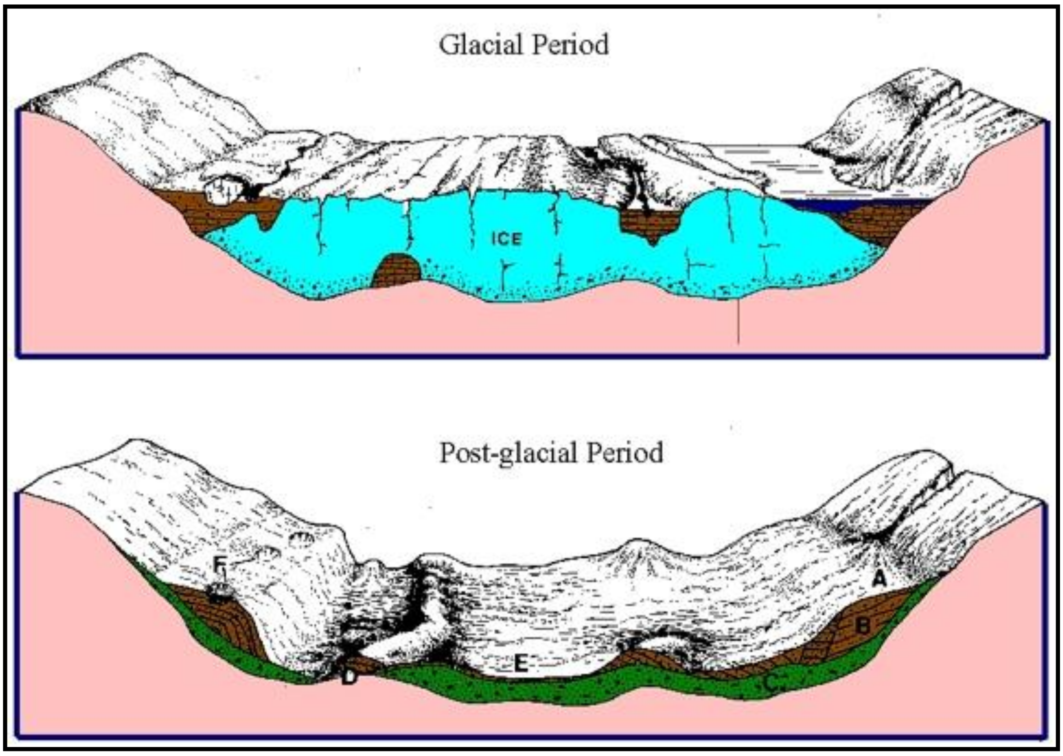
2. **Erratics** – These are ***boulders or rock fragments of varying sizes made of rock different from the local bedrock that were transported and later deposited in another place by glaciers***. Erratics are formed when rocks are uprooted or detached from the upper slopes by glacial erosion and deposited in the lower slopes. They may range in size from pebbles to huge boulders weighing thousands of tons and may be carried for long distances. They are usually resistant to the shattering and grinding effects of glacial transport. Erratics composed of unusual and distinctive rock types can be traced to their source of origin and serve as indicators of the direction of glacial movement. Erratics can be found in the ***Gorges valley on Mt. Kenya; Kamusoso and Bujuku valleys on Mt. Rwenzori***.

3. **Drumlins** – This is ***a smooth, low, rounded, elongated hill composed of glacial deposits such as boulder clay***. They are usually about 1km long and about 100m high. They usually occur on the till

plain in large groups or swarms aligned to the direction in which the glacier was moving. They are formed beneath the ice either by the remoulding of older till, or by the ice shaping till that it has deposited irregularly. Examples can be seen in ***Teleki valley on Mt. Kenya***.

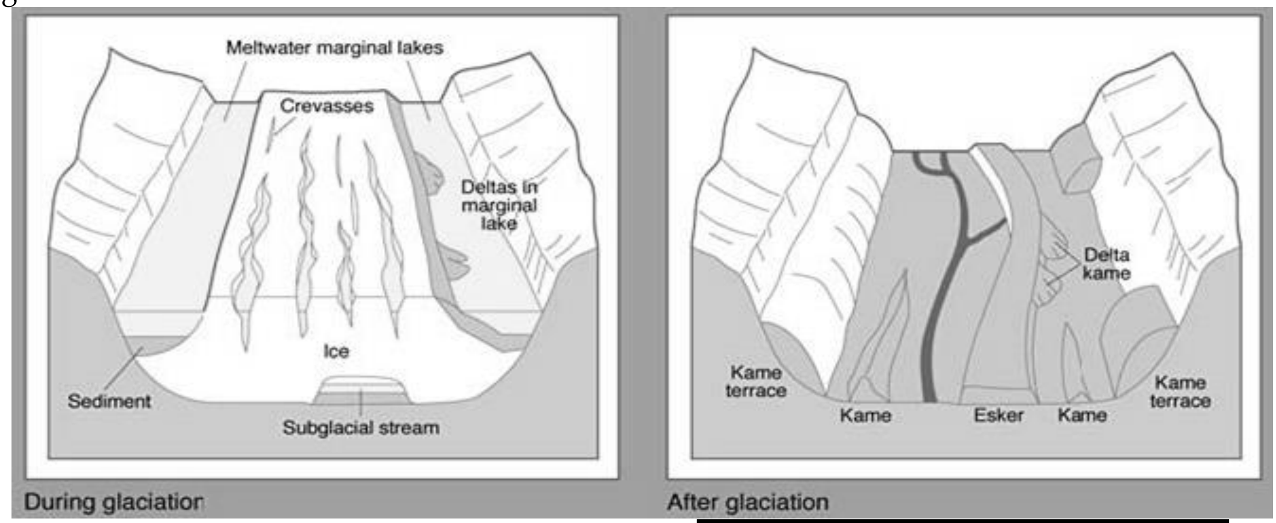


4. **Eskers** – This is ***an elongated, steep sided ridge composed of stratified sand and gravel deposits***. Eskers may be more than 30m high and several kilometers long. They are formed when melt ice water flowing beneath or within the glacier creates permanent sub-surface or sub-glacial tunnels where materials or deposits may build up. When the glacier finally retreats or melts, the tunnel walls collapse and the sorted or stratified river deposits become exposed on the surface as eskers. Other eskers form where streams drop their load in a mound as they emerge from the ice front. When the ice retreats the mound is extended into an elongated ridge. They are similar to a terminal moraine ridge but differ in a way that eskers contain stratified layers of till (are layered) and lie at right angles to any adjacent terminal moraine ridge. Examples are in the ***Bujuku valley on Mt. Rwenzori; Gorges and Teleki valleys on Mt. Kenya***.



B - Kame Terrace; C-Glacial Till; D-Esker; E-Kame; F- Kettle

5. **Kames** – This is ***an irregular mound or hill of stratified sand, gravel and till***. Kames vary greatly in size and shape and occur in isolation or in groups. They are ice-contact features formed in, on or at the margin of stagnant ice. They are formed from the accumulation of debris/sediments in a crevasse/depression on the glacier surface, and is then deposited on the land surface when the glacier melts or retreats.



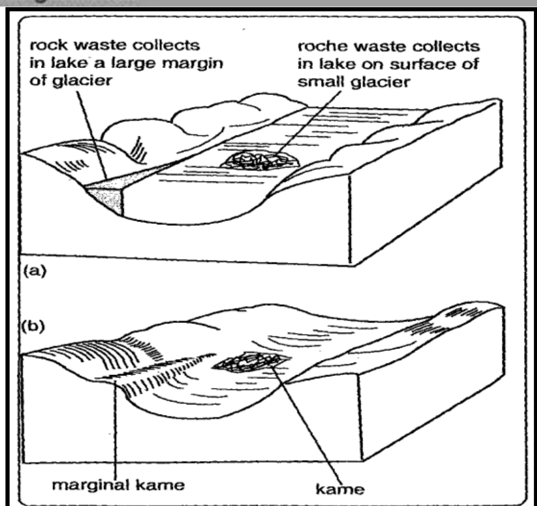
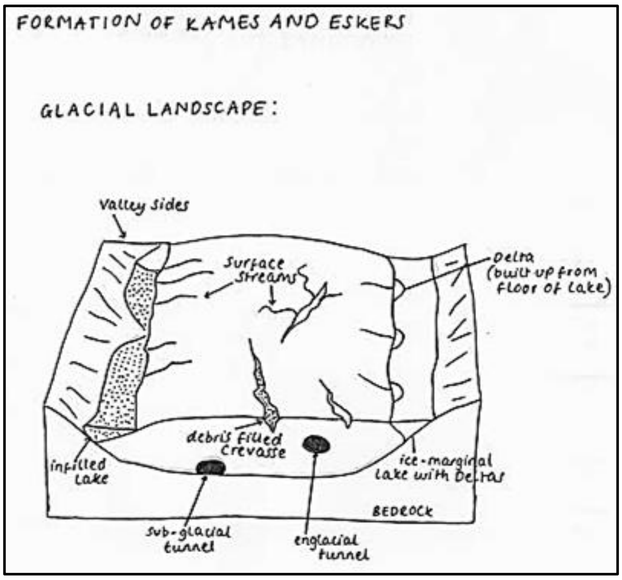
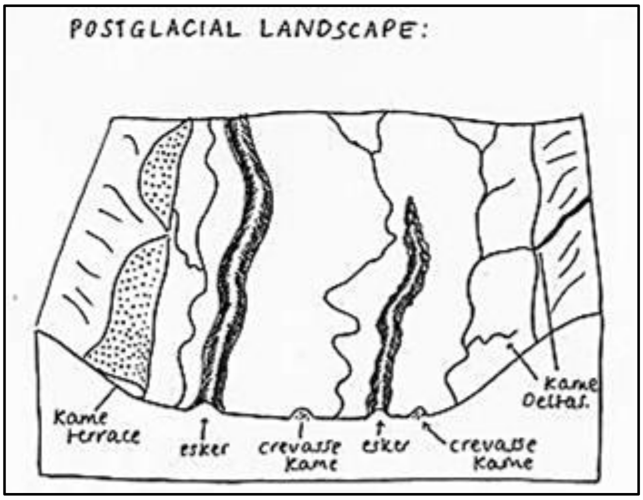


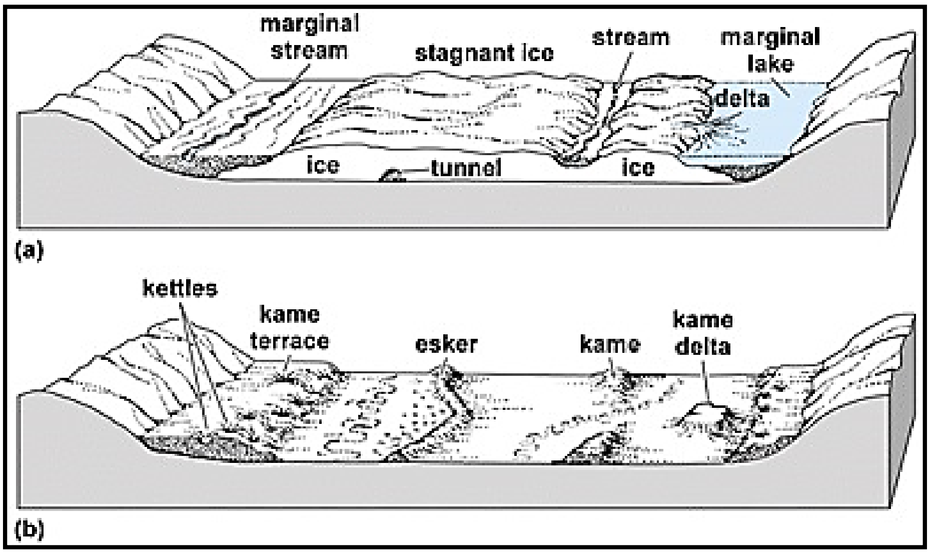
Fig.8.35: Development of a kame during a glaciation in (a) and after glaciation in (b)

Kame, La Bluff, Ile de la Grande Entree, Canada

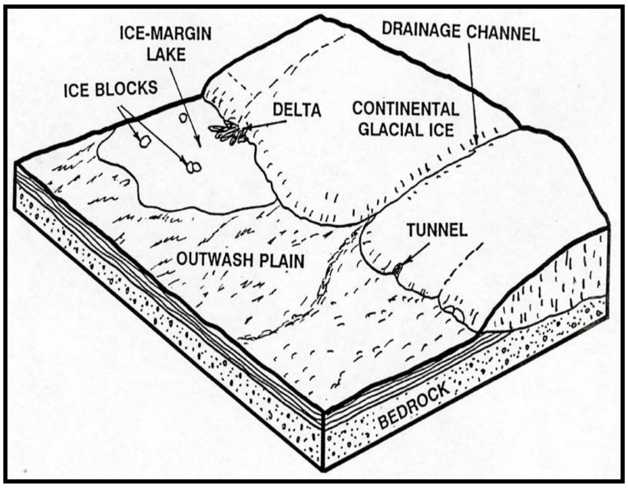




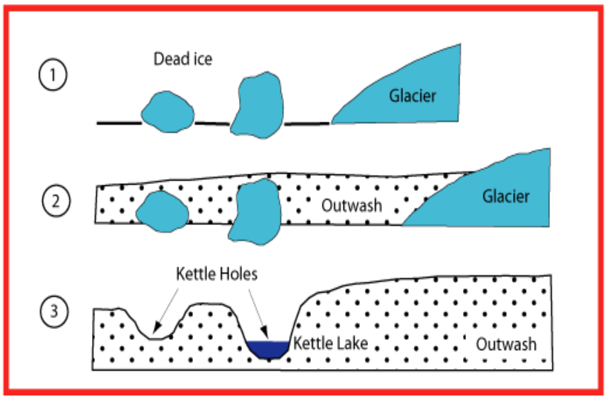
6. **Kame terrace** – This a ***narrow, irregular terrace or embankment of sorted or stratified sand and gravel along a valley side***. They are formed by the deposition of sand and gravel in narrow lakes held between a glacier and the valley side. When the ice melts or retreats the deposits will slump down and form a terrace along the valley sides. Examples can be found in the ***Kamusoso valley on Mt. Rwenzori and Hobley valley on Mt. Kenya***.



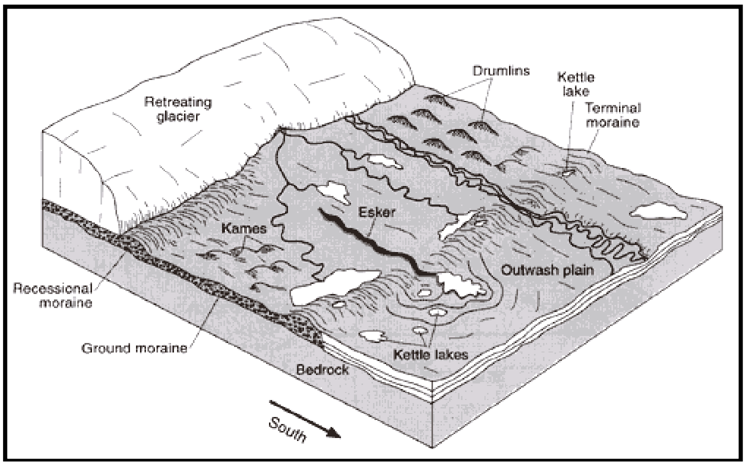
6. **Outwash Plain** – This is ***a wide gently sloping plain of gravel, fine sand and clay***. The deposits are often over 50 meters thick. They are formed when melt water from the stagnant glacier carry and deposit large amounts of sorted or stratified debris on a broad plain beyond the ice front. The material is sorted by size with coarse gravel being deposited first followed by fine sand and clays farthest. An outwash plain may contain braided streams and kettle lakes. Examples can be found in the ***Mubuku valley on Mt. Rwenzori and Teleki valley on Mt. Kenya***.

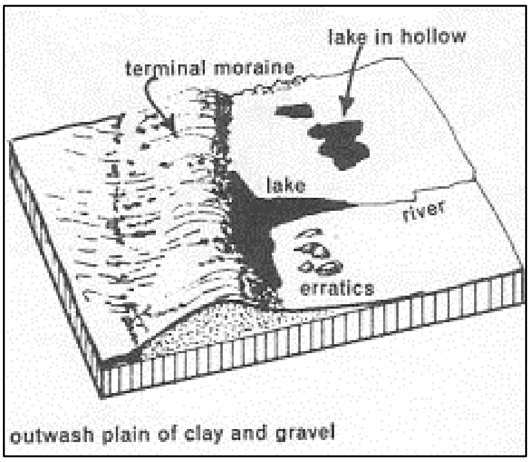


7. **Kettles or Kettle Holes** – This is ***a shallow, circular depression found in an outwash plain***. They are formed when an ice block is detached and left behind by a retreating glacier within glacial outwash or till. The ice block later melts leaving behind a shallow depression in the glacial till called a **kettle or kettle hole**. Water may collect within the hole to form a **Kettle lake**. Examples include ***Lake Mahema on Mt. Rwenzori and Lake Ellis on Mt. Kenya***.



8. **Terminal Moraine Ridge** – This is ***an irregular mound or ridge of unstratified or sorted fragments of all sizes, such as till, boulders or debris and gravel deposited at the snout or end of the glacier***. It may be about 20-50 meters high and extending for several kilometers as a belt of low hills. A terminal moraine ridge that is well developed indicates that ice remained stationery for a long time. This feature is formed by extensive deposition along the front or snout or edge of an ice sheet and the deposits build up when the glacier is stationery. A terminal moraine ridge may dam or block Rivers forming lakes called ***Moraine dammed lakes,*** e.g. ***Tyndall Tarn in the Teleki Valley on Mt. Kenya; Lac Gris in the Kamusoso Valley, Lakes Marion & Dominique on Mt. Rwenzori.*** **Examples of moraine ridges can be seen in the** ***upper Kamusoso Valley and Mubuku Valley on Mt. Rwenzori; Teleki Valley and Gorges Valley on Mt. Kenya***.





REASONS FOR THE LIMITED GLACIAL ACTIVITY IN EAST AFRICA

There are several mountains in East Africa, however not all of them are glaciated. Only three mountains are glaciated i.e. Mt. Rwenzori, Mt. Kenya and Mt. Kilimanjaro. Several reasons are advanced for the limited glaciation on the mountains in East Africa;

- Latitudinal location - East Africa is located astride the equator where temperatures are hot throughout the year. It is only in very high altitude areas where temperatures fall below 0^0C that glaciers exist. Hence the limited high latitude areas result in limited glacial activity.

- Altitude – Following the principle of the higher you go the cooler it becomes, glaciers in East Africa cover only areas as high as 4800 meters a.s.l. yet areas with such altitude are limited. Most of East Africa is a plateau lying below 2500 meters a.s.l. which altitude cannot permit permanent snow existence.

- Precipitation – In East Africa much of the precipitation is received as rainfall except for a few high altitude areas where precipitation is received as snow, i.e. tops of Mts. Rwenzori & Kenya.

- Vulcanicity – Most highlands in East Africa are volcanic and as such are warmer than expected due to the hot interior. This warmth prevents the accumulation of snow to form glaciers, e.g. Mt. Elgon.

- Global warming – At present, the earth appears to be facing rapid warming and this had resulted in melting of most glaciers including those in East Africa. It is estimated that since 1950 world temperatures have risen by over 2.5^0C. The rise in temperatures has an effect of melting away glaciers, for example on Mt. Kilimanjaro and Mt. Rwenzori thus limited glacier cover.

- Rain shadow effect – Glaciers are mainly found on the windward slope of the mountain which receive heavy precipitation. The winds that descend the leeward slope are warm and dry hence leading to little or no rainfall thus limited glacial activity on such a slope. It is noted that the western side of Mt. Rwenzori (windward side) is more glaciated than the eastern side (leeward side) which experiences warm and dry descending winds.

- Erosion by rivers and streams as they flow on the sides, top and beneath the glaciers resulting in erosion or removal of glaciers.

THE VALUE OF GLACIATION TO MAN

- Glaciers provide water for drinking and irrigating crops. For example the Chagga of Tanzania use the melt water from Mt. Kilimajaro for irrigation and the Bakonzo use melt water from Mt. Rwenzori for irrigation too.
- Glaciers can generate hydroelectric power. Glaciated valleys provide a perfect opportunity for the production of hydroelectric power. Waterfalls issuing from hanging valleys are potential areas for generating hydroelectric power.
- Glaciers act as tourist attractions. The scenery of a glaciated area is spectacular, with its wide valley floor, pyramidal peaks, cirques, crashing waterfalls and sharp arête's. Many people love to see this scenery. Glacial valleys also provide some fantastic rock climbing opportunities, photography, and other outdoor activities.
- Agriculture. Upland glaciated areas are not particularly conducive to farming, with their steep slopes, high precipitation, low temperatures and relatively thin, poor soils. However sheep farming occurs, under the method of transhumance, which meant grazing the sheep on the high mountain pastures during the warmer summer months, before bringing them down to lower valley areas in the winter. Also silviculture can be carried since the soils are thin and cannot support crop growing. Lowland deposits of glacial till are often very good areas for agriculture. Being lowland, the temperatures are more suitable for crops and the glacial till is very fertile. Such soils are often poorly drained and need additional drainage before they become really good.

- The wide u-shaped valleys form natural route ways in highland areas for transport since the steep valley sides make it difficult to run roads up and down the hills.
- Some areas of glacial sediment are used for settlements, such as the wide u-shaped valleys provide suitable sites for settlement.
- Outwash sands and gravels provide important sources of aggregate for making concrete because they are already fairly well sorted and were laid down by fresh water. Such materials are used in the construction industry.

Negative effects
- Upland glaciation has removed most of the fertile top soil making such regions unsuitable for arable farming.
- Extensive areas of land are sometimes turned into numerous lake landscapes by moraine deposits. Such landscapes provide little opportunity for development by man.
- Avalanches are a danger to man and his activities as they may lead to damage of property and loss of lives.

REVISION QUESTIONS:

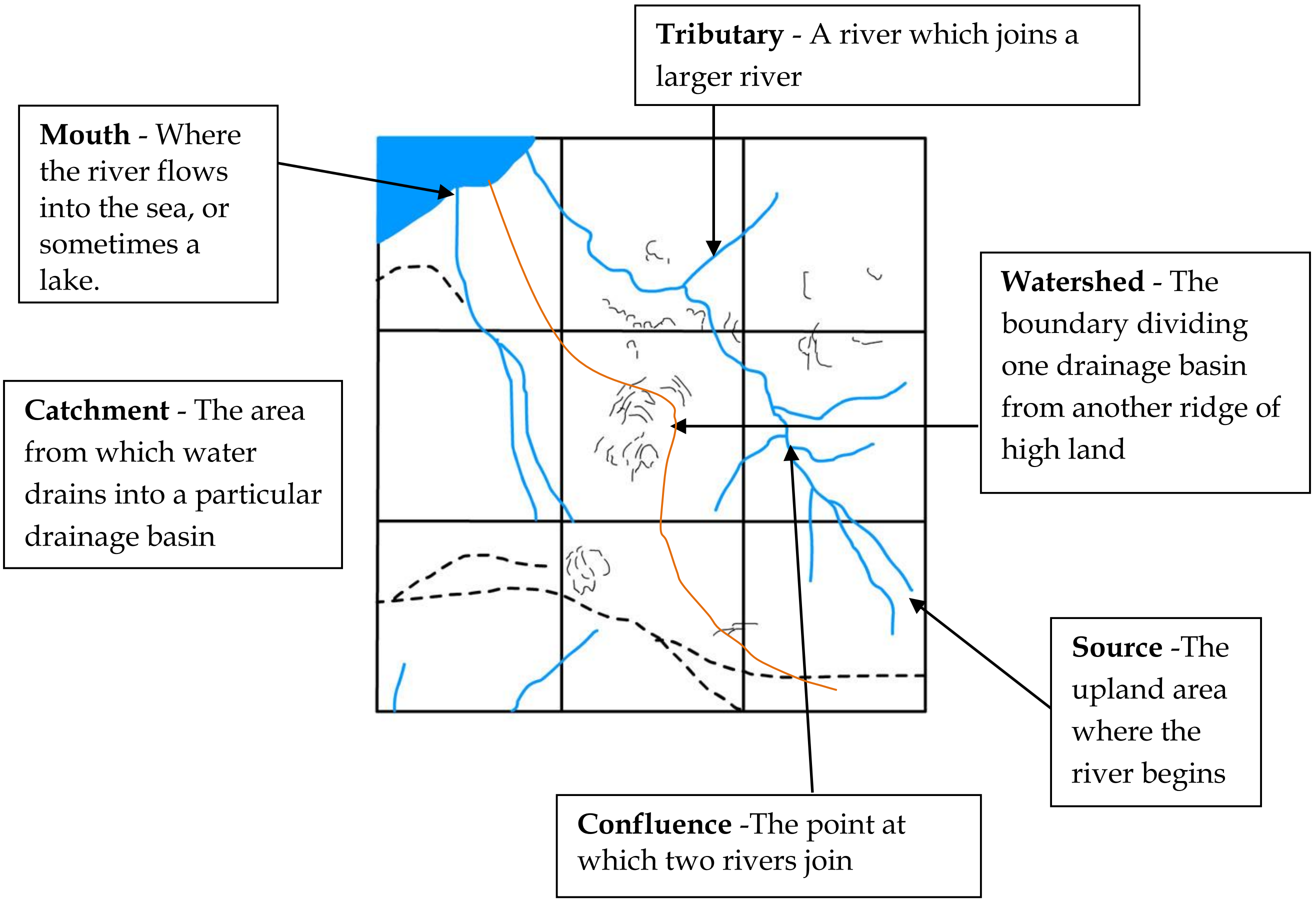
1(a) Account for the occurrence of glaciers in EA.
(b) Describe the processes which have led to the formation of any one glacial erosional feature in EA.
2. Account for the formation of the following lowland glacial landforms.
(a) till plain (b) drumlins (c) crag and tail (d) terminal moraine
3. Explain the processes responsible for the formation of the following glacial deposition features:
(a) lateral moraine, (b) drumlin, (c) till plain.
4(a) Describe how a glacier is formed.
(b) With reference to specific examples, describe the landforms associated with glacial deposition in the highland areas of EA.
5. Explain the processes responsible for the formation of the following glacial erosional features:
(a) Cirque (corrie), (b) pyramidal peak, (c) arête.

RIVERS, RIVERINE LANDSCAPES AND DRAINAGE PATTERNS

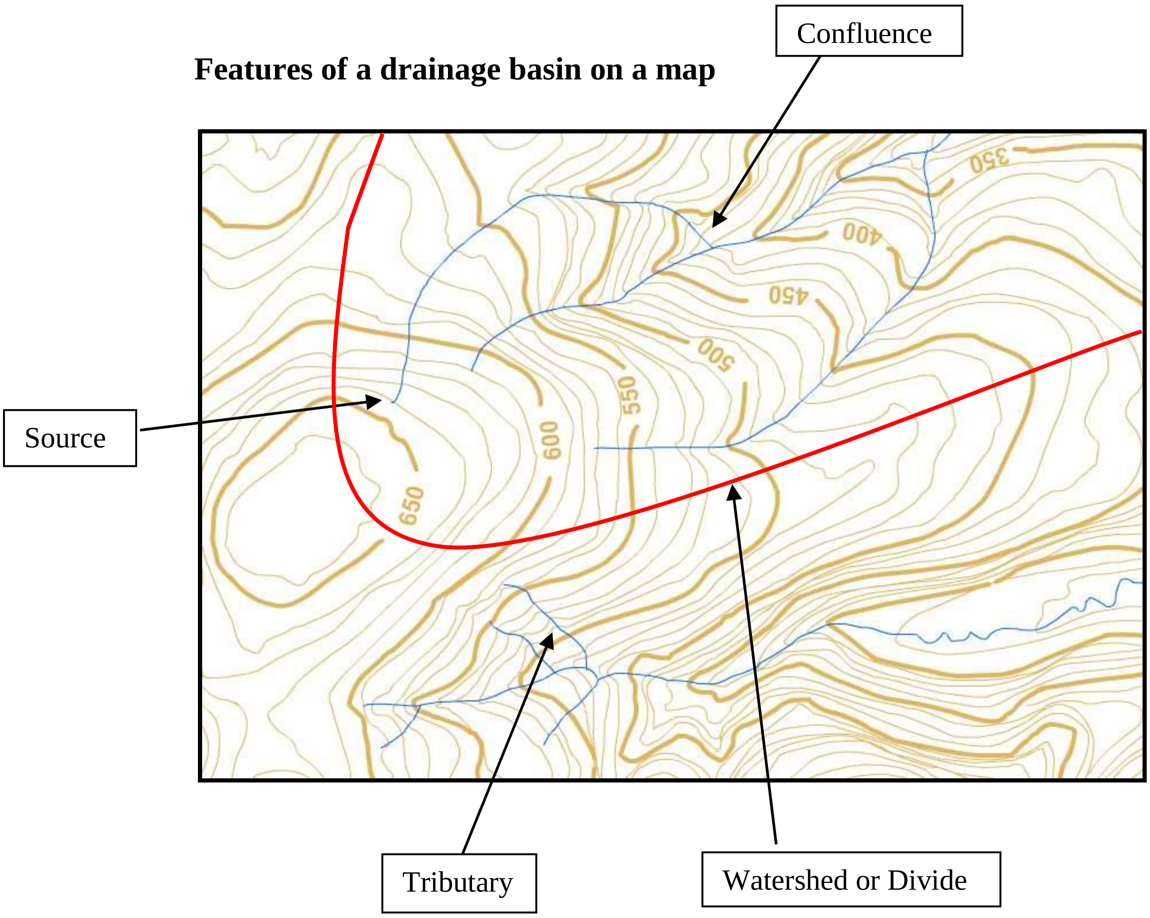
A river is a body of water in motion flowing downslope in a well-defined channel from source to mouth. A river can also be defined as ***a mass of water flowing over land through a defined channel and in a specific direction from source to mouth***. A river ***is a natural watercourse, usually freshwater, flowing towards an ocean, a lake, a sea, or another river***.

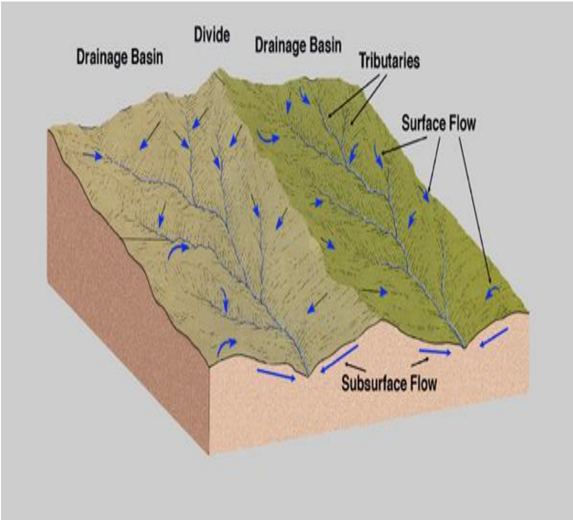
Rivers generally start at a ***source***, like a natural spring, a lake or a marsh, but it is generally in an ***upland*** region where rainfall is usually heavy throughout the year while others may originate from melting glaciers, such as river Mubuku on Mt. Rwenzori. The uplands therefore form the ***catchment areas*** of rivers. The crest of the mountains is the ***divide or watershed*** from which streams flow downslope on both sides. Most rivers flow into a larger body of water, like an ocean, sea, or large lake and this is called the ***mouth***.

The development of a true river valley is the first stage of river development. As a river flows it erodes and widens its channel, thus opening up into a true river. The path taken by a river is known as its ***course***. The river gradually swells as other streams or tributaries join it. The river and its tributaries form a ***river system***. A river system therefore is ***the total arrangement of a river together with its tributaries and sub-tributaries***. The total area covered by a river system is called the ***drainage system or catchment area***. A highland region or elevated boundary separating two drainage basins is called a ***divide*** or ***water shade***. A junction of two streams or rivers is called a ***confluence***. Where a small stream joins a larger stream is called a ***tributary***.



Features of a drainage basin on a map





Rivers are the major agents of denudation. They carve out channels as they flow, transport and deposit material they have eroded. Material carried by a river is collectively known as the ***load***.

The stream channel is the conduit or passage for water being carried by the stream. The stream can continually adjust its channel shape and path as the amount of water passing through the channel changes. The amount of water past a certain point during a given time is called ***River Discharge***. The power or ability of a river to carry its load is known as ***River Energy*** or ***Competence***. A river's energy affects its effectiveness to erode, transport and deposit. The greater the energy, the greater the ability to erode and transport. River energy mainly depends on the ***volume and speed of water***. ***The greater the volume of water, the greater is the energy***. The volume increases from source to mouth. The ***speed of water depends on the gradient of the channel***. ***The steeper the gradient, the faster the speed of water and the greater the energy***. Speed is also influenced by *friction of the water against the sides and channel bed (shape of channel), hence speed is generally greater in large deep channels where such friction is limited*. Channel development is affected by a number of factors, they include;
- The gradient of the slope
- The speed of the river
- River discharge

When the discharge increases, erosion and channel enlargement also increase.

RIVER EROSION:

This is the fundamental function through which rivers effect landform development. Through erosion rivers can widen their channel and valley (lateral erosion), and lengthen their profile (headward erosion). Rivers erode through the following processes;

(a) **Abrasion or Corrasion** – This involves ***wearing away the bed and banks of the river using the load as a grinding tool***. Stones, boulders and sand are used to scour (polish, remove, and scrub) and excavate the bed and walls of the river channel. Abrasive action is more responsible for vertical erosion and depth of *potholes*.

(b) **Hydraulic Force/Action** – The ***sheer force of fast moving water which is able to loosen and remove or wash away loose or weak materials, such as gravel, silt and sand, from the bed and banks of the river***. Some of the water splashes against the river banks and surges into joints and cracks thus weakening/disintegrating rocks. This process is most effective in well jointed rocks and leads to the formation of *plunge pools*.

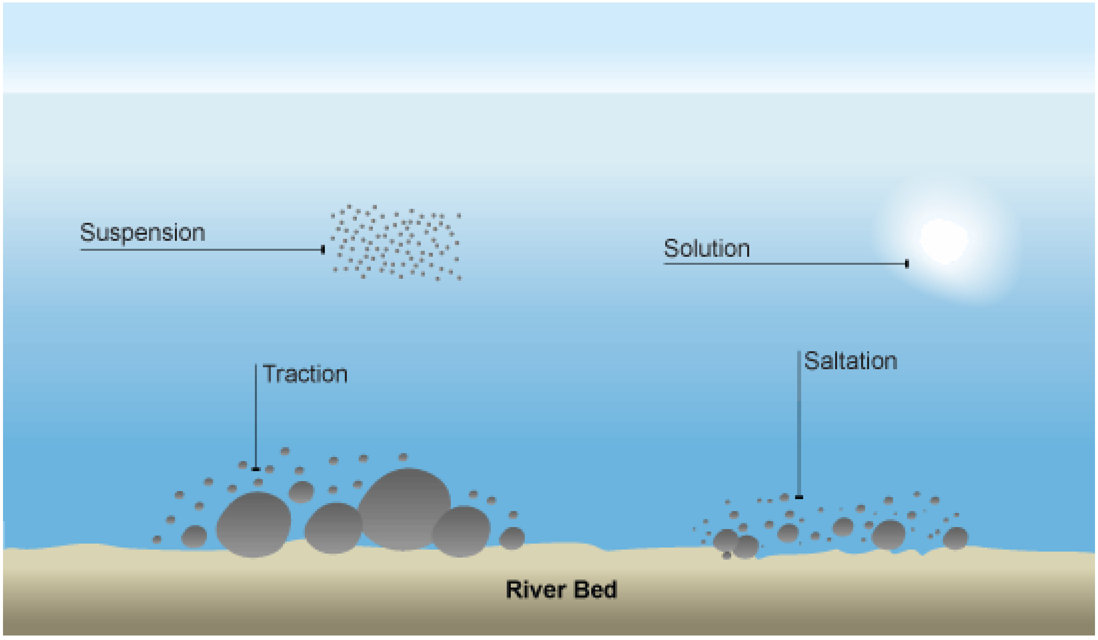
(c) **Attrition** – This is the process by which ***the loosened or eroded material or debris being carried away is broken down by colliding against each other and against the river bed and banks***. Over time, the debris becomes smaller and eventually is reduced to fine particles called silt.

(d) **Solution/Corrosion/Chemical Action or Erosion** – In this process the ***river water may dissolve the soluble minerals in rocks and carry them down the river***. For instance water flowing over rock salt and calcareous rocks such as limestone removes materials in solution. This process depends on the chemical or mineralogical composition of the rocks.

Rivers carve channels by lateral, vertical and headward erosion.
Lateral erosion – This involves the ***wearing away of the channel sides or banks of the river which widens the V-shaped valley***. It's most effective at the curved bends or outside banks of meanders of the river. (Sideways erosion)
Vertical erosion – This involves the ***deepening of the channel or river base by gradual down cutting especially by abrasion***. (Downward erosion)
Headward erosion – In this process the ***river increases its length***. This occurs at the source of the stream when a river cuts back at its source and so increases its length. Headward erosion occurs most at steep parts of the channel, such as waterfalls, and when rejuvenation occurs.

RIVER TRANSPORT:

Rivers also carry out transportation of already eroded material or ***load***. This load includes weathered debris from the valley sides and rock debris from the channel bed and sides. The size of the load varies according to volume and speed of the water. A river carries its load downstream until it's deposited in areas where the river energy is too low to carry or lift the load. A river's ability to carry its load is called the ***river's competence***. When a river is able to transport large materials like boulders, it means that the river is competent while in situations where a river only transports light material like silt, its competence is low. Energy levels are usually higher near a river's source, when its course is steep and its valley narrow. Energy levels are lowest when velocity drops as a river enters a lake or sea (at the mouth).There are four basic ways in which a river transports its load.
(a) **Traction** - This involves ***rolling or dragging of large rocks such as boulders, rocks & stones along the river bed***.
(b) **Saltation** – In this process ***small particles like small pebbles and stones are bounced along the river bed***. They are thus transported in a series of hops and jumps along the river bed (leap frogging motion).
(c) **Suspension** – This is the ***movement of very fine materials like silt, mud sand, and clay floating or suspended/held up in water as the stream flows***.
(d) **Solution** – This is the ***movement of materials dissolved in water such as limestone, salt and calcium***.



RIVER DEPOSITION:

When the river's competence reduces, the load is dropped on the bed. This dropping of load is called ***deposition***. Deposition takes place when stream energy is insufficient to carry all load. This mainly results from a reduction in speed or velocity of the river and this also may be due to reduced gradient, channel, shape and size among other factors. Materials deposited by a river a generally known as ***alluvium***. The heavier material like large boulders and pebbles, is deposited first and later the finer debris like silt, deposited last. Deposition is greatest in the lower course of the river especially during floods. Deposition may occur when;

- There is not enough water to transport the load during a dry season
- A river flows across a desert where there is a high rate of evaporation.
- A river flows across permeable rocks which allow water to infiltrate into the underlying rocks such as sand and limestone
- A river carries a larger load than it can transport.
- There is a sudden decrease in gradient e.g. river leaves the mountain and flows onto a plain
- A river flows into a lake or sea.
- One side of the river is shallower than the other (e.g. the convex bank of a meander)
- There are aquatic plants or rocks obstructing river flow.

THE DEVELOPMENT OF A RIVER VALLEY

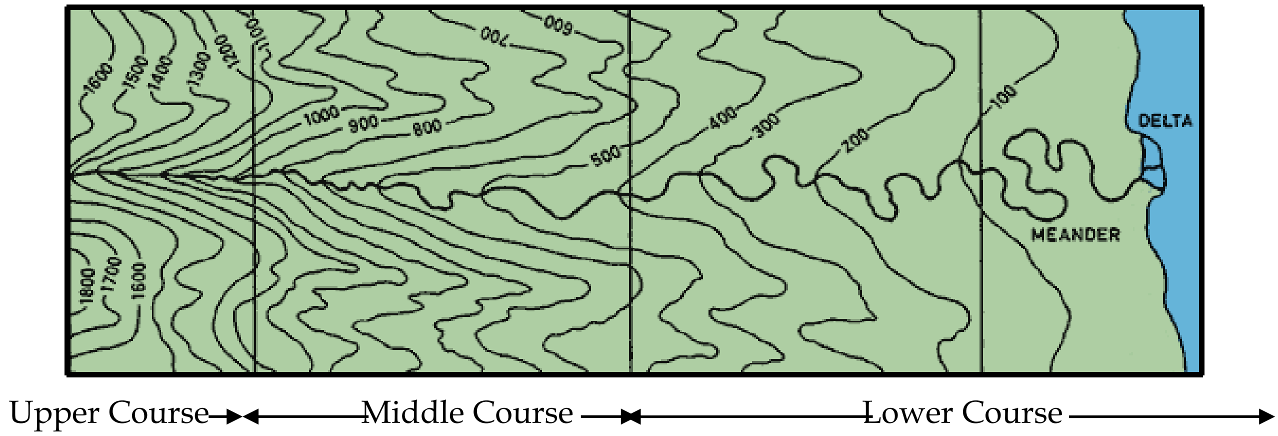
As a river gradually develops its long profile, so the cross profile and the general features of its valley also develop. A fully developed river valley is divided into three distinctive stages; the youthful/upper/torrent stage, mature/middle/valley stage and old/lower/senile stage.

N.B:

(a) The long profile of a river is a section showing the slope of the river from source to mouth. The gradient is steeper in the upper stage, moderate in the middle and low in the last stage.

(b) The cross profile of a river is a section showing the vertical shape of a river from bank to bank. In the upper stage the valley is V-shaped, in the middle stage the valley is an open U-shape while in the lower stage the valley is widely open.

ILLUSTRATION OF A LONG PROFILE OF A RIVER



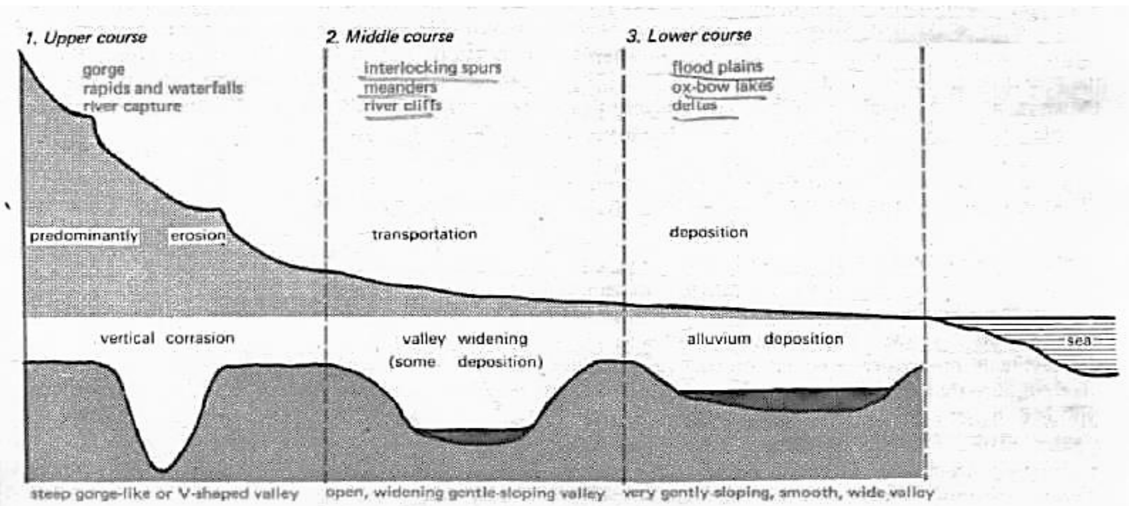
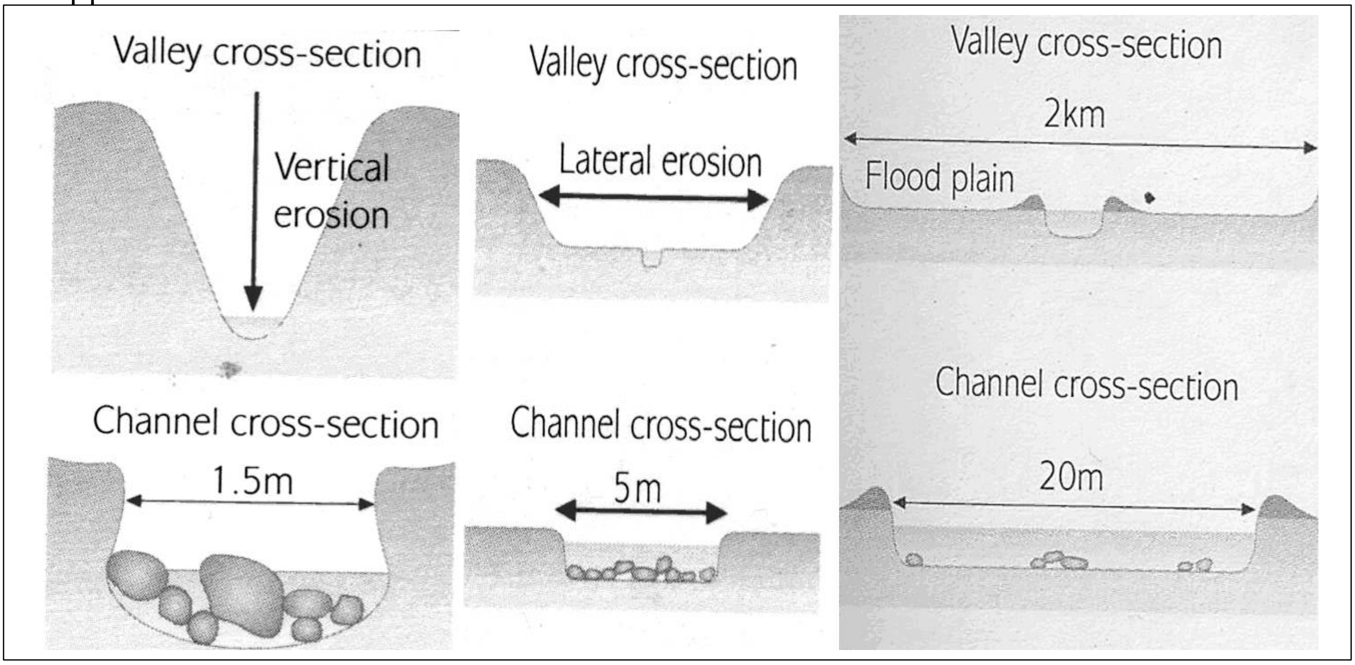


Fig.36 The graded long profile and typical cross section of a river from source to mouth

Upper Course Middle Course Lower Course



	Youthful Stage – Upper course	Mature Stage – Middle Course	Old Stage –Lower Course
Characteristics	• Vertical and headward erosion dominant • Rough channel bed • High competence, low capacity • Steep gradient / slope • High turbulence • Narrow channel • Straight course • Transportation is largely by traction & saltation	• Vertical and Lateral erosion dominant • Wider and deeper channel • Competence decreases, capacity increases • Gradient is gentler • Transportation by saltation, suspension & solution	• Deposition dominant • High discharge & velocity • High capacity, low competence • Meandering course • Wide flood plain • Channel depth & width at maximum • Low gradient/slope • Transportation by suspension & solution
Features	v-shaped valley, waterfalls, rapids, potholes, gorges, Interlocking spurs	Meanders, river cliffs, slip off slopes, flood plains, bluffs	Levees, deltas, point bars, sand bars, oxbow lakes, meanders, larger flood plain, raised banks

YOUTHFUL STAGE

This is the first stage of the river as it moves downstream from the source. The river channel is rough and shallow because there are large stones, rocks and boulders in the river channel. The river flows very fast due to the steep gradient, thus **erosion is dominant** due to high energy. This stage is also known as the ***Upper or Torrential stage***. The river is characterized by the following;

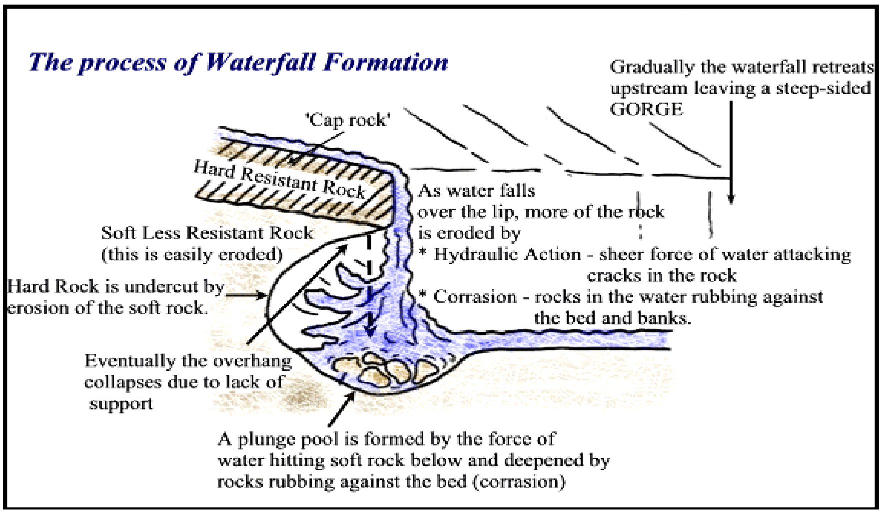
- The valley has a steep gradient
- The river is flowing fast due to the steep gradient
- The valley has a deep steep sided V-shaped cross profile
- Vertical erosion is dominant through attrition, abrasion and hydraulic action
- It has a small channel and many short tributaries
- The river winds between interlocking spurs

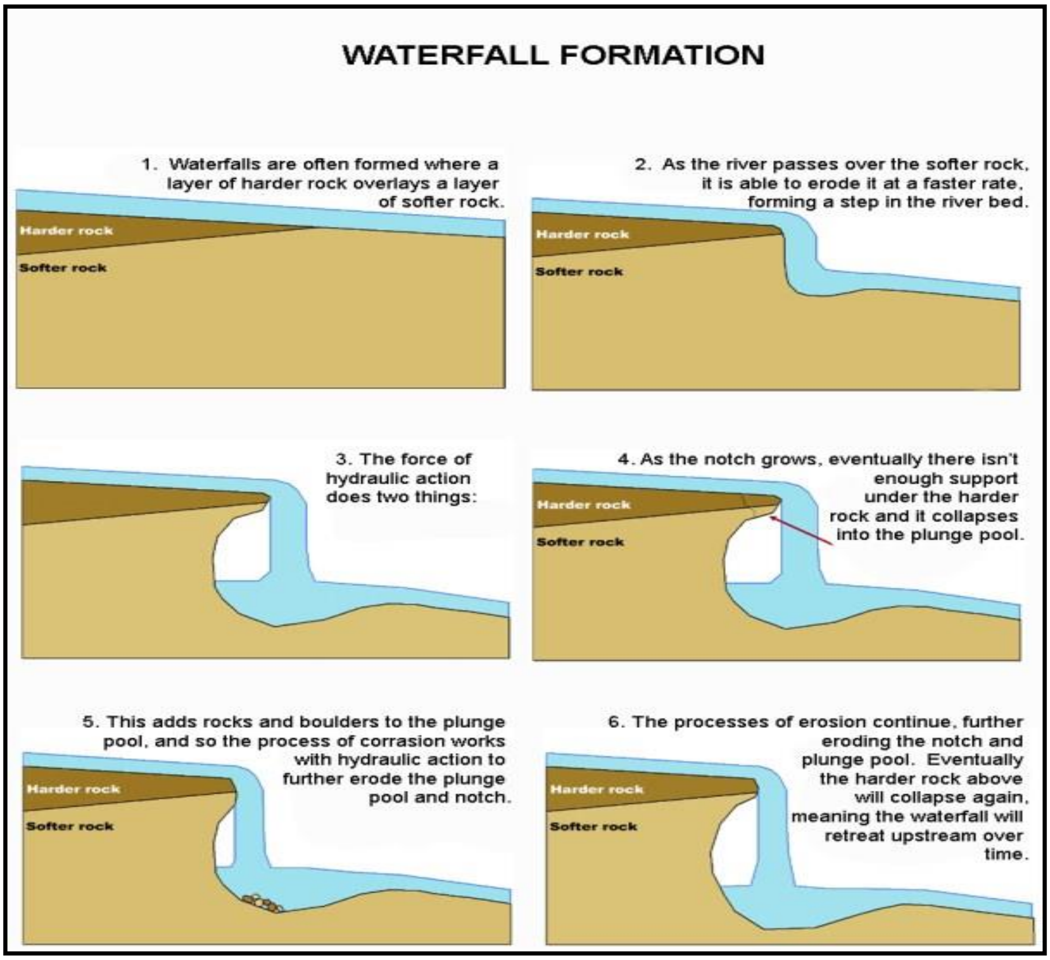
- Transportation is largely by traction and saltation
- There are many waterfalls and rapids

During this stage the river forms several erosional landforms such as waterfalls and rapids, plunge pool, pot holes, v-shaped valley, gorge and interlocking spurs.

1. **Waterfalls** – This is a ***sharp break in the bed of a river channel over which the river flows***. Waterfalls are commonly formed when a river is young, that is, in the upper section of a river. At these times the channel is often narrow and deep. Examples include ***Sipi falls in Kapchorwa, Kisizi falls in Rukungiri, Sezibwa falls, Sisiyi falls in Mbale***, among others. Waterfalls are formed in several ways as discussed below;

(a) When an outcrop of hard rock overlying soft rock in the river bed. This is the most common cause especially where the resistant rock outcrop is horizontal or dips upstream. The softer underlying rocks are more easily eroded causing a steeper gradient and eventually a waterfall as water starts to fall over the hard rock. (*As soon as a groove appears in the rock below the resistant rock, pebbles will gather, being trapped and swirled around. This abrades the lower rock, eventually forming a deep groove*). Examples include *Sezibwa falls in Buikwe and Tana falls on R. Tana in Kenya*.

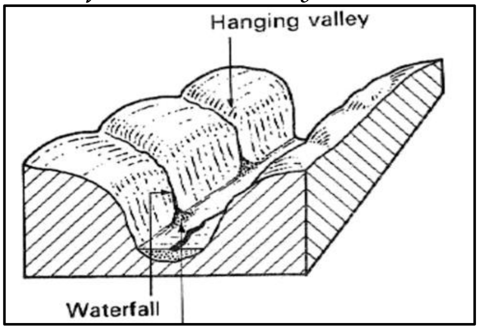




(b) Waterfalls may also be formed when there is uplift of land. Faulting for instance leads to the vertical displacement of rocks along fault lines creating a waterfall where the river drops over the edge of the fault scarp, for example ***Turkwell falls in Kenya, Pangani falls on R. Pangani in Tanzania, Victoria falls on R. Zambezi in Zambia and Kalambo falls in Zambia***.

(c) Waterfalls are also formed when a river flows over a plateau edge, especially when flowing from a high level to low plain, for example the ***Livingstone falls on R. Congo in the DRC, Augrabies falls on R. Orange in South Africa and Boti falls in Ghana***.

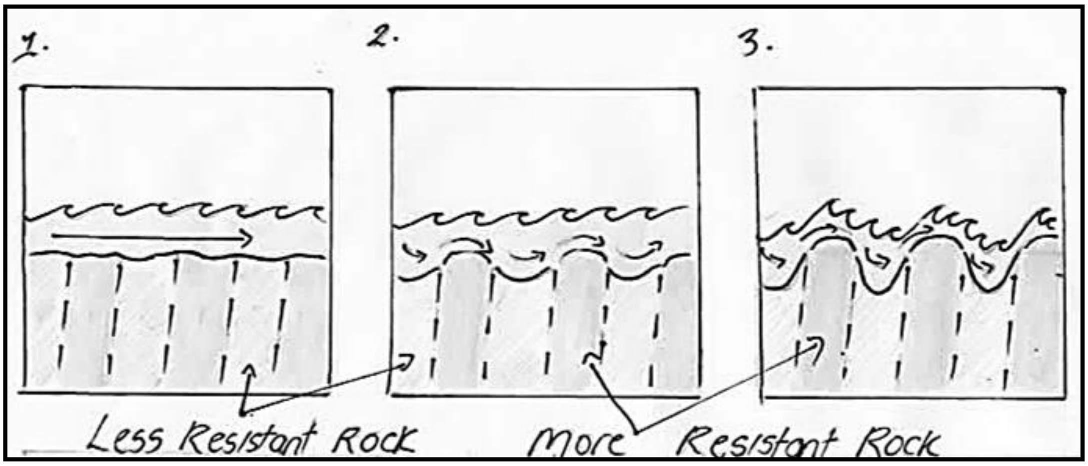
(d) Waterfalls may also form where a river descends down the main U-shaped valley from a hanging valley, for example ***Vivienne falls on Mt. Kenya***.



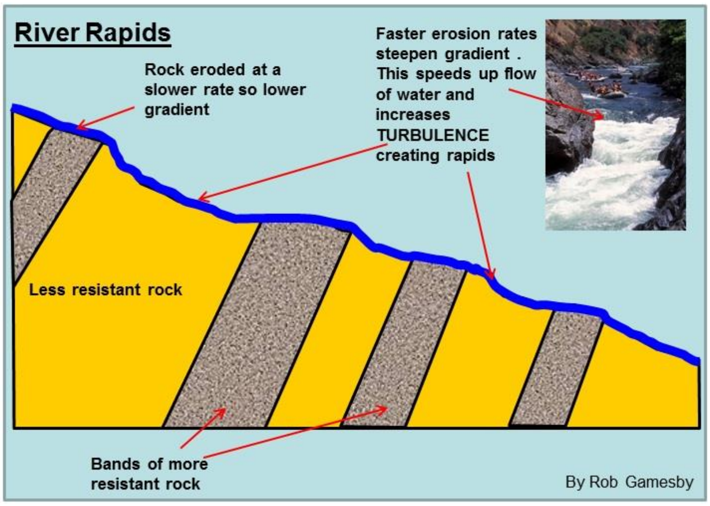
(e) Waterfalls may also form where rejuvenation of a river has formed a sharp knick point resulting into waterfalls, for example ***Charlotte falls in Sierra Leone***.

(f) Waterfalls may also form where the river enters the sea at a cliff. A fall may develop near the mouth of a river if wave erosion cuts back the cliff face or where sea level has fallen, for example ***Lobe falls in Cameroon***.

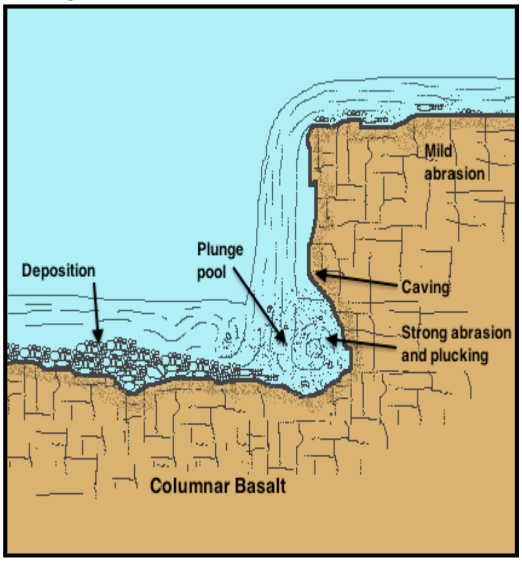
2. **Rapids** – This is a ***section of rough, fast-flowing water in the river channel where the bed is steep and rocky***. In contrast to waterfalls there is no defined break of the slope but rapids may extend for several kilometers along the river valley. Thus rapids are the point of the river where the water runs very fast but there is no sudden break of the slope in the river valley. Rapids are formed as a river flows over a series of alternating soft and hard rock in the river bed. As the water flows the soft rock is eroded at a faster rate than the hard rock. This causes the hard rock to jut or stand out above the soft rock making peaks and troughs. These peaks and troughs in the river bed cause the water to become turbulent as it flows over them, creating rapids. Examples of rapids include ***Nile Cataracts, Egypt and Sudan, Felou rapids on R. Senegal, Mali, Popoli rapids on River Sassandra, Ivory Coast, on the lower Congo River, DRC***.

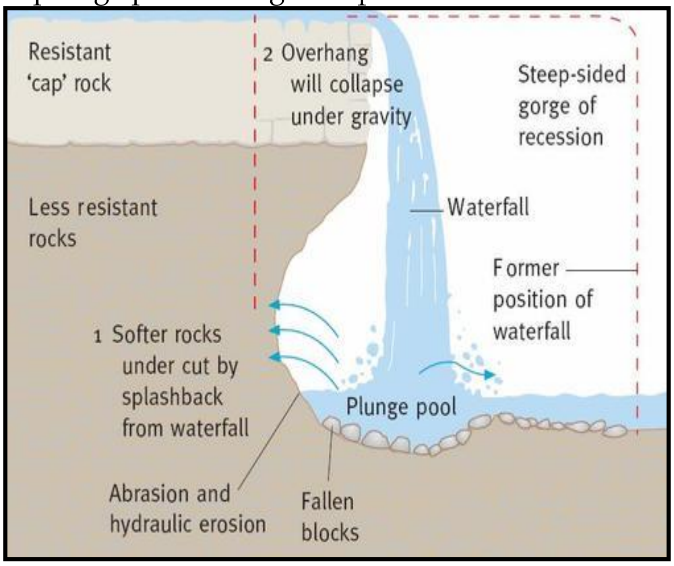


Rapids on the Nile River, Uganda

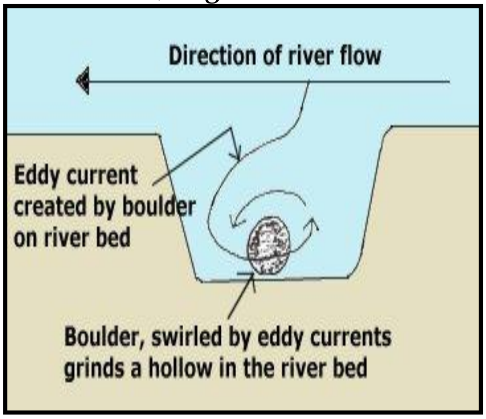


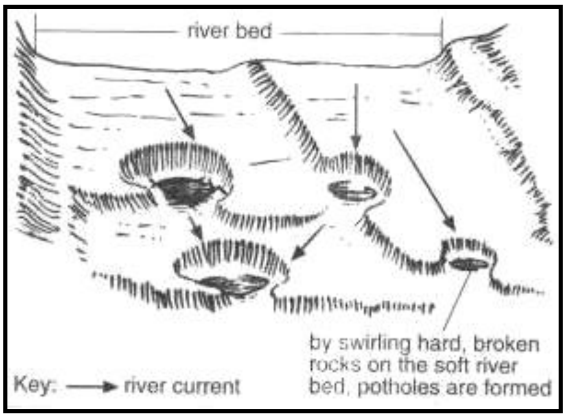
3. **Plunge Pool** – This is ***a broad shallow depression/hollow at the base of a waterfall***. As water rolls from the waterfall to the bottom, it lands with great force and in the process will pluck off loose rock material at the base of the waterfall through hydraulic action creating an extensive depression called a plunge pool. In addition pebbles trapped in the depression are used as a grinding tool to further widen and deepen the plunge pool through the process of abrasion.





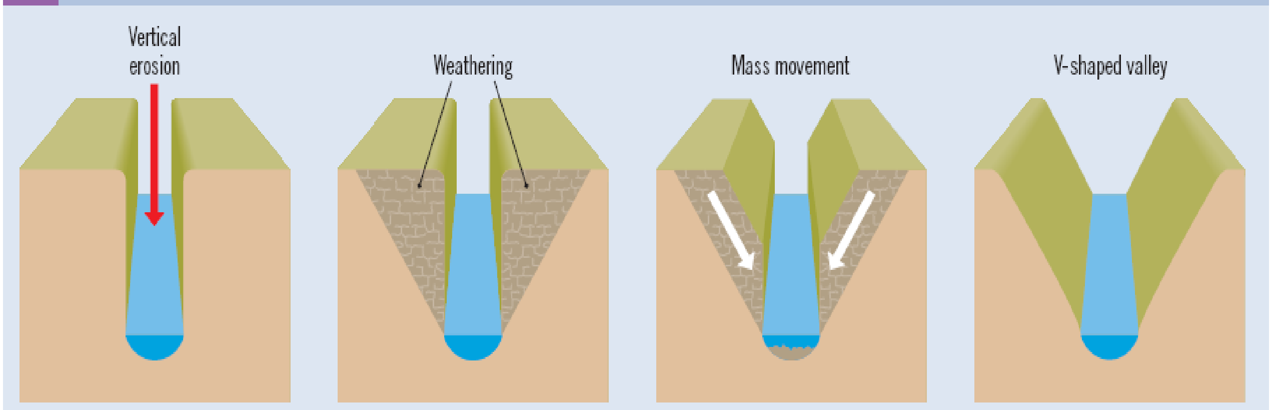
4. **Potholes** – This is a ***broad circular hole cut into the bedrock of the river bed of a fast flowing river.*** They are formed and enlarged by the abrading action of sand and pebbles carried by eddies, or circular water currents in an uneven bed of a fast flowing river. Eddy currents swirl or spin the stones around in the naturally occurring small depressions in the river bed, carving, widening and deepening holes in the rock through the prolonged process of **abrasion**. These holes known as potholes gradually get bigger or wider and deeper. Examples are found on ***river Manafwa on the slopes of Mt. Elgon, river Mobuku on the slopes of Mt. Rwenzori, river Ikiwe, south Machakos, Kenya; river Kaduna, Nigeria***.

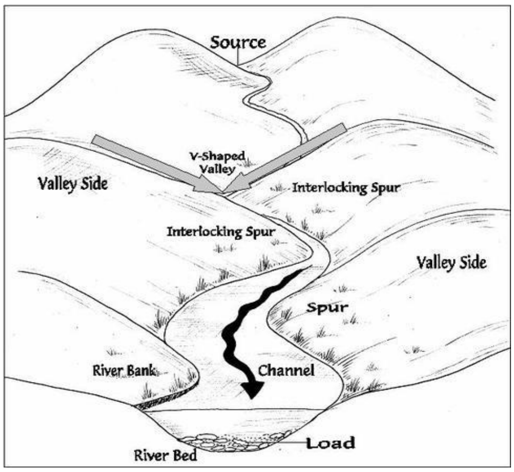


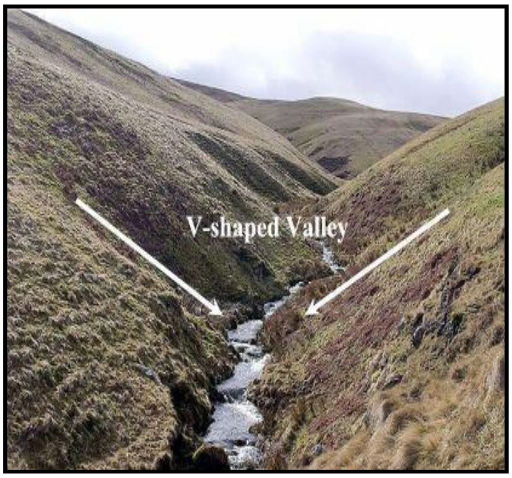


5. **V-Shaped Valley** - A V-shaped valley, sometimes called a river valley, is a narrow valley with steeply sloped sides that appear similar to the letter "V" from a cross-section. They are formed by strong streams, which over time have cut down into the river bed through pronounced down-cutting or vertical erosion while the valley sides are cut back by weathering and mass wasting. These valleys form in mountainous and/or highland areas with streams in their "youthful" stage. At this stage, streams flow rapidly down steep slopes. Vertical erosion in the form of abrasion, hydraulic action and solution in the river channel results in the formation of a steep sided valley. Over time the sides of this valley are weakened by weathering and mass movement of materials occurs gradually creating the distinctive V-shape. Such features are common in the upper courses of rivers such as ***Semliki, Mubuku, and Nyamugasani on Mt. Rwenzori***.

2.13 Formation of a v-shaped valley

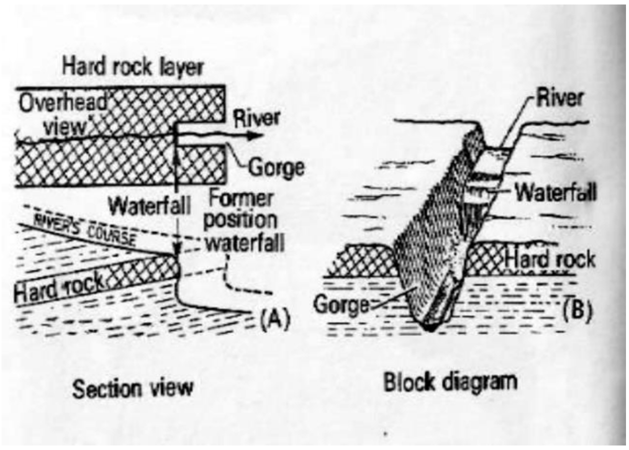


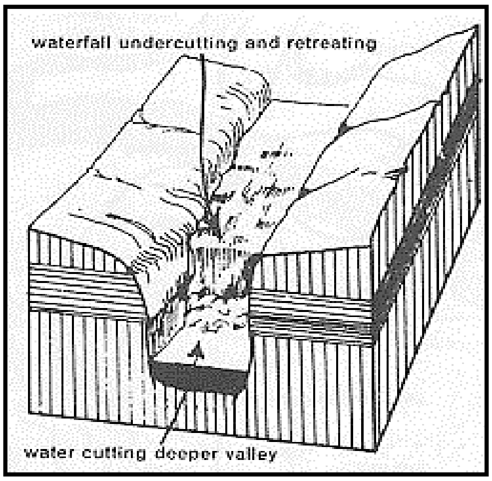


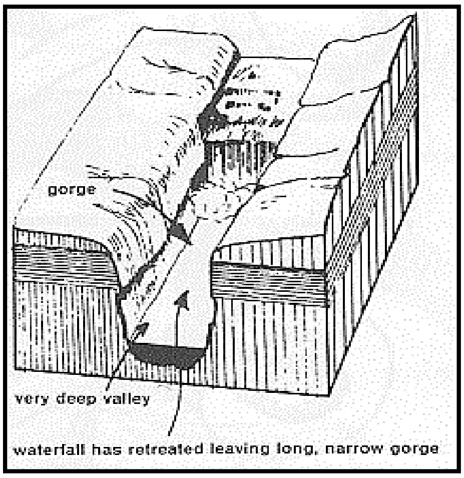


6. **Gorge or Canyon** – This is a ***deep, narrow and steep-sided river valley carved into the landscape by a river***. They are most common in the upper stage of a river, but under special conditions they may form along any stage of a river course. Gorges are formed where a waterfall is retreating upstream leaving a **steep sided valley** known as a gorge, e.g. ***Batoka Gorge, below Victoria Falls***. It is also formed when a river flows across a plateau with horizontal alternate layers of hard and soft rocks. Thus there will be intense vertical erosion while there is little weathering of the valley

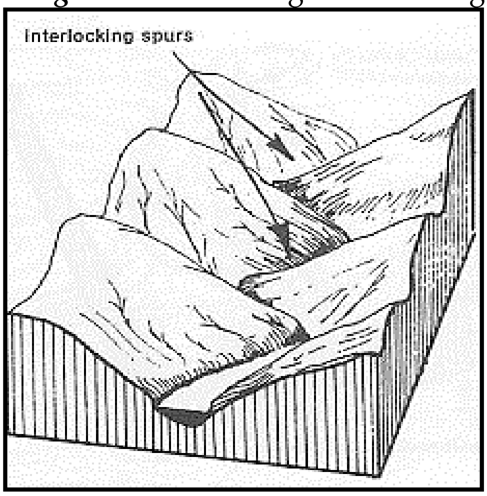
side or lateral erosion creating a gorge, i.e. valley deepening is faster than widening. Also where a river flows across a region of limestone rocks such that vertical erosion may be very great compared to weathering of valley sides, e.g. ***Fish river Canyon, Namibia***. A gorge may also develop when a river flows along a line of weakness such a fault, such as ***river Kaduna in Nigeria***. Also where a river cuts into (incises) into the land surface due to a fall in base level, e.g. ***Lupata Gorge, Mozambique*****. Other examples of gorges include the** ***Great Ruaha, Tanzania, Sabaloka Gorge, Sudan and Komati Gorge in South Africa***.

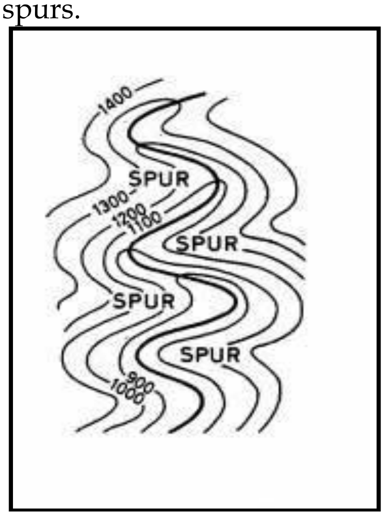






7. **Interlocking Spurs** – These are ***areas of the valley (hills) that stick out into the river forcing it to meander or wind around them***. As the river erodes the landscape in the upper course, it winds and bends to avoid areas of hard rock. This causes projections or promontories or the forelands of highlands called spurs to interlock like the teeth of a zip, thus forming interlocking spurs. ***Rivers Semliki and Nyamugasani*** flow through interlocking spurs.





Contour representation of spurs

Interlocking Spurs

MATURE STAGE

This stage is characterized by the following;

- The valley has an open V-shape cross profile. This is because **lateral erosion** is more dominant than **vertical erosion** hence the open appearance.
- The gradient is gentler
- Volume of water increases as more tributaries join the main river and this in turn means that the rivers' load increases.
- The work of the river is predominantly transportation with some deposition.
- The speed of the river reduces, i.e. its moderate due to the reduced gradient.
- Interlocking spurs are removed by lateral erosion to form bluffs.
- Menders and river bends begin to develop
- The valley floor begins to widen
- The load consists of mainly rounded and small stones.

The mature stage experiences erosion, transportation and deposition roughly in equal proportions. This leads to the formation of both erosional and depositional features. Erosional features include cliffs or bluffs that are pronounced at the beginning of the mature stage. Depositional features include meanders, slip-off slopes and the beginning of a flood plain, are pronounced at the end of this stage.

OLD STAGE

The characteristics of this stage include;

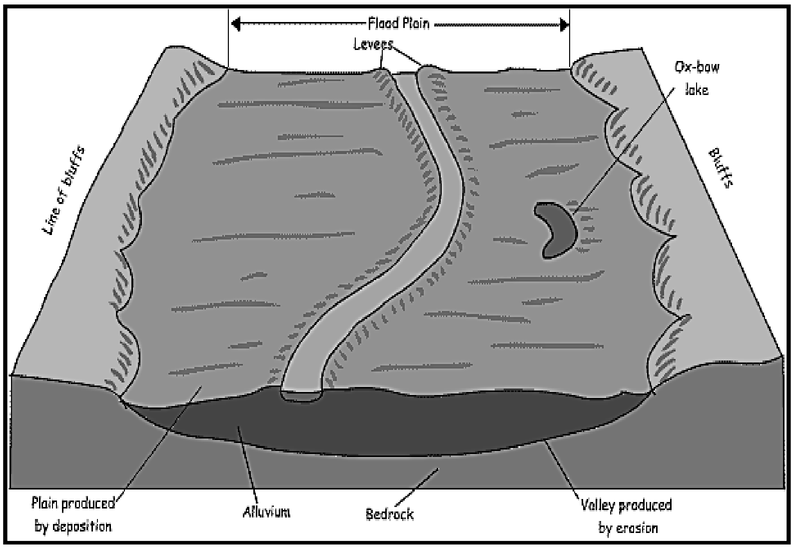
- The valley has a wide flat plain cross profile
- Gradient is very gentle, almost at sea level
- The speed of the river is very slow due to reduced gradient
- Deposition is dominant due to the reduced speed
- The valley floor is covered with a layer of sediments
- The load is mainly silt and other fine materials
- Meanders, bluffs, slip-off slopes and cut-offs are very pronounced.

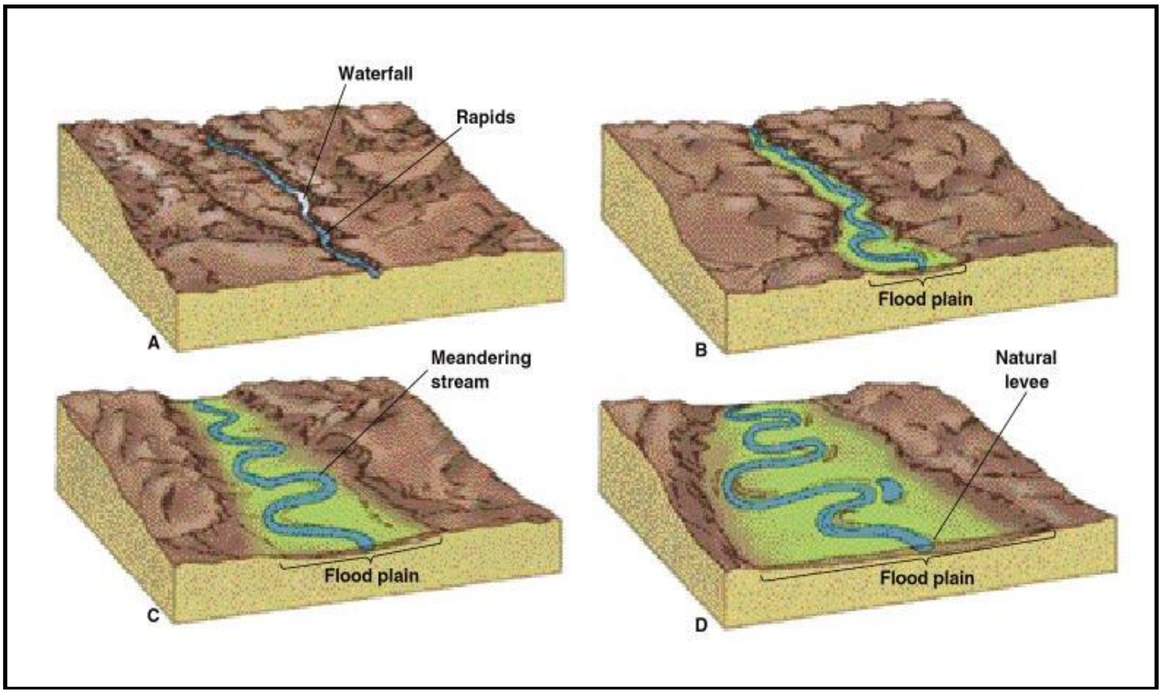
In the old stage the river moves downstream across a broad, level plain heavy with debris brought down from the upper course. Lateral erosion of the river banks is dominant while vertical erosion has almost ceased. The work of the river is mainly deposition. River deposition occurs when river energy is insufficient to carry all load. This may be due to;

- Lowering of the gradient which reduces the speed/velocity of water. This means that the river energy (competence or capacity) is reduced thus the river is no longer competent to carry the entire load.
- Reduction in the volume of water because of channel widening or where a narrow valley opens into a broad valley.
- The volume of water may reduce when the river flows through an arid area due to prolonged dry season and evaporation resulting in reduction in water volume hence deposition.
- A river may deposit when the load is too much for the river to transport (overloaded).
- When the river flows into a stationary water body such as a lake or sea and the load is laid down forming a delta.
- Presence of obstacles along the river channel such as vegetation or rock outcrops.

Material deposited by a river is generally known as **alluvium**. Landforms that develop due to deposition by rivers include;

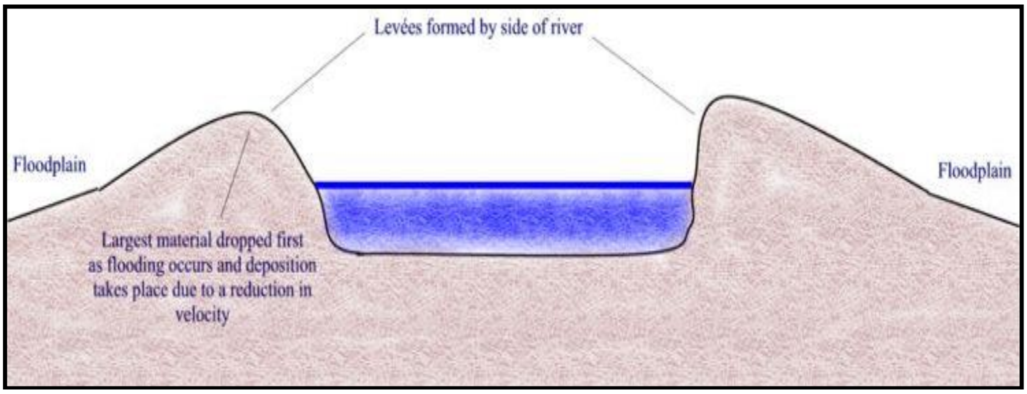
1. **Flood plain/Alluvial plain** – This is ***a wide gently sloping flat plain of alluvium deposited on the floor of the river valley or adjacent to the river channel***. Flood plains are made by a meander eroding sideways through lateral erosion as it travels downstream thus widening the valley floor. During annual floods a river leaves behind layers of sediment spread over the low-lying adjacent areas. These gradually build up to create the flood plain. Most flood plains are marshy with several swamps and small lakes. Examples can be seen along ***rivers Rwizi in Mbarara; Ngaila, Nyando and Tana in Kenya and Rufigi in Tanzania***.

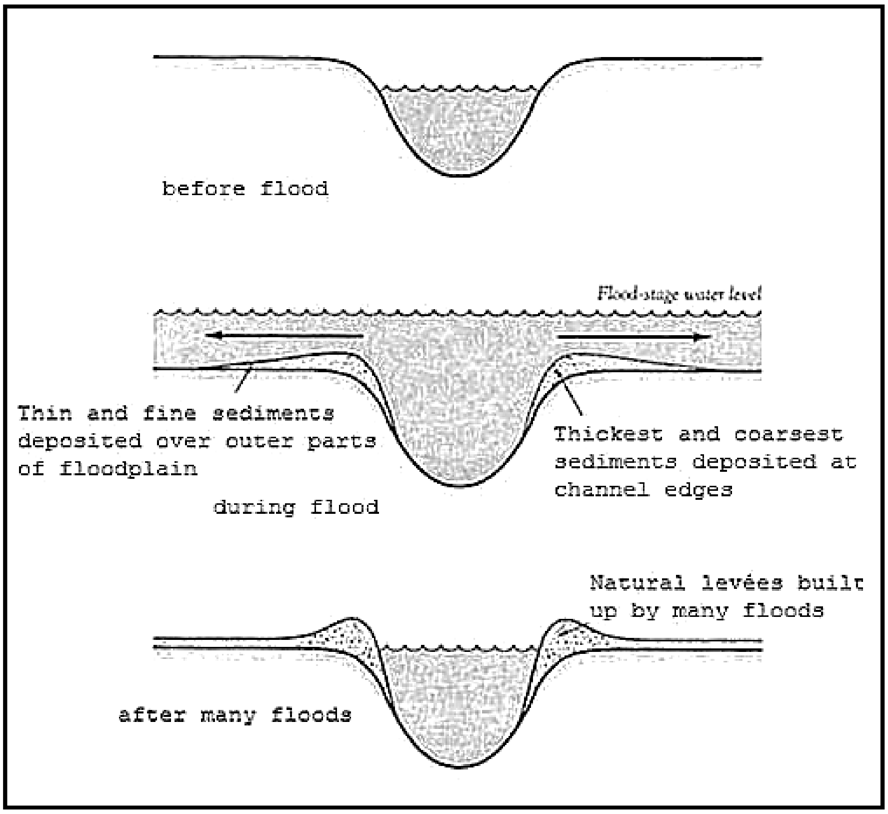




Formation of a Flood Plain

2. **Levees**, **embankment**, **floodbank** or **stopbank** – These are ***natural embankments built by rivers alongside the channel***. They rise above the level of the adjacent plain towards which they gradually slope. Levees are formed through successive flooding and deposition of sediments or alluvium along the river channel. Deposition is greatest near the river channel because as the water floods out of the main channel its speed is immediately checked by friction with the banks and the heavier sediments are deposited first forming embankments. Over time (and after many flood events) these embankments build up and become more stable forming raised banks called ***levees***. Examples can be seen on the ***lower Omo river as it enters Kenya, rivers Malaba, Nyando, Ngaila and Tana in Kenya; river Nile***.

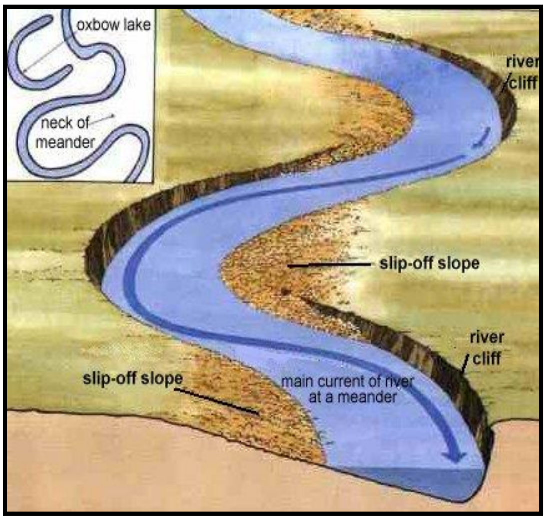


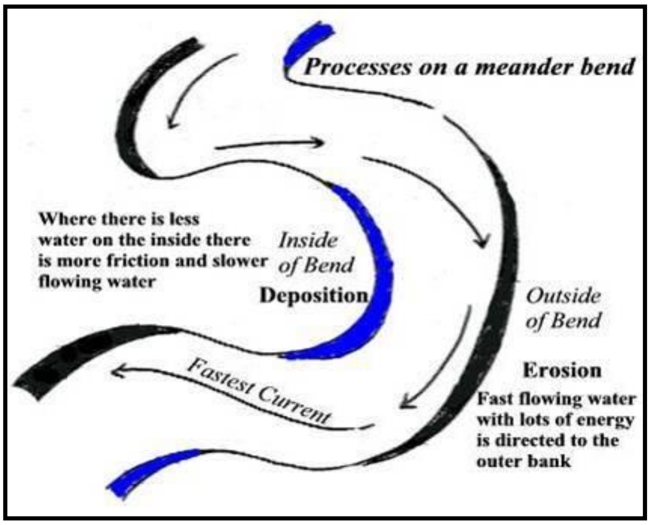


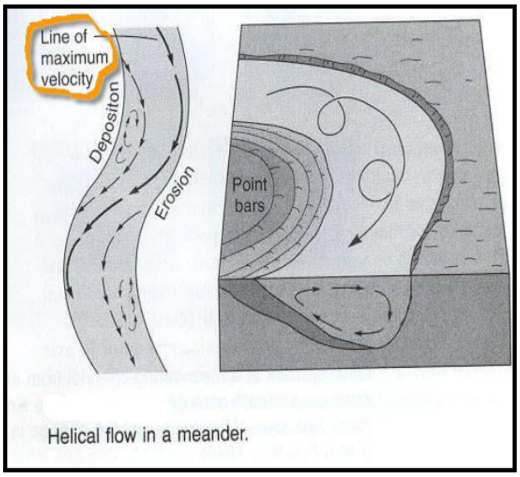
3. **Meander** - This is a ***curve or bends in the course of a river or a curved bend of a river channel***. Meanders are formed in both the mature and old stages of a river. The origin of meanders is not fully understood, however it's believed they are formed due to alternating undercutting (lateral erosion) and deposition between the outer and inner banks or bends. As water moves downstream and around a bend, it moves in a ***spiral fashion/helical/helicoidal flow or cork-screw action***. It moves towards the outer bank of the curve at a great speed, eroding the bank. The eroded materials is then carried towards the opposite bank or inner bend and is deposited there because of the great friction between water and the river bank and bed, thus reducing the speed. The water then moves downstream towards the next bank in a spiral manner and the process is repeated. Over time at the outer bank, a ***river cliff or cut bank*** is formed and the bank becomes concave with a steep slope shape. At the opposite bank or inner bend, a gentle ***slip-off slope or river beach or point bar*** is formed and the bank becomes convex in shape.

Meanders may also form where a river is avoiding obstacles of hard/resistant rocks and boulders along a river channel thus it follows regions of soft rocks resulting into meanders. They are also formed by the development of alternate deep and shallow sections that form on the bed of a straight channel and cause the stream to swing from side to side as it is deflected by the shallow sections

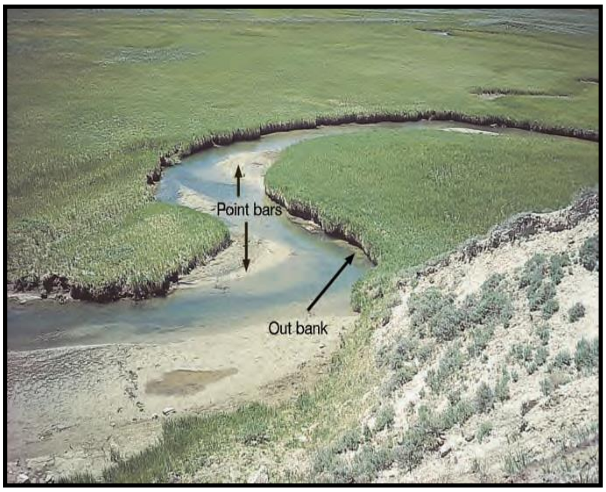
Examples include ***river Rwizi in Mbarara, river Mpanga in Fort Portal, rivers Ngaila, Mara and Tana in Kenya***.



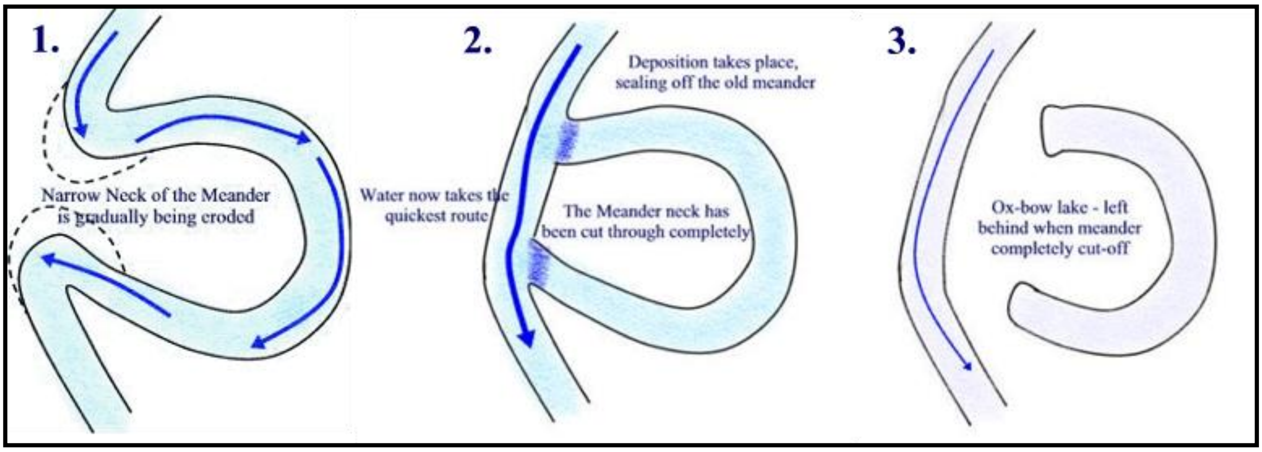




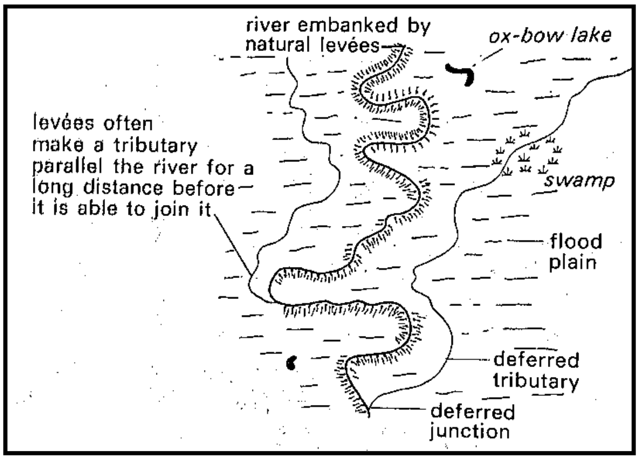
Helical flow in a meander.



4. **Ox-bow Lake, Horseshoe Lake, Loop Lake, or Cutoff Lake** – This is a ***U-shaped or horse-shoe shaped body of water, now separated from the main stream to create a lake***. Such lakes are formed along parts of the flood plain where meanders are so sharp that only a narrow neck of land remains between two meander loops. Eventually when it floods the river cuts through the neck of the meander forming a new straighter channel. Deposition gradually seals off the old meander forming an oxbow lake. Over time ox-bow lakes may lose their water as vegetation and sediment fill them in forming a **meander scar**. Examples are along ***rivers Nzoia, Tana, Semliki and Rufigi; Wilge river, South Africa; rivers Sebou & Beht, Morocco***.

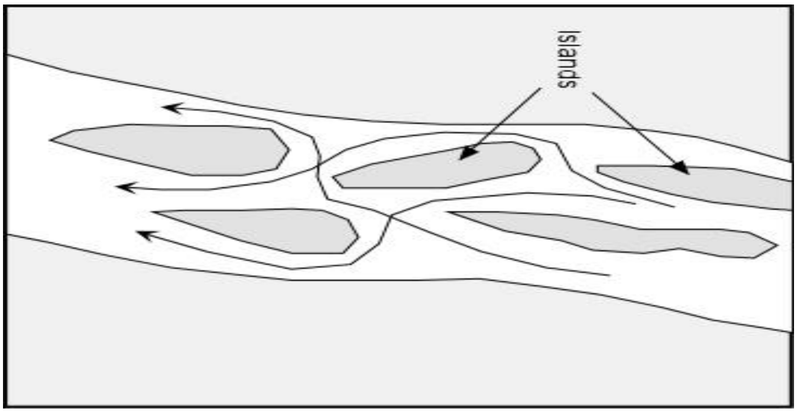


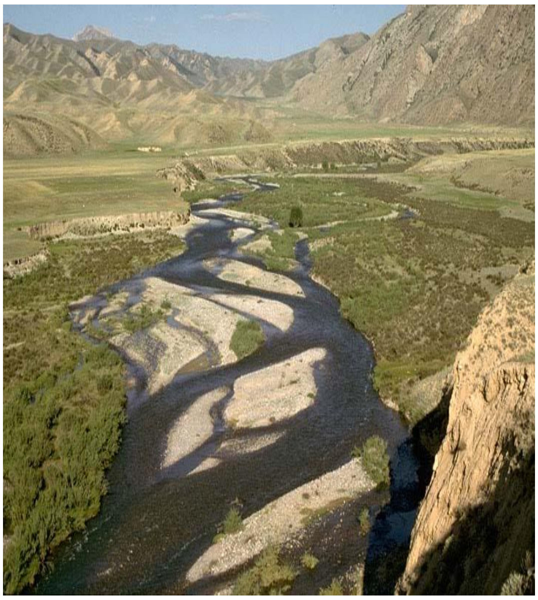
5. **Deferred Tributary/Junction/Confluence or Yazoo Stream** – This is a ***stream or tributary that is forced to flow alongside or parallel to the main river before being able to rejoin the main river***. This is caused by floods which build up a levee across the original confluence or junction of two rivers forcing the tributary stream to flow alongside the main stream before being able to rejoin it finally. The new confluence or junction is found further downstream the old junction. The new confluence is called a ***deferred junction or confluence*** while the tributary whose confluence is interfered with in this way is called a ***deferred tributary***. Examples include ***rivers Sebou & Beht, Morocco***.



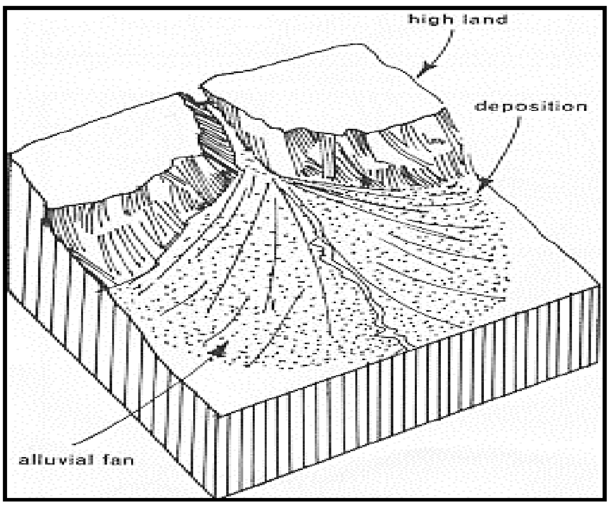
6. **Braided Channel / Stream** – This is ***an extremely wide, shallow river channel that consists of a network of interconnecting minor channels separated by small and often temporary islands of sand and alluvium called <u>braid bars or eyots</u>.*** The sand bars and minor channels are generally unstable and during floods may all be submerged. Braids develop with the deposition of large amounts of coarse sand and gravel on the river bed that gradually build up forming small islands and splitting the river into a series of smaller channels. Braiding mainly occurs in streams with a heavy load flowing between banks of easily eroded material and in arid and semi-arid regions with little vegetation and high erosion rates. Braiding is common along ***river Congo, DRC; river***

Kilombero, Tanzania; River Nile between between Malakal & Khartoum, Sudan; Mangoky River, Madagascar.





7. **Alluvial/Debris Fan/Dry Delta** – This is a ***fan or cone-shaped deposit of fairly coarse sediments laid down by a stream with a large load as it emerges from a steep, narrow valley into a wide gentle plain or broad valley.*** This feature is formed when the speed of flow is suddenly greatly reduced e.g. when a stream rushing down the hillside reaches the gently sloping valley floor. When this happens, the river is unable to carry much of its load and this alluvium usually sands and gravels is suddenly laid down in a fan shape. Alluvial fans are similar to deltas except that they are formed on land and are sometimes called '***dry deltas***'. Examples include ***Lume fan formed by river Lume as it reaches the Semliki plain; Luri and Lumemo fans in the Kilombero valley, south Tanzania; Blida fan, SW of Algiers, Algeria; Amekrane fan, Morocco***.



8. **Deltas** – This is a ***large, flat, low-lying swampy plain of river or alluvial deposits laid down where a river flows into a stationary water body such as an ocean, sea or lake***. A delta is formed when a river with a large load and low velocity flows into an ocean or lake. As the deposited load sinks to the bottom in the mouth of the river, layer upon layer of sediments may accumulate to form a gently sloping platform. In time, the platform may extend up and above the sea level to form a delta. Deposition results both from the reduction in speed as the river enters the sea and also from coagulation of fine or tiny particles of silt and clay mixing with salt water (***flocculation)***. Over time, the deposited material blocks existing river channels and forms small islands separated by distributaries. In order for a delta to form, the following conditions must prevail;

- ❖ The river must have a large load (active vertical and lateral erosion in the upper course of the river to provide extensive sediments)
- ❖ The velocity or speed of the river must be low to allow most of the load to be deposited in the river mouth.
- ❖ The load must be deposited faster than it can be removed by wave action, i.e. rate of deposition exceeds rate of sediment removal or erosion by tides and currents.
- ❖ Absence of barriers or obstacles like dykes, at the river mouth.
- ❖ There must be a very gentle or low gradient to allow accumulation of materials at the river mouth.
- ❖ The river mouth should be large enough to accommodate all the debris.
- ❖ The sea or lake that is being joined must be shallow for easy buildup of the delta.
- ❖ The coast should be sheltered
- ❖ There should be no strong tidal currents to wash away the sediments.

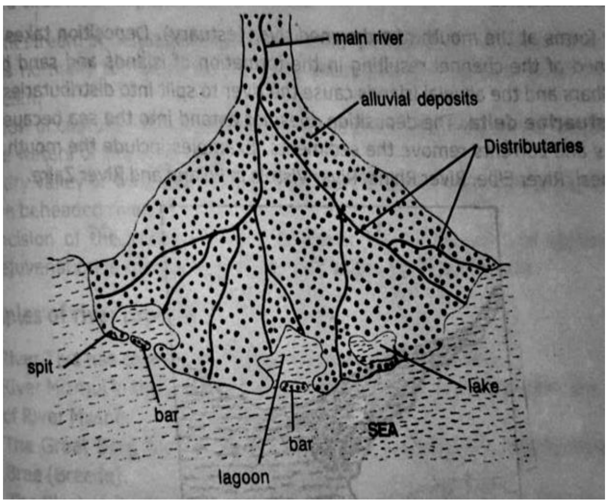
TYPES OF DELTAS

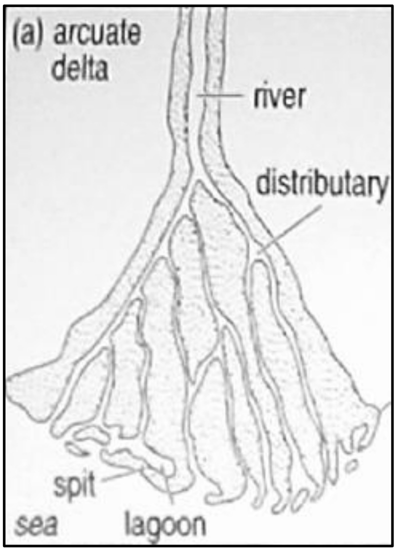
Delta's can be categorised into three main shapes, namely arcuate, bird's foot and estuarine.

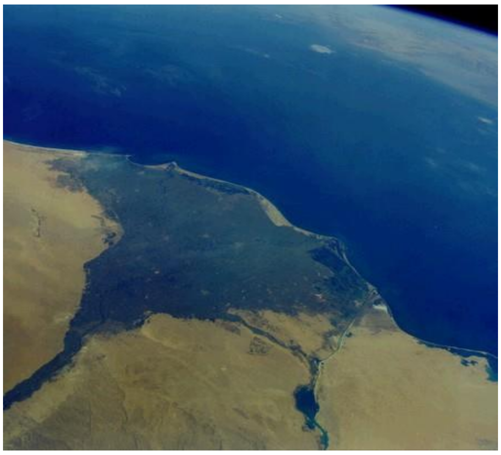
(a) **Arcuate (fan-shaped) Delta** – This is the most common type of delta. It is a cone or triangular shaped delta built by rivers with many distributaries carrying both fine and coarse sediments such as sand and gravel. It has a convex, rounded seaward edge due to the smoothening effect of strong sea currents. Examples include ***Yala and Tana deltas in Kenya; Rufigi delta in Tanzania; Semliki delta on Lake Albert in Uganda; Nile delta in Egypt; Niger delta in Nigeria; R. Mangoky and Tsiribihina, Madagascar***.

Characteristics:

- It's made of fine and coarse sediments such as gravel and sand;
- It has many distributaries;
- It's triangular in shape;
- It has a rounded seaward edge or shoreline.







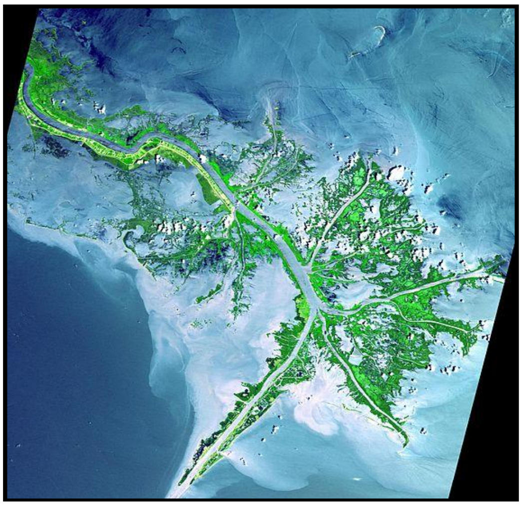
Nile Delta

Niger Delta

(b) **Bird's Foot delta** – This is formed by rivers carrying large loads of very fine sediment such as silt into water where wave energy is low, i.e. relatively calm offshore water to enable accumulation to take place. Such deltas tend to have one or very few major distributaries projecting into the sea. Examples include ***rivers Nyando, Nzoia, Turkwell, Kuja and Kerio in Kenya; river Omo delta in Ethiopia***.

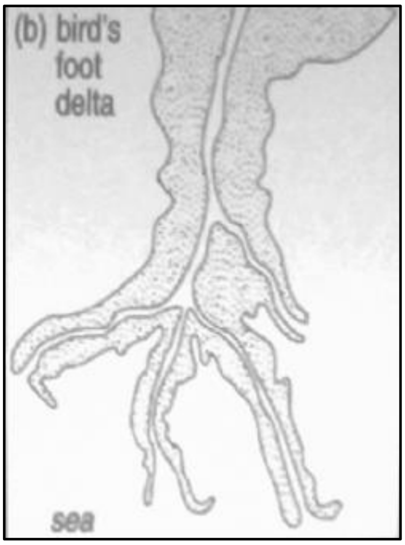
Characteristics:

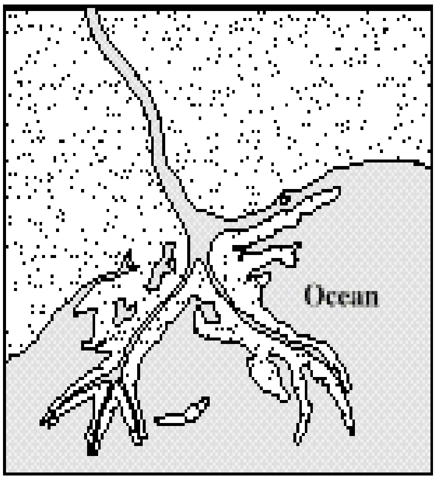
- It's composed of very fine sediments, mainly silt;
- It has a few very long distributaries bordered by levees;
- It has a bird's foot shape.



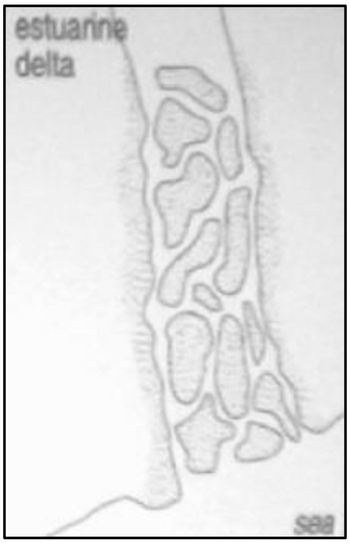
Mississippi Delta – USA

Omo River Delta, Turkana area – Northern Kenya





(c) Estuarine Delta – This develops when a river deposits sediments into a submerged or drowned river mouth or estuary that eventually becomes filled with sediment, forming many sand banks and islands with several distributaries. Examples include ***R. Rufigi, Tanzania; R. Congo in DRC; Betsiboka delta, Madagascar; R. Zambezi, Mozambique and R. Seine, France***.



RIVER CAPTURE OR PIRACY

This refers to the diversion of part or the whole of a river's course or drainage system or watershed into the system of an adjacent and more powerful river. The capturing or pirate stream must be able to erode (headward erosion or back-cutting) its valley more rapidly than the weaker neighboring stream. For river capture to be successful the following conditions must prevail;

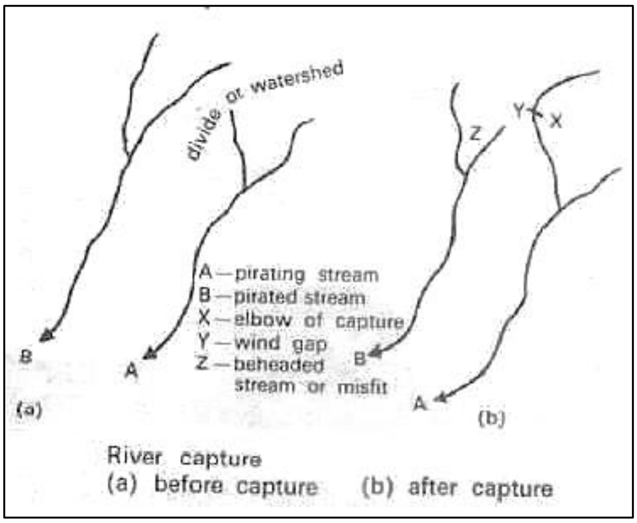
(a) The powerful or pirate stream and the weaker stream must flow in adjacent valleys.

(b) The capturing stream must be flowing at a lower level than its victim (weak stream).

(c) The pirate stream must have more active headward and vertical erosion than its neighboring stream.

Stream A is situated at a higher gradient or has more water will cut back more rapidly than stream B. Stream A may eventually break through the divide and capture or pirate stream B.

Z is the **misfit stream**. Rejuvenation will take place in river A. Area Y is known as the **wind gap**.



Examples of river piracy include the ***Tiva river capture of the former tributary of river Galana in Kenya; river Cunene capture in Angola; river Volta capture in Ghana; river Niger capture in Nigeria; Great Berg river capture in South Africa***.

Evidence of River Capture

(i) **Elbow of capture** – this is a sharp change in the direction of a river course at the point of capture. In other words it is the bend where the diversion of flow (river capture) occurs.

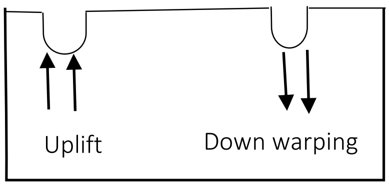
(ii) **Wind gap or Dry Valley** – this is a dry valley below the point of capture that is left between the captured stream and the misfit stream. The floor of the valley may be covered by alluvium.

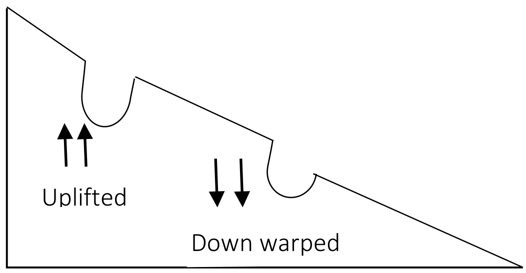
(iii) **Misfit or Beheaded stream** – this is a stream that appears too small for its valley. The beheaded stream having lost its headwaters may be reduced in volume causing it to appear too small for its valley. Thus it's described as a *misfit or beheaded or underfit river*.

(iv) **Knick point**. Due to increased erosive power from its enlarged headwaters, the pirate stream may be rejuvenated and cut or incise its valley below the point of capture. If the pirate stream was flowing at a much lower level than its victim, the capture will cause a fall in base level for the captured stream and thus lead to the formation of a knick point such as a waterfall.

Causes of River Capture

- **Differences in water volume**. One river may have more water than the neighboring stream, thus it will have more ability to erode its valley lower than the river having less water volume, i.e. greater vertical and headward erosion, eventually capturing the headwaters of its weaker neighbor. For example the tributaries of Tochi, Okele and Arocha in Northern Uganda were captured in this way by R. Nile.
- **Difference in rock hardness**. Where two adjacent rivers flow over rocks of different resistance, the river flowing over a soft/weaker rocks will erode its bed faster leaving its neighbor's flowing over hard rocks at a higher altitude. The tributary of a river at a lower altitude will extend by headword erosion to capture the waters of the river at higher altitude.
- **Rejuvenation**. If two rivers are flowing side by side then one river experiences rejuvenation, its bed will be eroded lower that the other. If a tributary stream develops from the rejuvenated river to the other, headwaters of the river will be diverted into the rejuvenated waters.
- **Tectonic earth movements**. If there are two rivers flowing adjacent to one another under similar conditions, uplifting or down warping will result into river capture. If down warping takes place along the course of one river, its bed will now be much lower than that of the adjacent uplifted river. A river flowing in a downwarped channel may extend its valley by headward erosion and capture the waters of the adjacent weaker river flowing over an uplifted channel.





RIVER REJUVENATION

Over a long period, a river assumes a generally smooth long profile. This is the most efficient profile for a river to have in order to transport water and sediment. It represents a state of equilibrium (balance) with the environment. In theory, a river will always be trying to achieve this smooth concave profile. Occasionally an event occurs that de-stabilises the situation, and causes the river to actively erode its channel in order to re-establish its smooth long profile. This renewed period of erosion is called **rejuvenation**.

Rejuvenation refers to the renewed erosive ability of a river within its old valley. When a river becomes more energetic, its erosive ability increases such that a river gains extra power. Such a river is said to have been made young again and starts to behave like a river in the youthful stage. Rejuvenation may be common in the middle and old stages of a river.

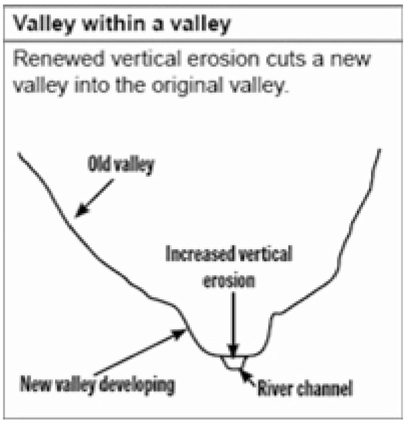
Causes of Rejuvenation

- **River capture** – When a river captures an adjacent weaker stream, the volume of water in the pirate river channel increases leading to increased energy to carry out erosion hence rejuvenation.
- **Increase in rainfall** – This results in increase in a rivers' discharge/volume thus increased energy and renewed erosive ability or rejuvenation.

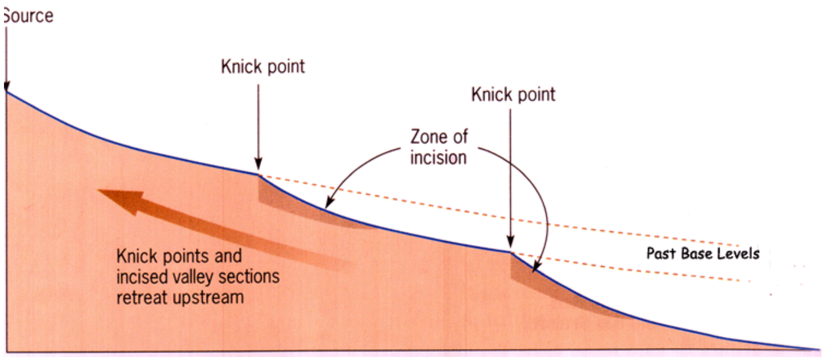
- **Earth movements** such as uplift or upwarp along a river channel causing gradual steepening of the river's gradient or slope. This increases the river velocity or speed, energy and erosive ability leading to rejuvenation.
- **Isostatic and eustatic re-adjustment** – Negative changes or fall in sea level create a knick point close to the coast resulting into increase in river's gradient, increased speed and its erosive ability.
- **Glaciation** – This occurs when there is an extreme drop in temperatures hence water is removed from seas and locked in form of ice caps and ice sheets. This results in fall in sea level and lowering of the base level of rivers. A steep gradient is created close to the coast which increases the river speed, energy and its erosive ability.
- **Reduction in the river load** – This leads to increase in the river energy and erosive ability thus rejuvenation.

EFFECTS OF REJUVENATION ON THE LANDSCAPE

1. **Valley within a valley/rejuvenated gorge**. This is a new valley which has been re-shaped from the old existing valley. In this case the river erodes a new valley within an older valley. It occurs where rejuvenation was fairly rapid and the fall in base level quite large to form a deep steep sided narrow valley within the former bigger valley. Examples can be seen on ***river Nyando in Kenya as it crosses the Kano plains; river Ngaila in western Kenya; rivers Kafu and Mpanga***.

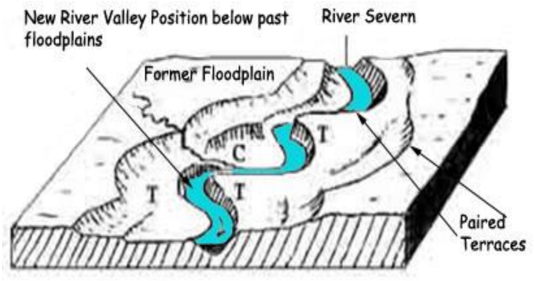


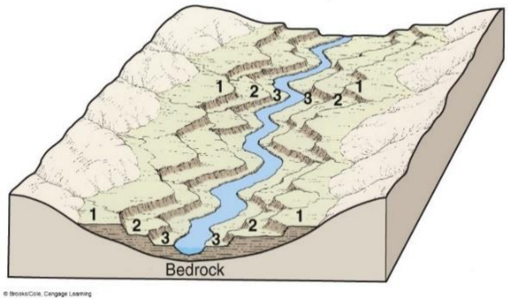
2. **Knick Points (Point of interruption)**. This is a sudden or sharp break of a slope in the long profile of a river where gradient increases suddenly. It marks the point where rejuvenation started. They may result from increase in discharge due to river capture. They may also develop at the edge of a resistant rock as it joins a region of soft rocks. A knick point is often marked by a waterfall. It's a point where the old long profile changes to a new profile. Examples include ***river Mkomazi in Tanzania, Gogo falls on river Kuja in western Kenya; Charlotte falls on river Orugu in Sierra Leone***.



3. **River Terraces or Paired Terraces**. This is a step or bench like strip of land found above the stream and its flood plain. They are usually covered by a layer of sand and gravel that represents a former level of the valley floor. When base level falls and rejuvenation occurs, vertical erosion increases allowing the river to cut its channel down through the former flood plain alluvial deposits (sands and gravels) parts of which remain as terraces above the new river channel. The terraces on one side of the river may correspond with those on the other side forming paired

terraces. Examples include along ***rivers Ngaila and Nyando in Kenya; Semliki and Kafu in western Uganda***.

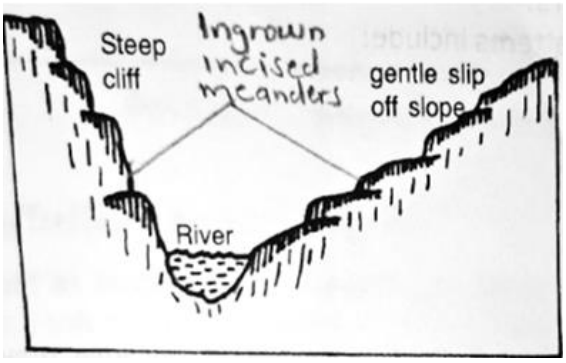


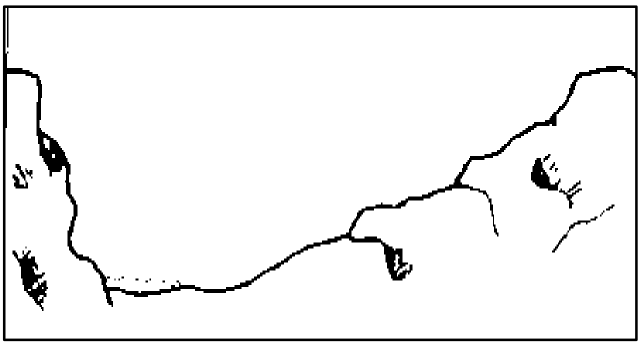


4. **Incised Meander**. This is a river meander that has been incised or cut deeply into the landscape in that the river now winds between steep valley walls or gorges. These meanders result from the vertical erosion of an already meandering river due to rejuvenation. It is this increased vertical erosion which cuts large scars into the landscape resulting in a meandering valley with no visible flood plain. There are three types of incised meanders; entrenched, ingrown and abandoned.

Incised Meander (USA)

(a) ***Ingrown Meanders*** – This is a valley with an asymmetrical cross-profile, where on side is steeper than the other. It normally develops in hard/resistant rocks when vertical erosion increases. Examples include ***R. Rwizi in Mbarara, R. Mubuku in Kasese, R. Manafa near Busia; R. Mwachi west of Mazeras, R. Kombeni, R. Cha Simba, R. Kombeni in Kenya; Sine River in Tanzania***.





(b) ***Entrenched/Intrenched Meanders*** – These are valleys with a steep-sided symmetrical cross-section or profile. This type develops on soft/weak rocks where base level falls rapidly and vertical erosion occurs along river meanders resulting into an entrenched incised meander or deep gorge appearance. Examples in ***river Mara and Kuja in western Kenya***.

(c) ***Abandoned Incised Meanders*** – These occur when incised meanders change their channels leaving behind an abandoned meander. The adjacent spur or cut-off forms an isolated hill known as a ***meander core***. Examples include ***river Bivane southwest of Durban (South Africa)***.

DRAINAGE PATTERNS

A drainage pattern is the layout or plan made by a river and its tributaries on the landscape; OR ***the way in which a river and its tributaries arrange themselves within their drainage basin***. Drainage patterns are governed by the topography or relief of the land, i.e. whether a particular region is dominated by hard or soft rocks, and the gradient of the land. They tend to develop along zones where rock type and structure are most easily eroded. Thus various types of drainage patterns develop in a region and these drainage patterns reflect the structure of the rock. Most patterns develop over a long period of time and usually become adjusted to the structure of the basin. There is no widely accepted classification of drainage patterns partly because several patterns are descriptive. There are two broad based groups of drainage patterns, namely;
1. Accordant drainage patterns
2. Discordant drainage patterns

Accordant Drainage Patterns (Patterns Independent of Structure)

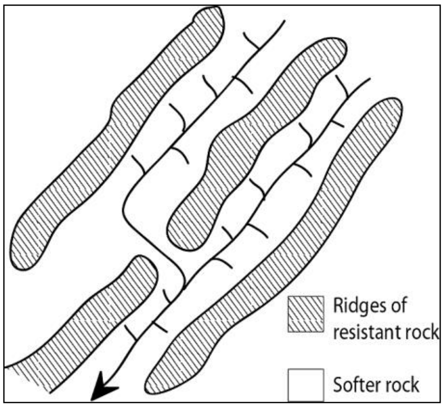
This is where the drainage pattern is related to the rock structure. They include the following;

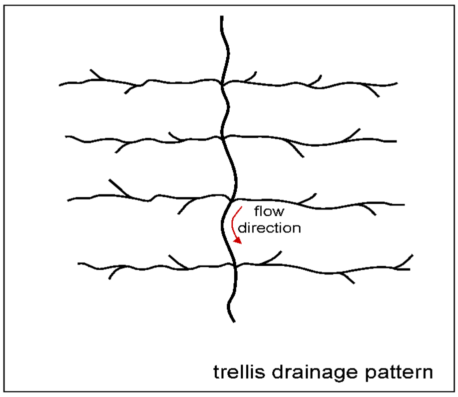
(a) **Dendritic Drainage Pattern**: This is the most common pattern and has a tree-like pattern in which the many tributaries (branches) converge upon the main river (trunk) at an acute angle (less than 90^0). Its name is derived from the Greek word '*dendron*', meaning a tree. This pattern develops where the river channel follows the slope of the terrain, as well as in areas with uniform rock hardness and structure (homogenous rocks) leading to uniform erosion, and on massive crystalline rocks such as granite. It also develops on horizontal to gently dipping sedimentary strata and in areas of heavy and reliable rainfall to allow large volumes of water in the channel. Dendritic systems form in V-shaped valleys. Examples include ***rivers Rufigi, Malagalasi, and Ruvuma in Tanzania; Tana, Ewaso-Ngiro and Nyando in Kenya***.

Conditions favoring the development of Dendritic pattern;
- The pattern develops in areas with homogenous rocks, i.e. rocks with uniform structure and hardness. This is common in crystalline granitic rocks.
- The slope should be gently dipping, such as the sedimentary rock strata.
- All the major and minor streams should flow in the direction of the initial slope of the area over which the pattern was established.
- There should be heavy and reliable rainfall.

(b) **Trellis Drainage Pattern**: In this pattern, tributary streams join the main stream at right angles (approximately 90^0). The main river with its major and minor tributaries flow more or less parallel to one another. Trellis drainage is characteristic of folded mountains. This pattern is also known as **rectilinear drainage**. Examples of rivers with trellis pattern include ***Mayanja, Kato, Tochi and Aswa in Uganda; Galana and Tochi in Kenya***.

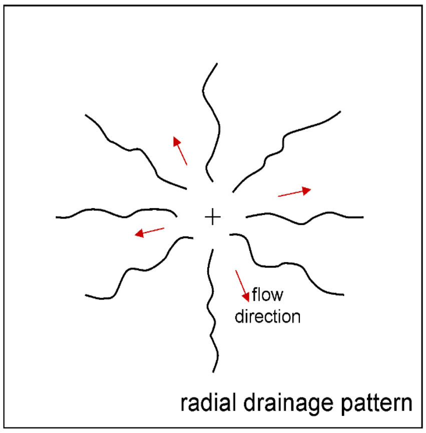
Conditions favoring the development of Trellis pattern;
- Presence of heterogeneous rocks, i.e. rocks with alternate belts of hard and soft rocks which lie at right angles to the general slope.
- Presence of folded and well jointed rocks or a faulted region.
- Large catchment area with heavy and reliable rainfall to provide large volume of water.
- They may also develop due to river capture where parallel rivers mainly drain water from others leading to abrupt change in flow hence angularity.

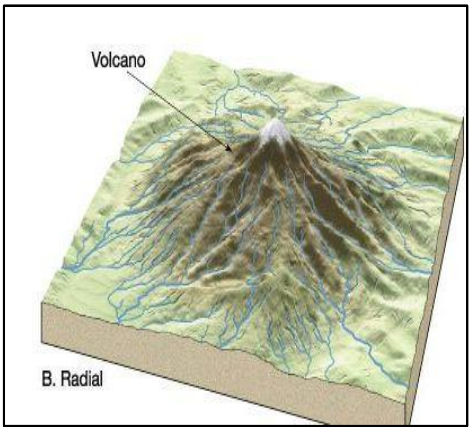




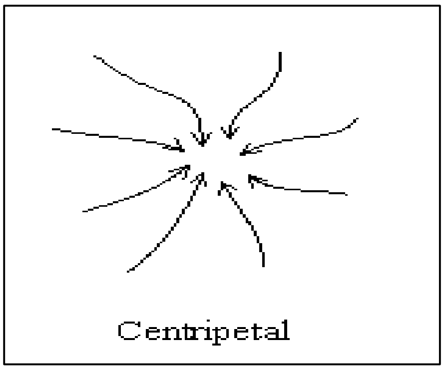
(c) **Radial Drainage Pattern**: In this pattern, streams radiate/flow outwards/diverge from a central high point like a dome upland or a volcanic cone. Examples include rivers such as ***Mubuku, Semliki, Nyamwamba, and Mpanga from Mt. Rwenzori; Sironko, Manafwa, Koitobos,and Siti from Mt. Elgon and on Mt. Moroto in eastern Uganda***.

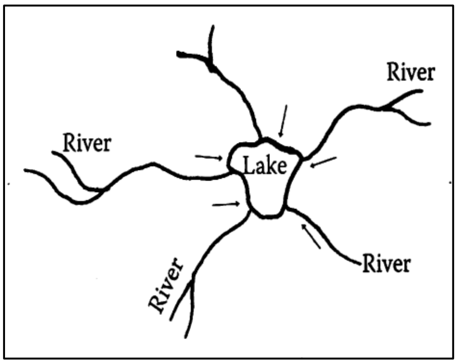
Conditions favoring the development of Radial pattern;
- Presence of a dome shaped or cone shaped highland
- Presence of a very steep slope
- Presence of rocks with uniform resistance (homogenous)
- Heavy and reliable rainfall providing a constant supply of rainfall. The water may also be got from melting glaciers and snow.



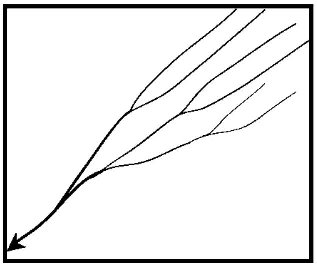


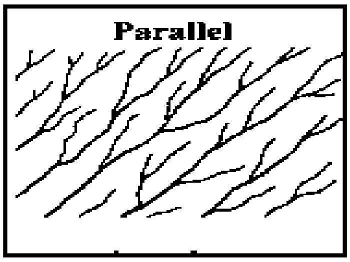
(d) **Centripetal Drainage Pattern:** In this pattern, streams converge from all directions inwards towards one main point or centre like a swamp, lake or lowland. This is the opposite of radial pattern. It develops in areas with depressions such as those formed by down warping and faulting, gently sloping landscape and in areas with homogeneous or heterogeneous rocks. The streams are guided by the slope which dips towards the depression. Examples include ***rivers Katonga, Kagera, Nyando, Nzoia, Mara and Ngaila which flow into Lake Victoria***.





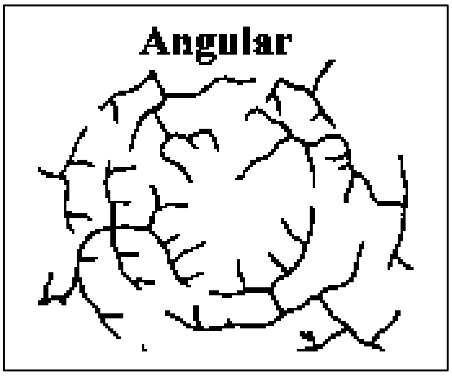
(e) **Parallel Drainage Pattern**: In this pattern, rivers flow downhill more or less parallel with each other for long distances with limited chances of joining. Its best developed on escarpments and in areas with alternating hard and soft rocks such that the hard rocks separate rivers that flow in soft rocks and are flowing on a gently sloping area (uniformly sloping area). Such streams are usually swift and straight, with very few tributaries, and all flow in the same direction. Examples include, ***rivers flowing southeast from the Aberdare Mountains in Kenya, that is, river Athi with several of its tributaries such as Nairobi, Kolu, Ruaraka, Gitathuru and Kaiti; others are the tributaries of river Tana like Thika, Tula, Mathioya and Chania which flow parallel to each other***.

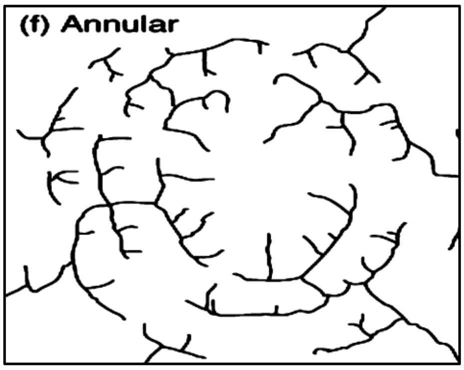




(f) **Annular Drainage Pattern**: In this pattern streams are arranged in a series of curves about a dissected dome, basin or crater following a roughly circular or concentric path along a belt of weak rocks. Tributary streams join the main stream at sharp angles in a series of curves. It is best displayed by streams following circular courses around a dissected dome or upland. Examples include ***Lake Bosumtwi in Ghana with Banko and Buonim rivers***.

Conditions favoring the development of Annular pattern;
- Presence of alternating hard and soft rocks occurring in centric zones. The subsequent streams around the dissected dome erode the valleys in the soft rocks. Streams follow circular courses around the dome conforming to the weaker rock outcrops and flow outwards.
- Presence of heavy and reliable rainfall.
- Presence of a dome or basin



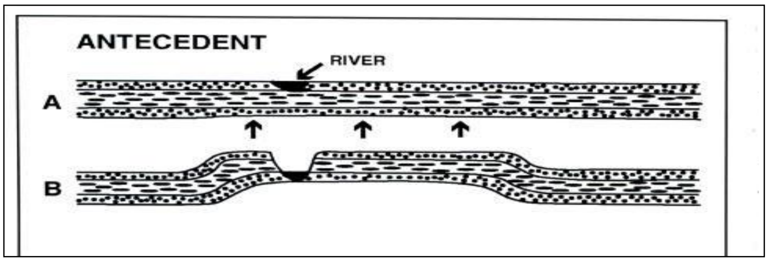


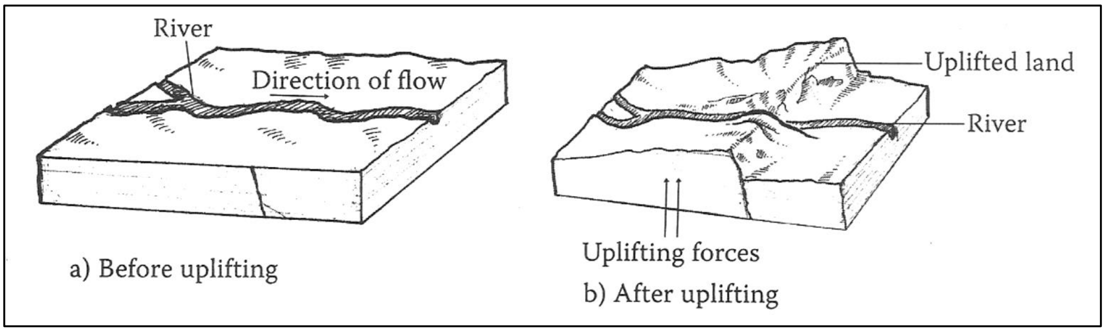
Discordant Drainage Patterns (Patterns Unrelated to Structure)

These are drainage patterns which show no relationship with the underlying rock type and structure. Such patterns are opposed to the dominant rock type and structure. They include;

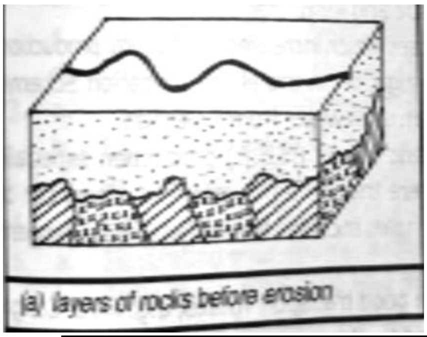
1. **Antecedent Drainage Pattern**: This is a pattern that developed on a landscape that is later uplifted or folded, but the river is able to maintain its course by eroding vertically to keep pace

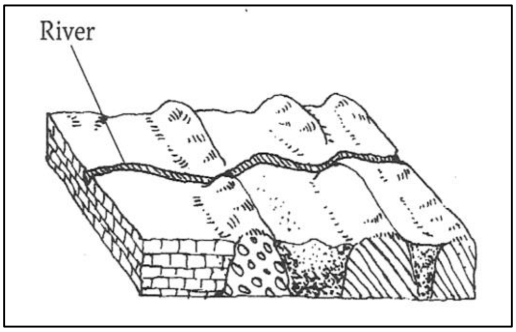
with the uplift. The stream is able to maintain its original course and pattern despite the changes in underlying rock topography, for instance a stream with a dendritic drainage pattern can be subject to slow tectonic uplift. However, as the uplift occurs, the stream erodes through the rising ridge 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 trellis drainage pattern. Antecedent river valleys are therefore older than the structures on which they flow. In East Africa this pattern is common along areas of recent earth movements and these include channels of rivers flowing into the rift valley floor, the edges of which were uplifted by tectonic movements and where rivers continue down cutting to keep pace with the uplift. Examples include ***river Nile which flows down the steep gorge of Murchison falls; the Great Ruaha river in southern Tanzania and river Gilgil in Kenya***.

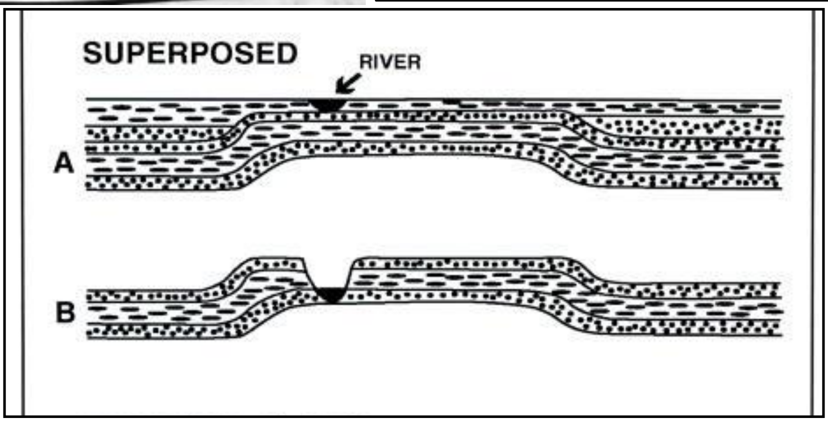




2. **Superimposed Drainage Pattern**: This pattern describes a river valley that developed on a former cover of rocks that has now been removed by erosion and is now superimposed/superposed (laid over) onto a previously buried and completely different rock structure. In other words, the river is superimposed/laid over a completely different or new type of rocks but maintains its original direction of flow. The stream erodes a gorge in the resistant bed and continues its flow as before. Therefore the stream is younger in age than the underlying rock structure. These patterns develops in areas where the ancient rock structure was once covered by sedimentary rocks or lava flows and are now exposed by denudation or erosion of the overlying rock cover. Evidence of superposed drainage is seen when remnants of the former overlying rock cover are still to be seen on either side of the river valley.







Importance of Rivers and their landforms

Rivers carry water and nutrients to areas all around the earth. They play a very important part in the water cycle, acting as drainage channels for surface water. Rivers drain nearly 75% of the earth's land surface.

Rivers provide excellent habitat and food for many of the earth's organisms.
Many rare plants and trees grow by rivers. Ducks, voles, otters and beavers make their homes on the river banks. Reeds and other plants like bulrushes grow along the river banks.

Other animals use the river for food and drink. Birds such as kingfishers eat small fish from the river. In Africa, animals such as antelopes, lions and elephants go to rivers for water to drink. Other animals such as bears catch fish from rivers.

River deltas have many different species of wildlife. Insects, mammals and birds use the delta for their homes and for food
Rivers have been a source of food since pre-history. They can provide a rich source of fish and other edible aquatic life.

Rivers provide travel routes for exploration, commerce and recreation. Boats or rafts were used to travel from one end of a river to another. In the same way, goods were also transported. With the transport of goods and the contacts of people between different parts of the same river, there were also many cultural exchanges. Thus, rivers helped to spread civilization.

River valleys and plains provide fertile soils. Farmers in dry regions irrigate their cropland using water carried by irrigation ditches from nearby rivers.

Rivers are an important energy source. During the early industrial era, mills, shops, and factories were built near fast-flowing rivers where water could be used to power machines. Today steep rivers are still used to power hydroelectric plants and their water turbines.

The coarse sediments, gravel and sand, generated and moved by rivers are extensively used in construction. In parts of the world this can generate extensive new lake habitats as gravel pits re-fill with water. In other circumstances it can destabilize the river bed and the course of the river and cause severe damage to spawning fish populations which rely on stable gravel formations for egg laying.

In upland rivers, rapids with whitewater or even waterfalls occur. Rapids are often used for recreation, such as whitewater kayaking.

Rivers have been important in determining political boundaries and defending countries. For example, The Orange and Limpopo Rivers in southern Africa form the boundaries between provinces and countries along their routes.

It is true, however, that rivers have also caused much misery and unhappiness to millions of people throughout history. They have caused floods and destroyed lives and property in all parts of the earth.

Some rivers are also important tourist spots, such as river Nile.

Revision Questions:

1. With reference to specific examples, account for the development of the following drainage patterns; Dendritic, Radial and Annular.

2. Examine the landforms resulting from river erosion and their effects on human activities in EA.

3. With reference to EA; dendritic pattern.

4. Explain the causes and describe the results of river capture.

5. With reference to specific examples in EA, account for river rejuvenation and show the influence of rejuvenation on the landscape.

6(a) Examine the processes leading to the formation of river deltas.

(b) Assess the importance of deltas in Africa.

7. Account for the formation of the following features;

(a) plunge pool (b) flood plain (c) meanders

8. Examine the causes and effects of river rejuvenation in EA.

Approach

- Define river rejuvenation

- Explain the causes of river rejuvenation

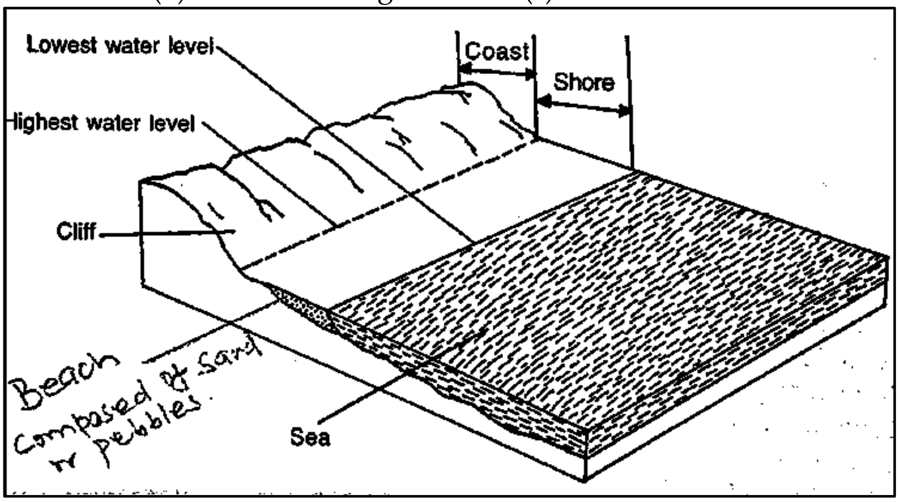
- Identify and explain, with illustrations the effects/landforms due to rejuvenation

COASTAL GEOMORPHOLOGY

Coastal geography is the study of the dynamic interface between the ocean and the land, incorporating both the physical geography (i.e. coastal geomorphology, geology and oceanography) and the human geography (sociology and history) of the coast. It involves an understanding of coastal weathering processes, particularly wave action, sediment movement and weather, and also the ways in which humans interact with the coast. Coastal geography is that branch of geography, incorporating physical and human geography, which deals with the study of the dynamic interface between ocean and land.

The term ***coast*** refers to ***the zone of contact and interaction between land and sea***. The coast of East Africa is generally smooth and only broken by a few indentations inform of river inlets or outlets. The coast is another area of concern to geomorphologists since a number of landforms are created there. The major landforms along coasts are a result of;

(a) Wave Action (b) Sea level changes (c) Coral reefs



WAVE OR MARINE ACTION:

Waves are undulations on the surface of the sea caused by the blowing of wind across the sea surface; **OR** ***they are ripples or oscillations on any water body***. Waves are very important in coast configuration because they carry out erosion, transportation and deposition. Waves transport energy from the point of disturbance to the coast. Waves when seen on the water surface seem to be moving forward but in actual sense the water doesn't move rather it's the shape of the ripples that moves forward while the water oscillates up and down.

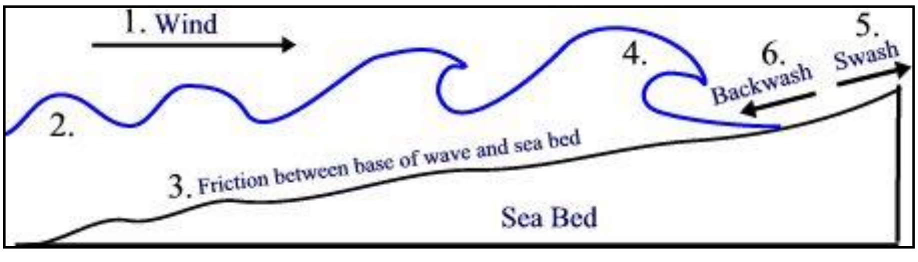
Formation of Waves

Waves on water bodies are generated in two broad ways;

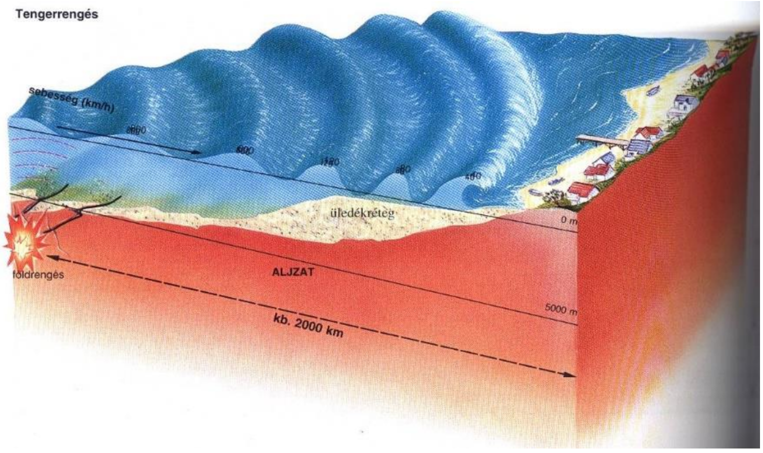
(a) By wind

(b) By catastrophic events or moving objects

(a) Wind Generated Waves – When winds blow over the surface of a water body, there is friction between the water and the wind. Energy is transferred from the wind to the water and forms the wave which normally moves along in the direction of the wind.

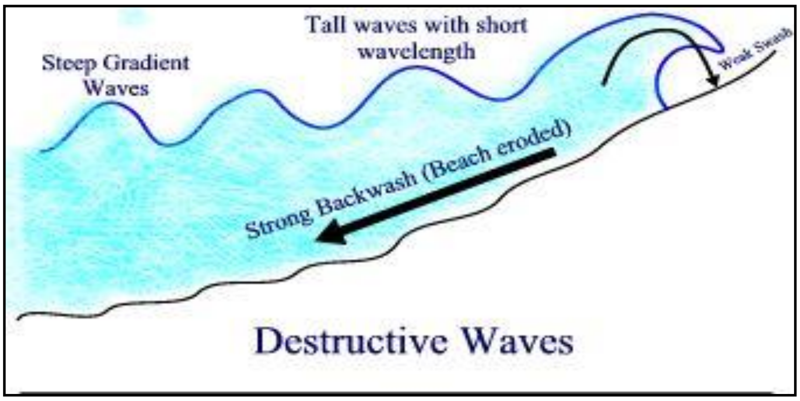


(b) Catastrophe Generated waves - Undersea earthquakes or displacement of water by landslides, volcanic explosions at sea, movement of the seafloor by faulting and other sharp motions generate waves which are usually seen. These waves are usually very strong and destructive in nature such as tsunamis. The tsunami of December 26, 2004, that killed more than 220,000 people is an excellent example.

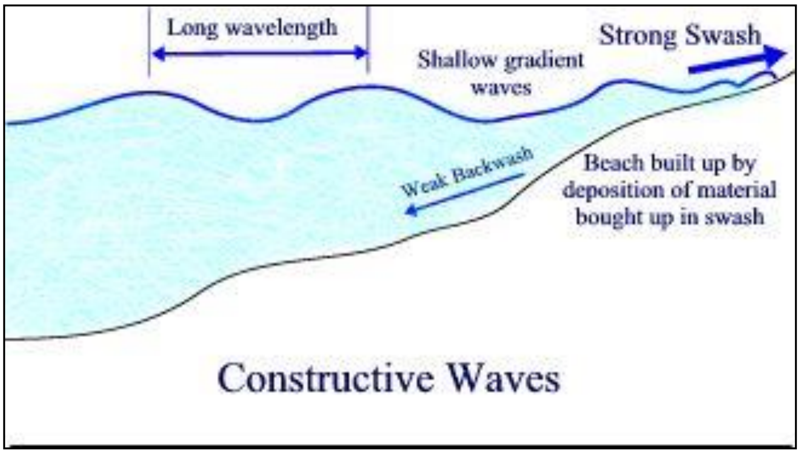


Waves which are pushed up the coast or wash up on the shore are called ***swash*** or a ***send***. Swash pushes sediment up the beach away from the sea. When the water from the waves starts to run back down the beach it is called the ***backwash***. Backwash pulls beach material towards the sea. The force of the swash and backwash determines whether the waves are **constructive waves** or **destructive waves.**

Destructive waves are waves with a stronger backwash than the swash, i.e. they do ***more erosion than deposition***. These waves are usually very high and very frequent. The swash of the wave tends to push material up the shore and the backwash tends to wash it back again. Such waves form coastal erosional landforms and are associated with stormy conditions.



Constructive waves are waves with a more powerful swash than the backwash i.e. they do ***more deposition than erosion***. They are less powerful than destructive waves and don't break as violently, that is, they are gentle and less in height. Thus constructive waves form coastal depositional features. Are associated with calm weather.



WAVE EROSIONAL LANDFORMS

These are a result of destructive waves. The effectiveness of wave erosion depends on the following factors;

(a) Wave energy. This is related to the size of the wave. Energy is transferred from the wind into the waves and this too depends on wind speed, length of time the wind blows and the fetch or distance over which the wind blows. Storm winds blowing for a long time over a wide area of water create waves with a lot of energy with more erosive power. The weaker the wave energy the less erosive the wave will be.

(b) Nature of rocks along the coast. Wave erosion is more effective and pronounced on areas with weak rocks, soluble and well-jointed rocks while hard and resistant rocks stand out as headlands.

(c) Exposure of the coast to wave attack. Coasts which are totally exposed to wave attack are easily eroded by waves while coasts that are sheltered by off-shore coral reefs and islands are less affected by wave erosion.

(d) Slope of the land. Coasts which are gentle and the rock dips upwards away from the sea are not easily eroded by waves while coasts that are steep are easily eroded since water is thrown against the coast and erodes the rocks.

(e) Orientation of the coast. Straight coasts are less eroded by waves while indented coasts are rapidly eroded by waves causing destruction.

(f) Stability of the sea. Coasts that susceptible to strong winds and other catastrophic events such as earthquakes are easily attacked by waves and eroded while calm coasts generate weak waves which are less erosive and less destructive.

(g) Availability and size of load which is used as an abrasive tool. An abundant supply of materials like sand, pebbles and boulders results in the coastline being eroded at a fast rate by abrasion. When such materials are limited, wave erosion will be slow or limited.

Wave Erosion Processes:

Coasts being at the boundary of the land and the sea are extremely vulnerable to erosion. They are attacked by the immense power of the sea and the weather. Waves erode the coast in the following ways;

(i) **Hydraulic Action**: This is where breaking waves exert a lot of pressure on cracks in a cliff face. As waves break against a cliff air is compressed and as waves retreat, air expands rapidly in the cracks causing rock fragments to fall off the cliff face as the process is done repeatedly.

(ii) **Abrasion or Corrasion**: This is the process by which waves use materials carried such as pebbles, sand and large rocks to scratch/scour and wear down coastal rocks. This leads to undercutting of the coast and the breakdown of rocks.

(iii) **Solution or Corrosion**: This is the solvent/chemical action of sea water where acids in the salt water slowly dissolve rocks on the coast. For example, limestone cliffs are gradually weakened as the salt water dissolves the calcium carbonate in the limestone.

(iv) **Attrition**: Materials carried by the waves such as, pebbles and sand, bump into each other and so are smoothed and broken down into smaller particles.

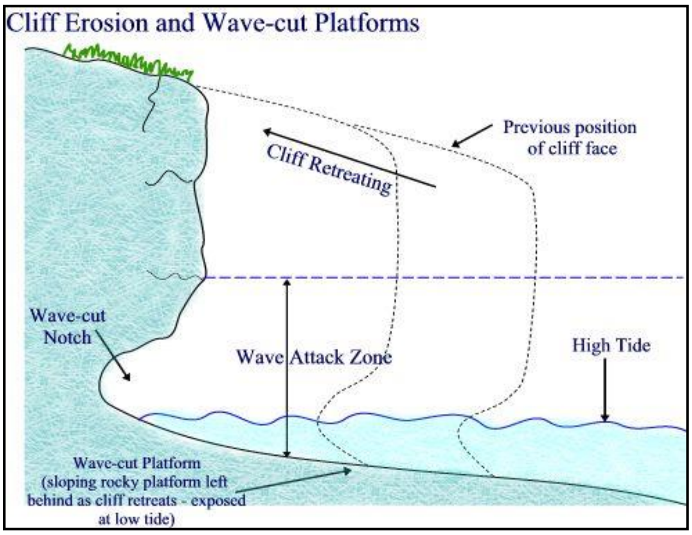
FEATURES PRODUCED BY WAVE EROSION

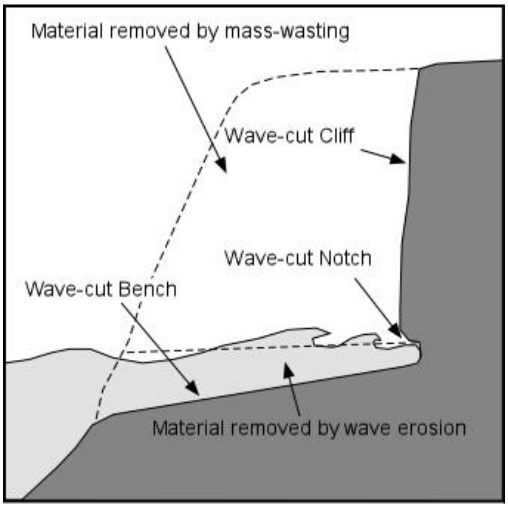
1. **Cliff**: This is a ***steep slope or rock face along the sea coast above high tide level***. Cliffs vary in height, profile and plan. Most cliffs are in areas of active marine erosion but it's only the cliff base that experiences wave attack. They are formed by a combination of wave erosion wearing away the base of the cliff through abrasion and hydraulic action undercutting the foot of a rock face along a line of weakness (fault) forming an indent or a dent called a ***wave-cut notch***. The notch is further eroded and enlarged to form a cave; further erosion combined with weathering and mass

wasting causes the overhanging part of the cave to collapse and retreat forming a steep slope or rock face or cliff. Examples can be seen at ***Fort Jesus in Mombasa, Fort Gereza, and at Kasenyi landing site on the shores of Lake Victoria***.

Cliff at Kasenyi on L. Victoria shores

Limestone cliffs (Dorset, UK)





2. **Wave-cut Platform, coastal benches**, **wave-cut benches** or **shore platform**: This is ***a narrow flat or bench-like area found at the base of sea cliff***. Wave-cut platforms are often most obvious at low tide when they become visible as huge areas of flat rock. It forms after destructive waves hit against the cliff face, causing undercutting between the high and low water marks, mainly as a result of corrosion and hydraulic power, creating a wave-cut notch. This notch then enlarges into a cave. Due to continued wave action the roof of the cave collapses, resulting in the cliff retreating landward while the base/floor of the cave forms the wave-cut platform.

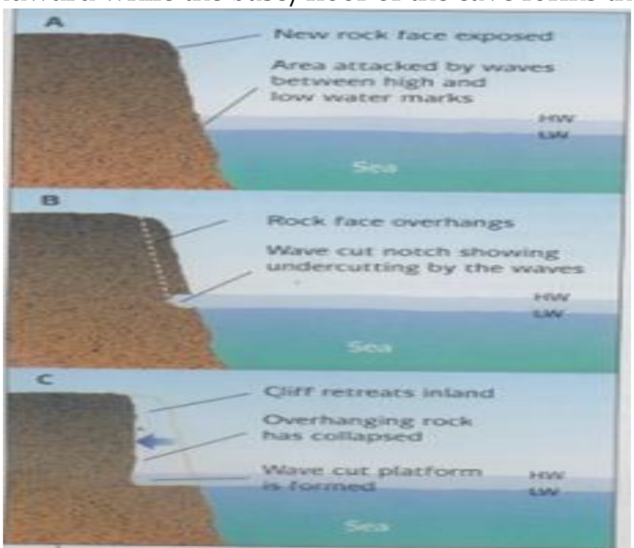
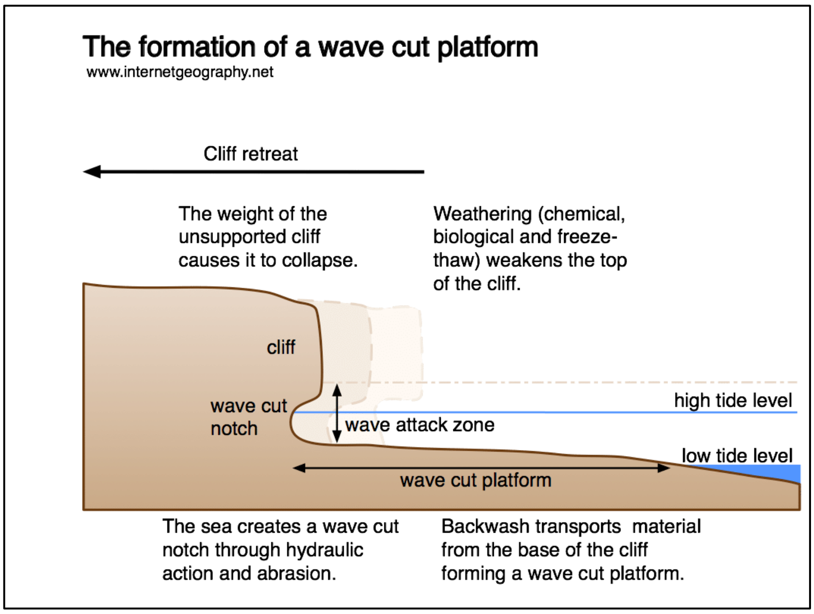
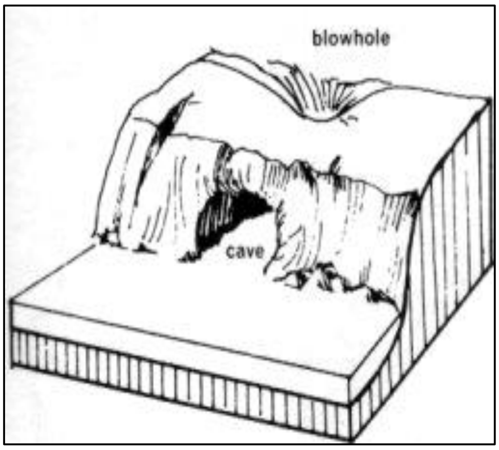


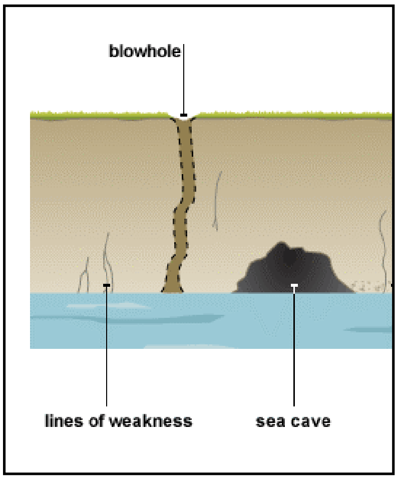
Figure 2 Formation of cliff and wave cut platform.



3. **Cave**: This is ***a cylindrical tunnel at the base of a cliff***. The cave is wide at the entrance and narrow at the end. They develop from waves that erode the foot of the cliff along areas of weakness such as joints, faults and cracks, through wave erosion processes such as hydraulic action, abrasion and solution; gradually these cracks get larger due to hydraulic pressure, developing into small caves. Further erosion widens the cave. Caves are common along the East African coast at ***Shimon, Tiwi beach, Kilifi, and Watamu along the Kenyan coast; Oyster bay in Dar es Salaam; along the shores of Lake Victoria at Resort beach***.



4. **Blowhole or Gloup**: It is associated with caves. A blowhole is a ***cavity or vertical tunnel connecting the roof of the cave with the top of the cliff***. It is formed when waves erode weak rocks along a joint in the cave roof and gradually enlarge the joint into a vertical tunnel. As water flows into the cave, air is expelled through the pipe like joint, sometimes producing an impressive blast of air or spray which appears to come from the ground. They are common where caves are found like at ***Shimon south of Mombasa and along the shores of Lake Victoria***.



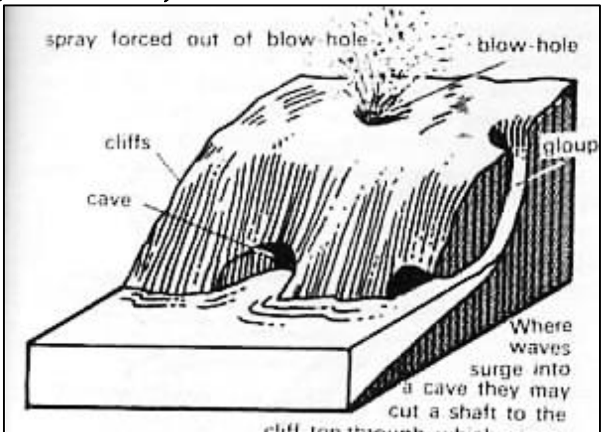
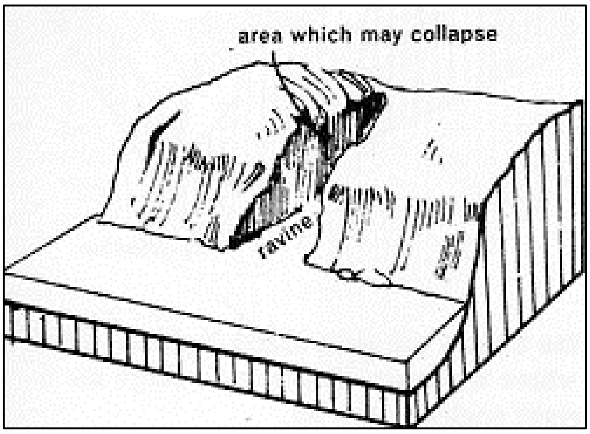
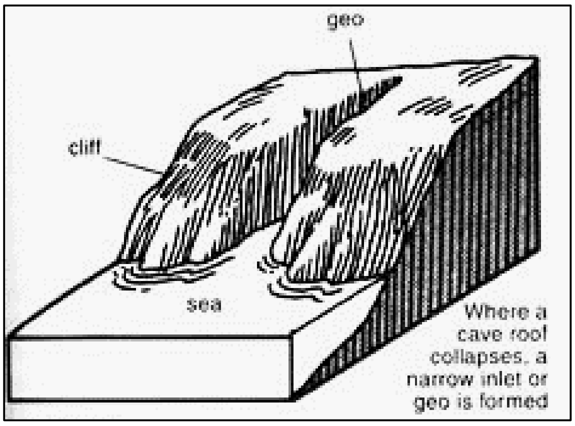


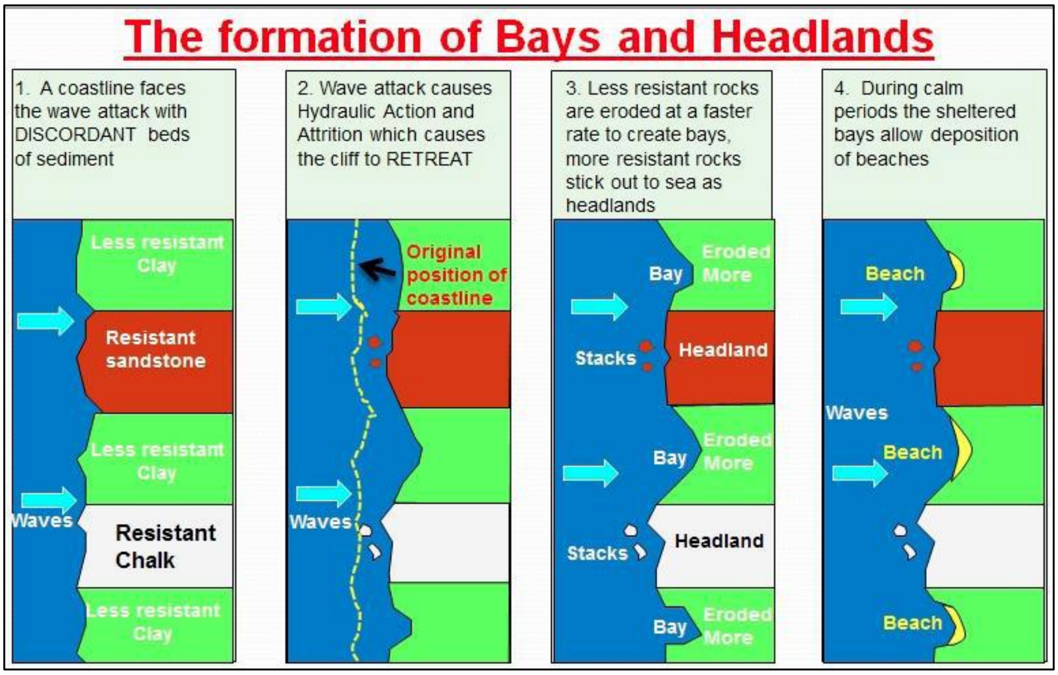
Fig. 79 Gloup

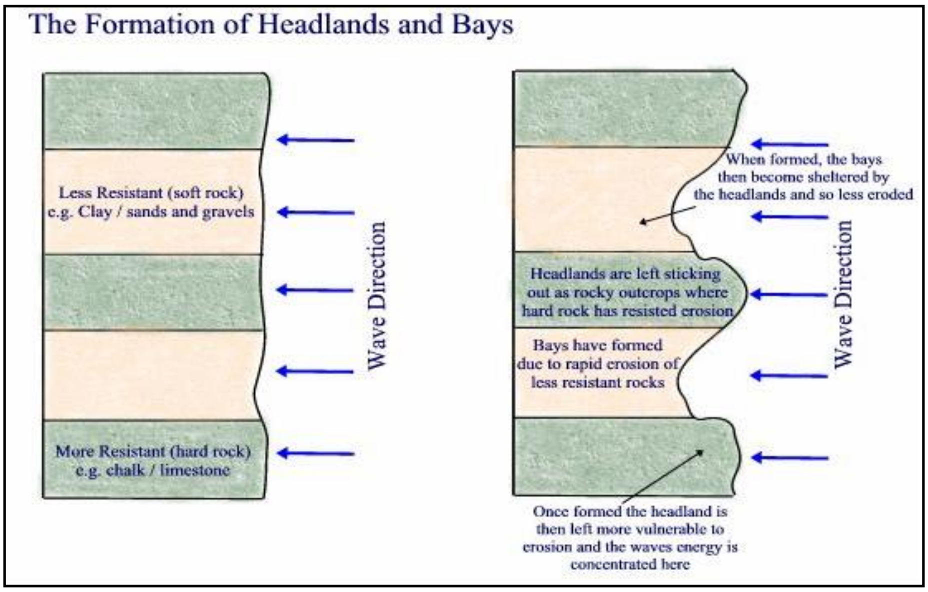
5. **Geo**: This is a ***deep, long and narrow steep sided inlet running inland from the edge of the cliff***. It is formed when the entire roof of the cave collapses due to continued wave erosion along major joints or faults.

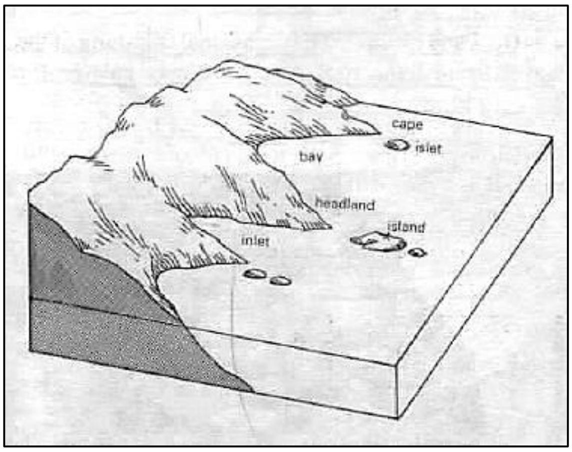




6. **Headlands and Bays**: A headland is a ***point of land which extends out into a body of water***. A bay is a wide ***indented area of land normally found between two headlands***. They are formed at coasts with alternating bands of hard and soft rocks outcrop at right angles to the coastline. The soft rocks are eroded to form bays while the hard rocks are left sticking out into the sea as headlands. Examples of bays are ***Kavirondo, Napoleon, Sango, Murchison, Homa and Winam gulfs on Lake Victoria***.







Bay and Headland at Kasenyi Landing site, Entebbe

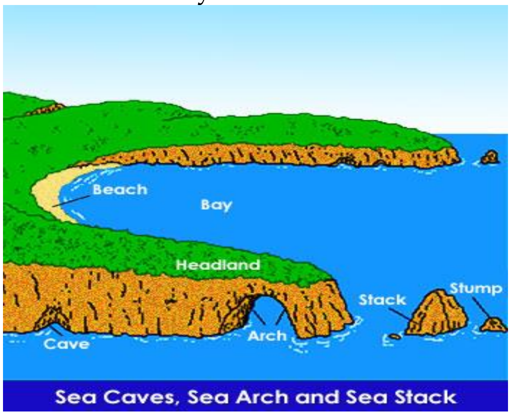
7. **Arch:** A sea arch is ***a natural opening eroded out of a cliff face or headland by wave erosion***. Destructive waves attack the foot of the cliff or headland through processes of wave erosion such as abrasion and hydraulic action, eroding areas of weakness e.g. **joints** - cracks in the rock. These cracks get larger developing into small **caves.** Further erosion widens and deepens the cave until it is eroded through the headland forming an **arch.** An arch may also be formed when two caves develop on either side of the headland and ultimately join creating a passage/tunnel through the headland.

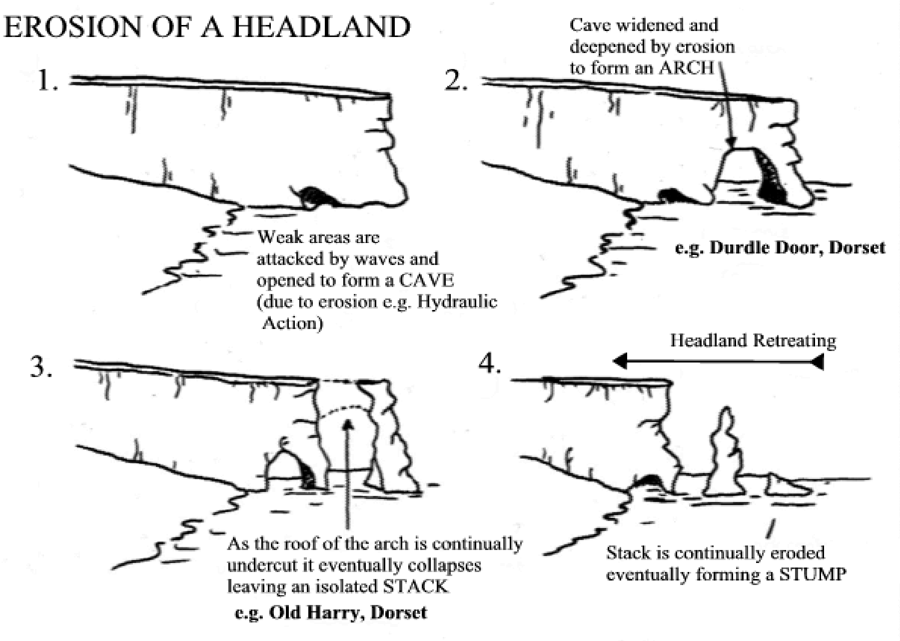
Double Door Sea Arch, Dorset Coast UK

8. **Stack or Island Rock**: This is ***a steep-sided isolated pillar or block of resistant rock separated from the mainland by sea***. Sea stacks begin as part of a headland or sea cliff. Relentless or continuous pounding of waves (hydraulic action) against a headland weakens cracks in the headland, causing it to later collapse, forming a free-standing pillar of rock called a stack. A stack may also form when a sea arch collapses under gravity due to sub-aerial processes like wind erosion. Examples can be seen at ***Kasenyi landing site along the shores of Lake Victoria in Entebbe***.

Stack at Kasenyi Landing Site, Entebbe

9. **Stump**: These ***are remains of eroded stacks that only appear at low tides***. It is formed when a stack is gradually eroded and eventually collapses to form a residual rock known as a stump. The stump is usually submerged during high tide and is only visible at low tide.

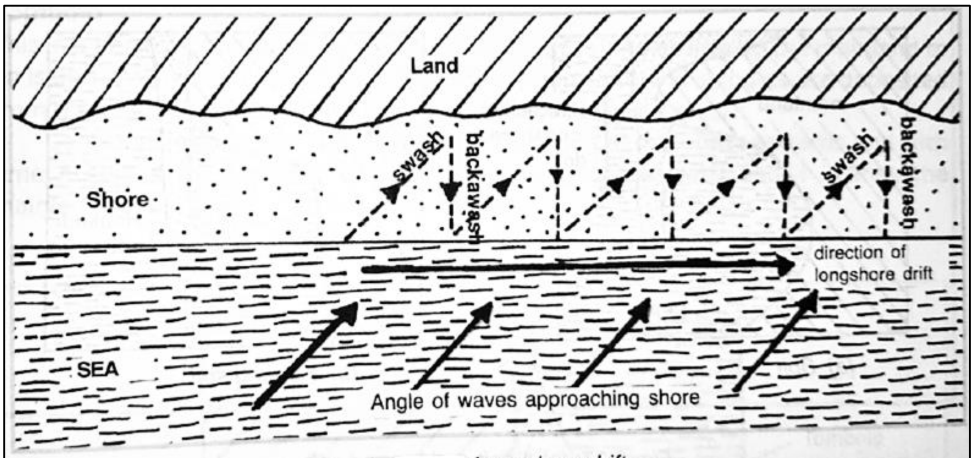




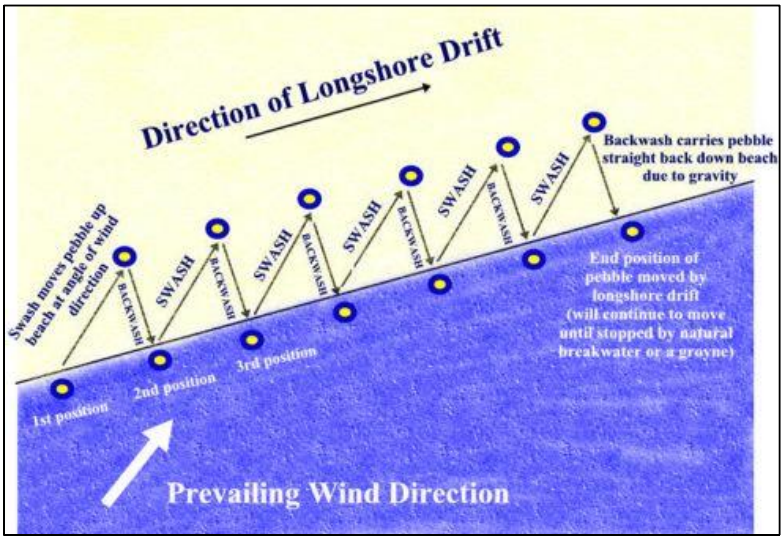
WAVE/MARINE DEPOSITIONAL LANDFORMS

Although some material eroded at the coast is washed out to sea, most of the material is transported along the coast by ***longshore drift***. Deposition will occur when the waves are no longer able to transport material due to a loss of energy. This is the case with ***constructive waves***, which are characterized by **a strong swash** that pushes the materials up the beach and **a weak backwash** that hardly removes the deposited materials. The smallest particles, such as silt and clay, are deposited away (farthest) from shore. This is where water is calmer. Larger particles are deposited on the beach. This is where waves and other motions are strongest. Deposition commonly occurs where the water is sheltered (e.g. a bay) and the waves lack energy; and where the coast is shallow and the increased friction between the water and the sea bed reduces the energy available for transport.

Longshore Drift: Waves break on the beach at an angle controlled by the prevailing wind direction. Swash moves materials diagonally/obliquely up the beach while backwash then moves material down the beach at right angles or straight back down the coast under the influence of gravity. As the processes continues material moves along the coast in a zigzag movement. This is longshore drift and it's responsible for deposition along the coast.

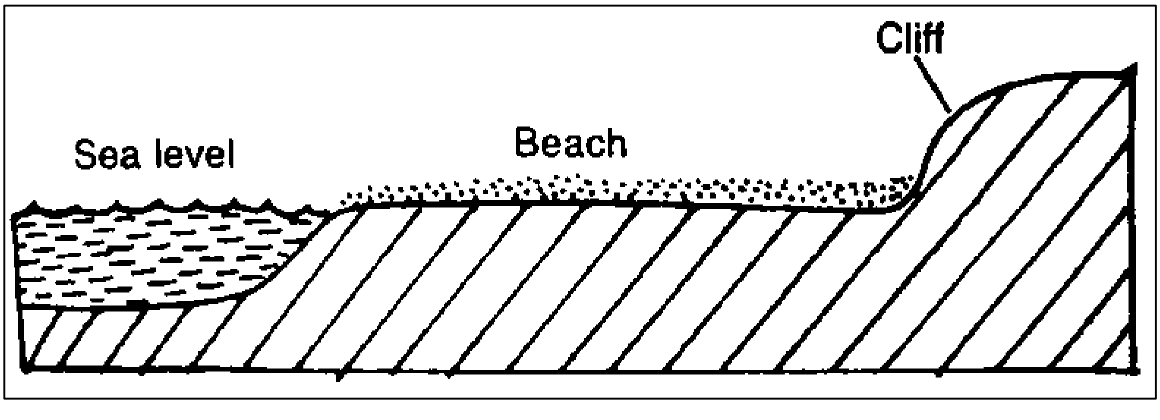


. Longshore drift.



Deposition of material results in the formation of a number of distinctive features as noted below.

1. **Beach**: This is the main feature of coastal deposition. A beach is defined ***as an accumulation of deposits such as sand, shingle, pebbles or a combination of all, along the coast; OR a gently sloping area of land between high tide and low tide water marks.*** The material that makes up a beach is derived from materials deposited at the mouths of rivers, or the erosion of cliffs along the coast. A beach is formed when longshore drift through constructive waves deposits materials on the shore. This occurs mostly during calm weather when constructive waves with a strong swash deposit sand and shingle up the coast; longshore drift brings more material from elsewhere along the coast. These materials accumulate between high tide and low tide to form a beach. Examples of beaches ***include Ssese Gateway beach, Resort beach, Nyali Beach in Mombasa, Ggaba beach, Lutembe, Aero and Sports beach***.

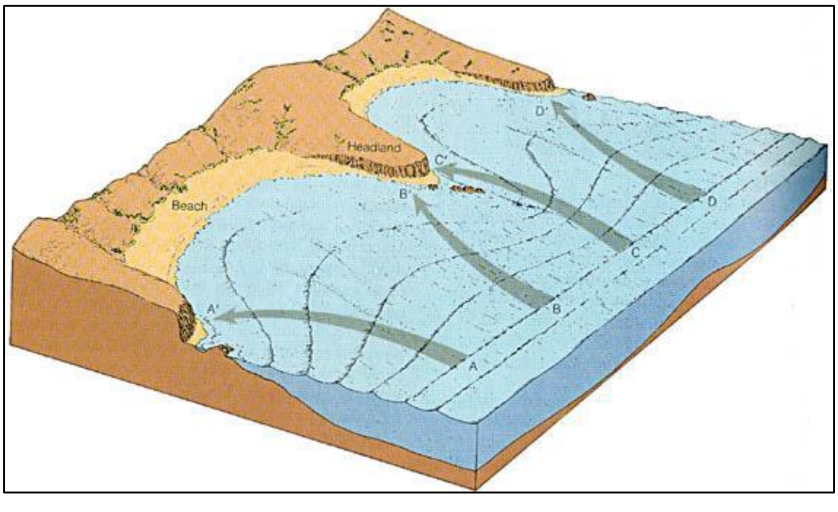


Kasenyi beach along Lake Victoria

2. **Barrier Beach or Bar**: This is ***a long sand or shingle ridge/bar above high tide, lying parallel to the coastline and separated from it by a lagoon***. They are formed on gently sloping coasts by longshore currents breaking off at a distance before the shore and depositing sand or shingle across the mouth of an inlet or harbor. Further deposition by wave action increases the height of the bar until it appears above sea level. The sand deposits gradually migrate towards the mainland as a barrier beach.

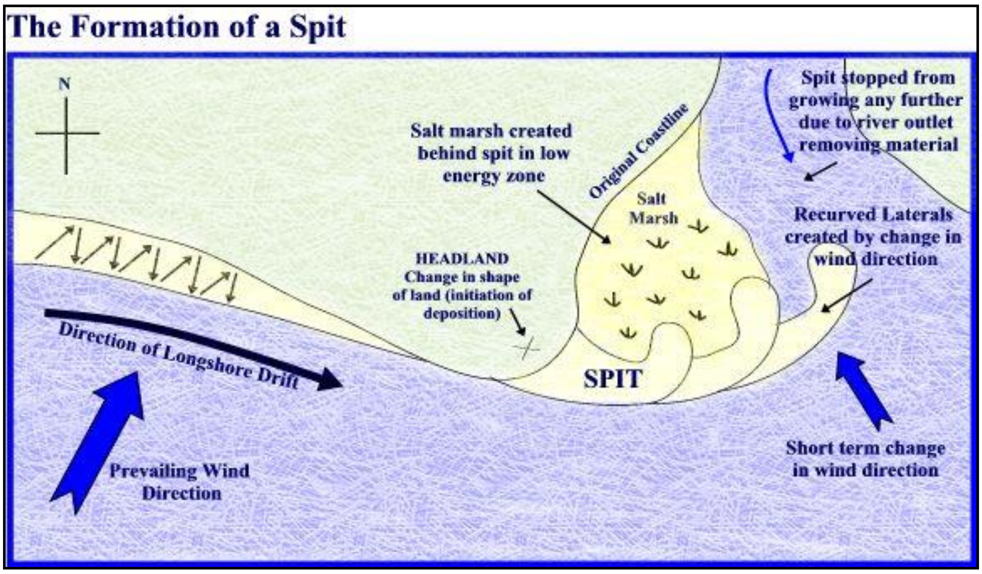
Barrier beach, NE coast of Canada

3. **Bay Beach or Bay Head Beach**: ***A crescent of accumulated sand, pebbles and shingles deposited by longshore drift between two headlands***. Bay head beaches develop at the head, or inner most part, of a bay where wave action is usually not very strong hence deposition occurs. The beach will not extend to the headlands since erosion from waves increases strongly towards the headlands and deeper water. Examples ***include Lutembe beach, Ggaba beach, Lido and Botanical beaches and at Kasenyi landing site along the shores of Lake Victoria***.



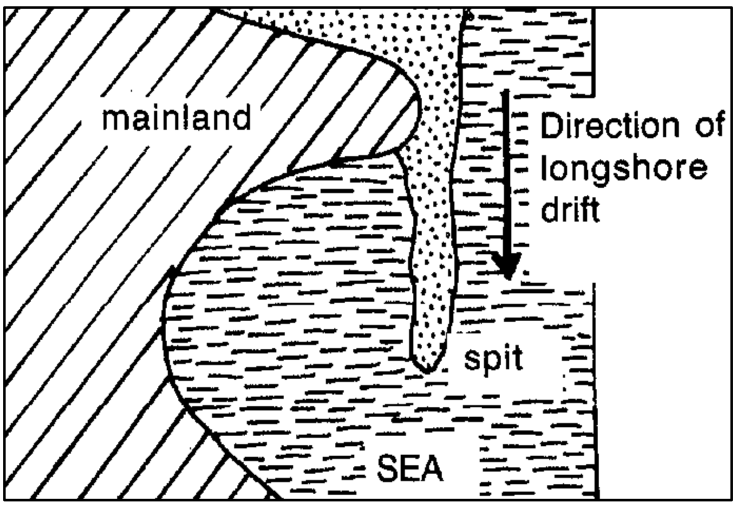
Bay head beach

4. **Spit**: This is ***a long narrow embankment or ridge of sand, shingle, pebbles or a combination of all the above, attached to the coast at one end and extending out into the sea***. Spits frequently form in areas of relatively shallow and sheltered water where the coast abruptly changes direction and often occur across the mouths of estuaries; they may lie parallel to the coast or grow at a curved angle to the coast. A spit is formed as longshore drift transports and deposits material along an indented coast, such as a river mouth or a bay. As material is deposited across the inlet it will pile up into a ridge or embankment of shingle, sand or pebbles forming a tongue or spit, with one end attached to the land and the other end projecting into the sea. If the spit grows to completely block a bay, it is called a **bay barrier** or **baymouth bar**. A salt marsh or lagoon may form in the sheltered, low energy zone behind the spit. Examples of spits include ***Butiaba and Buhuka spits on LakeAlbert***.



A Spit

A Baymouth Barrier

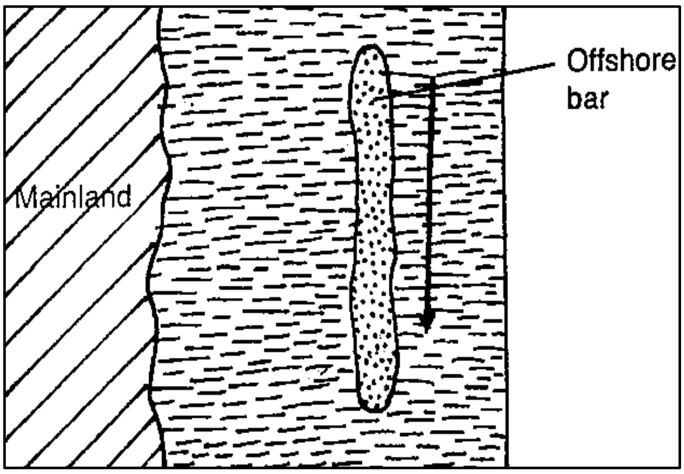


5. **Cuspate Spit**: This is formed when the spit re-curves and becomes attached to the shore at both ends.

6. **Cuspate Foreland**: This is ***a large triangular shaped deposit of sand and shingle or gravel projecting seaward; OR, a triangular accumulation of sand and shingle or gravel located along the coastline***. It is formed by the joining/converging of two spits at right angles enclosing a mass of water/lagoon. The lagoon is slowly covered up by silt and later colonized by vegetation. Their origin is also due to longshore drift operating on a coastline from two different directions. The two sets of storm waves build up a series of ridges, each protecting the material behind it, creating the triangular feature. Examples include ***Tonya and Kaiso cuspate forelands on Lake Albert***.

Cuspate Foreland, Chicago (USA)

7. **Offshore Bar**: This is ***a long narrow ridge of deposited materials such as sand, shingle, gravel and mud lying away from and parallel to a coast***. They are formed on gently sloping coasts and irregular coastlines when longshore drift repeatedly deposits materials before reaching the coast due to friction between the waves and the sea bed causing the waves to break at some distance from the coast. Over time, more materials are built up parallel to the coast to form ridge of sand called offshore bar. A body of coastal water may be partially or completely cut off from the open sea by the offshore bar called a lagoon. An example is at ***Lamu in Kenya***.



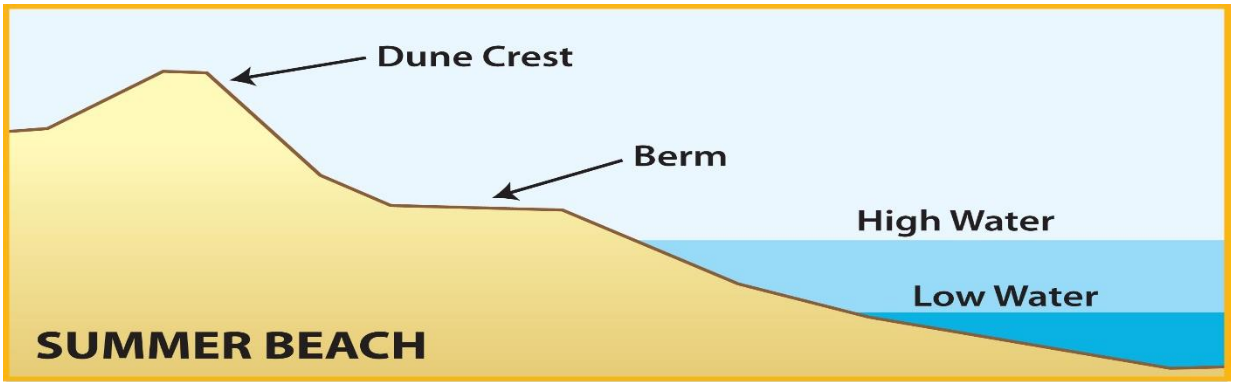
Offshore Bar

8. **Mudflats and Marshes or Tidal flats**: These are ***coastal wetlands found in sheltered areas such as bays, lagoons and estuaries; OR platforms of mud, silt and other forms of alluvium deposited along gently sloping coasts especially in bays and estuaries***. They are formed when large amounts

of mud, alluvium and silt are deposited by tides or rivers along a gently sloping coast. The deposited materials settle and build up a platform called a ***Mudflat*** or ***Tidal flat***. When it is colonized by vegetation it is known as a ***Marsh***. At low tide the mud is exposed as a mud flat leaving water only in permanent channels. At high tide the mud flat is covered with water. Examples can be seen at the mouth of ***R. Rufigi near Tanga***.

Mudflat

9. **Beach Berm**: This is ***a bench or ridge or terrace of a beach with a steep front found on the backshore or upper part of the beach, above the water level at high tide***. They are formed by the deposition of sand and other materials by low energy waves. They develop on beaches with a steep slope and where swash is stronger than backwash.

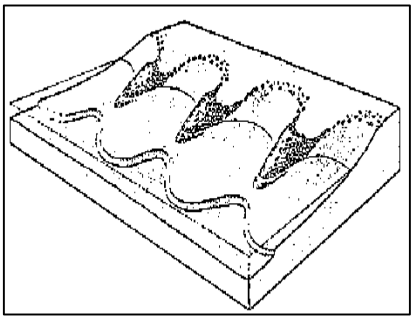


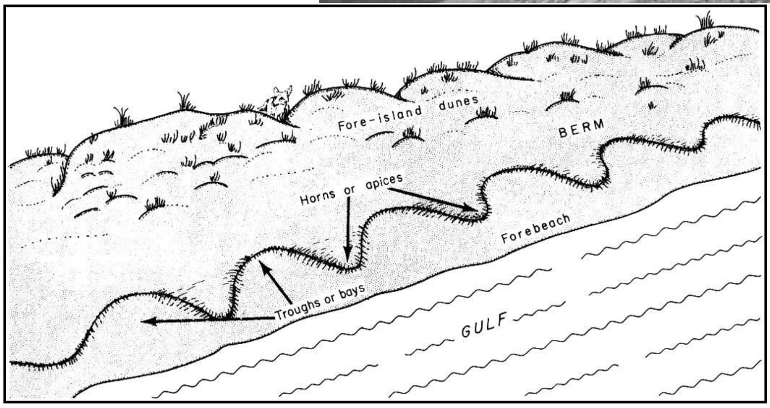
10. **Beach Rock**: This is ***a hard crust-like deposit of well cemented sedimentary rock projecting above the beach sand***. The sediment that is cemented to form beach rock can consist of a variable mixture of shells, coral fragments, rock fragments of different types, sand, shingle, pebbles, and other materials deposited by waves and cemented by calcium carbonate.

Beach rock along shore of Reunion Island

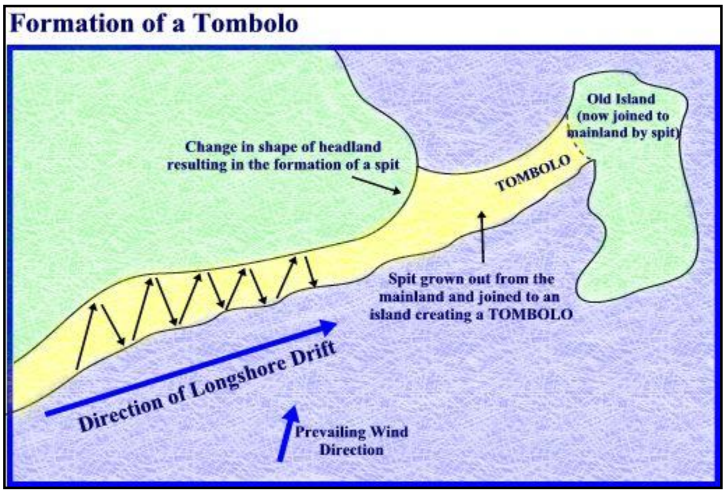
Beach rock composed of shell and coral fragments (sandstone)

11. **Beach Cusps**: These are ***horn shaped or crescent pattern projections of sand and shingle pointing seawards, separated by shallow and narrow indentations***. These relatively uniformly spaced beach features are composed of a series of ridges (horns or apices) and troughs (bays) that are roughly perpendicular to the shoreline. They are formed where large waves break parallel to the shore.





12. **Tombolo**: This is ***a ridge of sand, shingle and pebbles connecting an island to the mainland***. They are created through the process of longshore drift. A tombolo is formed where a spit continues to grow until it reaches an island, forming a link with the mainland. The ideal condition for their formation is an ample supply of material or debris for wave deposition to form connecting ridges and a low tidal range such that the deposited debris is not removed. An example used to be on ***Lake Victoria joining Bukakata landing site to Lambu*** *Island* but it was destroyed by heavy rains.



SEA LEVEL CHANGES (MARINE EUSTATISM)

Sea level change is the rise or fall of the sea relative to the adjacent land or a fixed point. Eustatic sea-level changes occur on an oceanic to worldwide scale. They result from either a change in the volume of seawater, or a change in the size of the ocean basin that contains it. Present-day sea level change is of considerable interest because of its potential impact on human populations living in coastal regions and on islands. The change in sea level can be positive or negative. A **positive change** in sea level is called ***submergence*** or ***sea/marine transgression***. In this case there is ***a rise*** in sea level. A **negative change** in sea level is called ***emergence*** or ***marine regression***. Here there is ***a fall*** in sea level.

Causes of Marine Eustatism

1. **Glaciation and Deglaciation**: Glaciation during the last ice age caused a fall in sea level because huge amounts of water froze into ice on high mountains and ice sheets in the Polar Regions. This occurred during the ice age of the Pleistocene period, approximately 2 million years ago when there was severe glaciation and the water was converted and stored as ice. However, deglaciation during the inter-glacial period characterized by warmer global temperatures melted thick ice sheets from continental landmasses causing a rise in global sea level when the water was released into oceans.

2. **Earth or Tectonic movements**: These are related to processes of warping, faulting, vulcanicity and seismic activity.
Up warping of coastal areas leads to a fall in the sea level (**emergence**) while down warping of coastal areas results into a rise of the sea level (**submergence**).

Up warping within the ocean basin will result into a rise in the sea level while down warping in the ocean basin results into a fall in the sea level.

Enlargement or expansion of the ocean basins due to plate divergence leads to a fall in sea level (**emergence**) e.g. the Atlantic Ocean is experiencing emergence of its coastlines since it's getting larger as plate movements cause North and South America to drift away from Europe and Africa respectively. On the other hand, contraction/narrowing of ocean basins due to plate convergence leads to a rise in sea level (**submergence**).

A regional uplift of the coastal areas due to faulting results in a fall in sea level while sinking of the coastal areas due to faulting results in a rise in sea level.

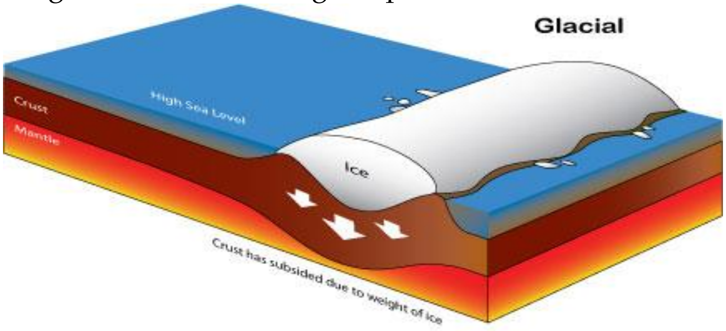
Volcanic activity along the mid-ocean ridges (as well as sub aerial vulcanism) releases lava onto the ocean basin which displaces water causing a rise in sea level.

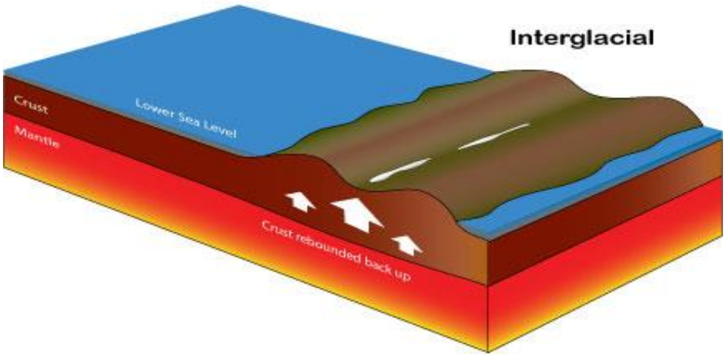
Earthquakes can cause both uplift and depression of land as a result of movement along fault planes hence rise or fall in seal level.

3. **Sedimentation**: Mainland rivers and streams discharge/deposit large quantities of sediments into ocean basins which displace water upwards hence a rise in sea level (**submergence**).

In addition man's activities such dumping of wastes results in displacement of water upwards within the ocean basins resulting in a rise in sea level. However, dredging, that is, removal of sediments, results in a fall in sea level.

4. **Isostatic changes**: Addition of material on continental areas increases weight on those areas causing continents to sink slowly hence a rise in sea level for example during glacial periods, ice accumulation pushes down on the crust, causing the lowering of the land relative to sea level thus a rise in sea level. This is called isostatic depression. When the ice sheets melt isostatic uplift occurs through reduction of weight on land, resulting in uplift of the land or crust thus fall in sea level.

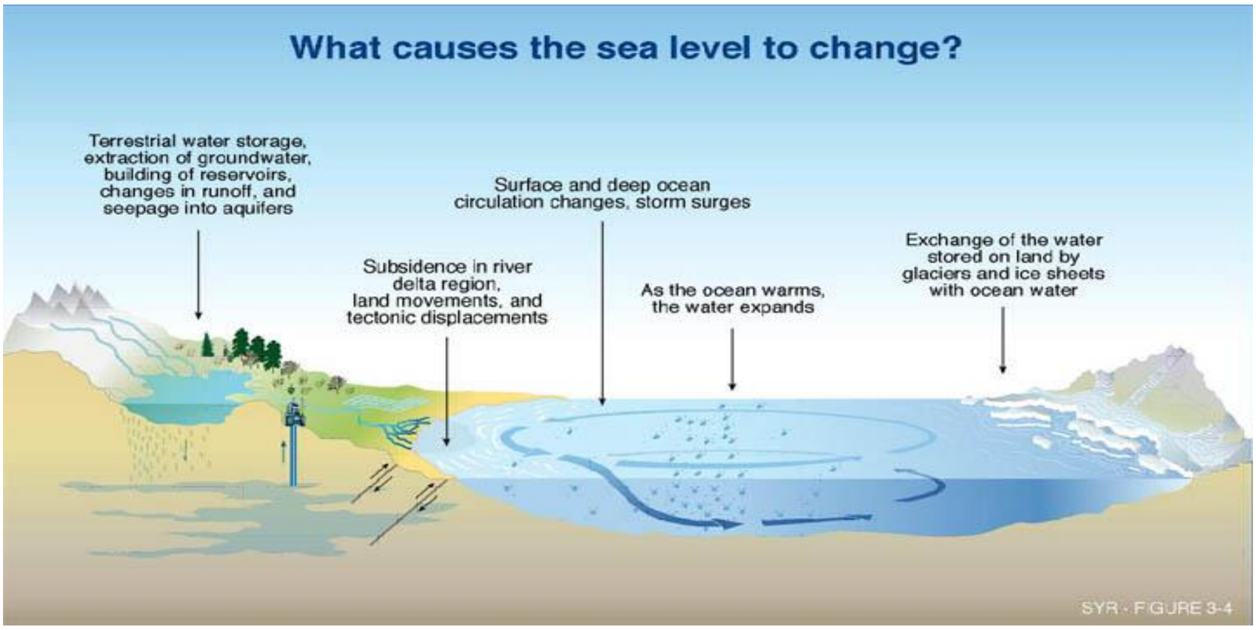




5. **Climate Change** (Pluviation and Desiccation): When there is an increase in rainfall such as El Nino and monsoons the sea level will rise since water will find its way into water basins either directly or indirectly through streams (pluviation), for example, the prolonged rainfall in 2019/2020 led to a rise in water levels on L. Victoria. On the other hand, abnormal shortage of rainfall results into a fall in sea level due to excessive evaporation of water from the sea during the prolonged dry season (desiccation).

6. **Thermal expansion of oceans**: As the global climate warms, the average level of the ocean is gradually increasing, because warmer water occupies a greater volume. Hot temperatures warm up water bodies making the water molecules to expand thus a rise in sea level. However during winter when temperatures go down, water molecules contract resulting in a relative fall in sea level.

7. **Global warming**: The steady rise in the average temperature over the surface of the earth is affecting climate by melting ice on continental landmasses, bringing erratic rains and flooding hence the rise in sea level. This has been attributed to the increase of greenhouse gases like carbon dioxide, methane and chlorofluorocarbons (CFCs) in the atmosphere. These gases are associated with the growing industrial pollution, increased automobile emissions and the destruction of large tracts of forest, especially in the tropical regions of the planet. Because these "greenhouse gasses" tend to trap heat within the earth atmosphere, the expected result is an increase in the rate of sea-level rise due to melting of glaciers and ice caps.



Summary of the causes of Sea level Change

Sea level changes have a great effect on the geography of the coast. When the sea level rises, areas around the coast become submerged or flooded, however, when the sea level falls, areas that were once submerged, appear or emerge. Thus there are two basic types of coasts;
(a) Submerged coasts resulting from a rise or positive change in sea level,
(b) Emerged coasts resulting from a fall or negative change in sea level.

SUBMERGED COASTS:

When the sea level rises coastal areas that were originally dry become submerged. The resulting features can be divided into two broad categories, i.e. highland features and lowland features.

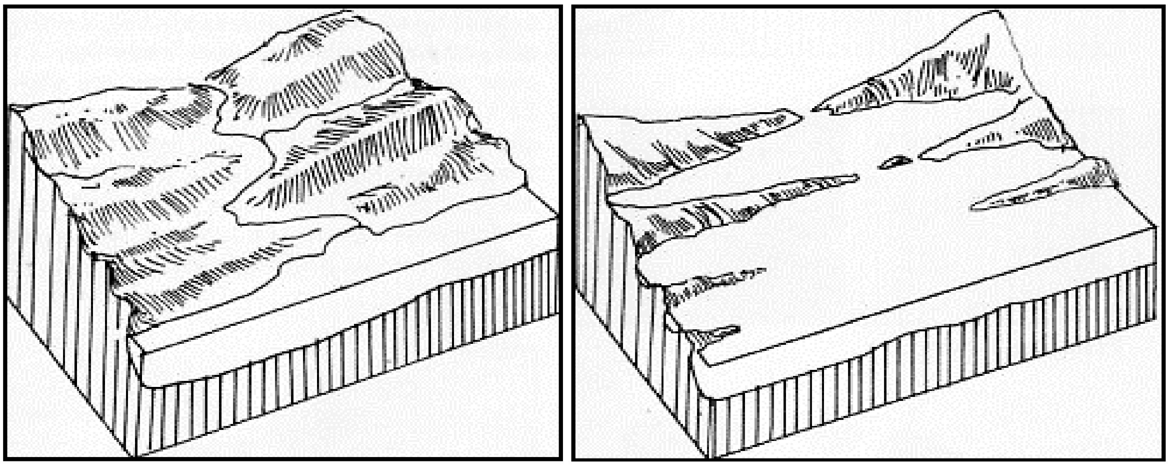
Submerged Highland Coasts:

1. **Ria**: This is ***a long, narrow drowned river valley that lies perpendicular/at right angles to the sea***. Before submergence, the river flows into the ocean through narrow valley. When the sea level rises, the lower parts of the river valley are flooded or drowned to form a ria. The sea level rises and fills up/floods the valleys around the hills. The old hilltops stick up above the surface of the water and the old rivers' valleys become deep bays. The ria is funnel shaped or v-shaped channel, wider and deeper at the entrance but shallower and narrower inwards. Examples include ***Kilindini harbour and Dar el Salaam harbour***.

Before submergence: This is the terrain before sea level rises (or the crust subsides, or both). Active streams have carved the valleys and continue to do so.

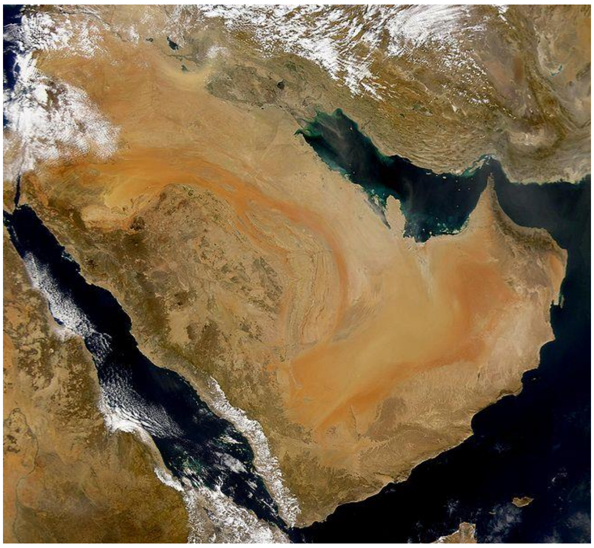
Submergence: Rising sea levels and/or crustal sinking submerge existing coastline. The shoreline rises up the sides of the stream-carved valleys, creating narrow bays. Streams that occupied the valleys add freshwater to the bays, making them estuaries of mixed fresh and saline waters. Streams also provide sediment to the shoreline.

2. **Dalmatian or Longitudinal Coast**: This is ***a coast with a chain of off islands running parallel to it***. These form when valleys parallel to the coast become flooded/submerged due to a rise in sea level and the tops of ridges now appear as chains of islands parallel to the new coast. The drowned valleys between the island chains are sometimes referred to as ***sounds***. Examples include ***Pemba and Zanzibar islands; Smith sound on Lake Victoria***.



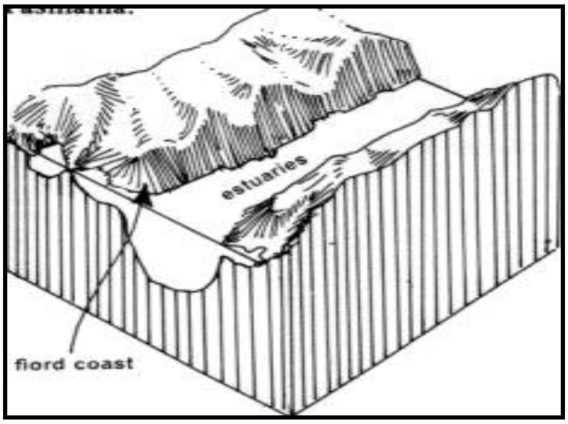
Before Submergence After Submergence

3. **Peninsula**: This is ***a piece of land that is almost entirely surrounded by water but is connected to the mainland on one side OR an elongated piece of land projecting/extending towards the sea***. A peninsula can also be ***a headland (head), cape, island promontory, bill, point, or spit***. It is formed where highlands lie at right angles to the coast and their valleys are later submerged or drowned leaving the highlands or peaks projecting into the sea as a peninsula. Examples include ***Entebbe peninsular; the Horn of Africa, which juts into the Arabian Sea; among others***.



Arabian Peninsula

4. **Fjord or Fiord**: This is ***a long, deep narrow inlet with steep sides or cliffs, formed along glaciated upland coasts***. Thus it is a drowned or submerged glacial valley. These were formed when glaciers eroded the valleys below sea-level, forming a U-shaped valley or glacial trough. When the ice melted the valleys were flooded or submerged when the sea level rises. Fiords are common in the coasts of New Zealand, Norway and Sweden.



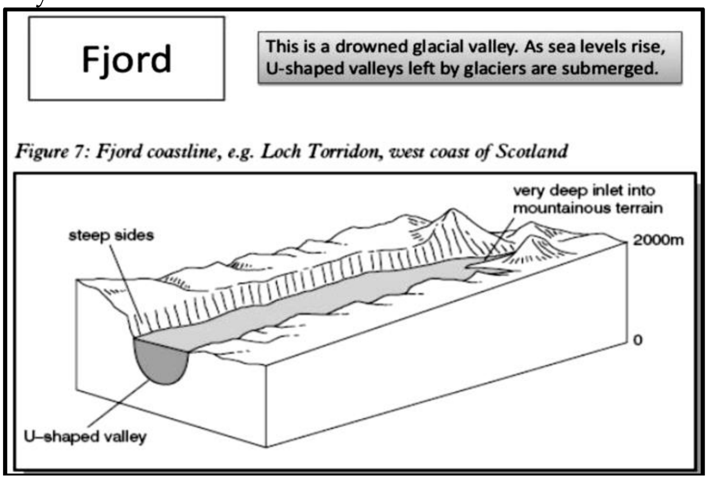
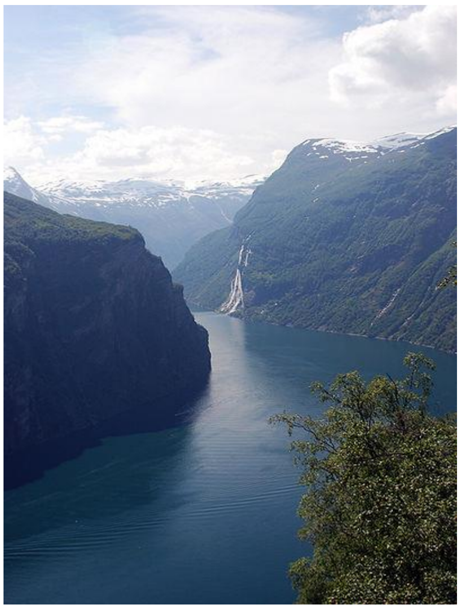


Figure 7: Fjord coastline, e.g. Loch Torridon, west coast of Scotland

Fiord, Norway



Geirangerfjord, Norway

Submerged Lowland Coasts:

1. **Estuary**: This is ***a drowned river mouth in a lowland area/coast***. They are usually wide, shallow and funnel shaped. An estuary is similar to a ria except that a ria is formed in a submerged

highland coast while an estuary is formed in a lowland coast. A rise in sea level along a lowland coast causes the sea to penetrate or flood inland areas along a river valley. The flooded parts of the river valley form the estuary. They are often known as ***bays, sounds, lagoons, harbors, or inlets*** (note though that not all water bodies by those names are necessarily estuaries). Estuaries can be found at the ***mouths of rivers Rufigi and Wani*** along the East African coast.

Estuary - River Nith, Scotland

2. **Mudflats**: These are ***platforms composed of deposits of fine silt and alluvium from rivers or waves***. They are formed when mud, alluvium and silt are deposited continuously by rivers along a gently sloping coast as the river joins a sea or ocean. The deposited materials settle and build up a platform called a ***Mudflat*** or ***Tidal flat***.

3. **Swamps and Marshes**: These are formed along the sea resulting from a rise in sea level. When a mudflat is colonized by vegetation it is known as a ***Marsh*** or ***Swamp***.

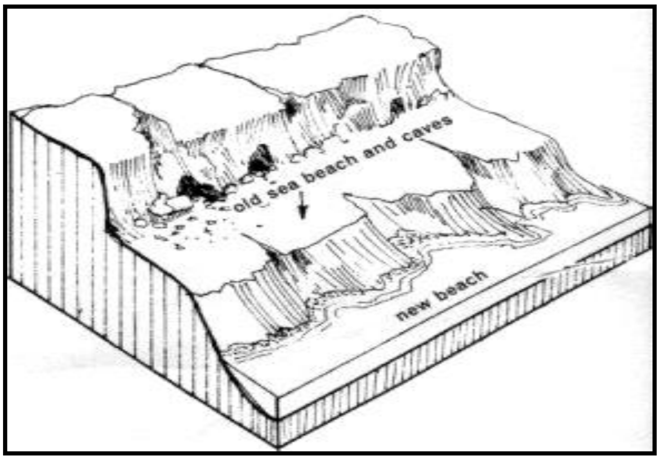
EMERGED COASTS

Emerged coasts develop where there is ***a fall or regression in sea level***. In this case the land which was originally covered by water is now exposed or emerges or appears leading to the formation of emerged features (Coastal areas which have become raised above current sea level). Emergence is mainly due to isostatic readjustment (**isostacy**, or **isostatic uplift**).

Emerged or Raised Coast

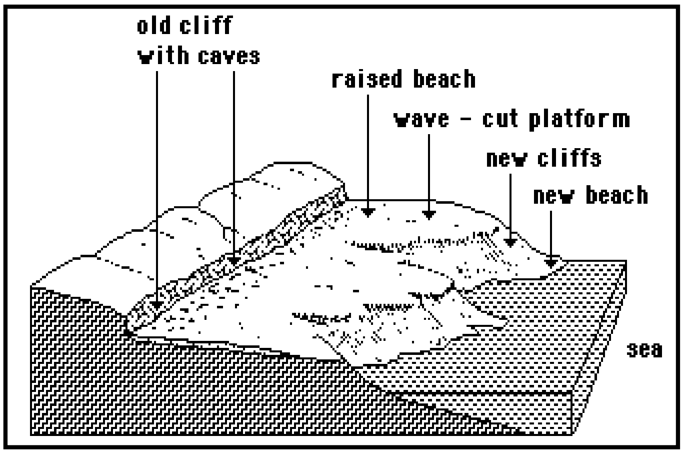
Feature formed by emergence of coasts include;

1. **Raised Beaches**: This is ***a beach that is raised above the shoreline by a relative fall in sea level, OR a gently sloping surface with accumulation of sand, shingles and pebbles deposited by constructive waves that now appears above the current zone of wave action due to a fall in a sea level***. Before submergence, constructive waves deposit sand and shingle materials to form a gently sloping platform called a beach. When the sea level falls, wave action also falls to lower levels or to a low tide thus deposition will take place at the low tide level forming a new beach. The original beach is left high above the present zone of wave deposition, and is called a **raised beach**. Examples can be found at ***Bagamoyo, Diani, Shimoni and Tiwi beaches*** along the East African coast; the ***Entebbe peninsula*** has a series of raised beaches.



Raised Beach, British Isles

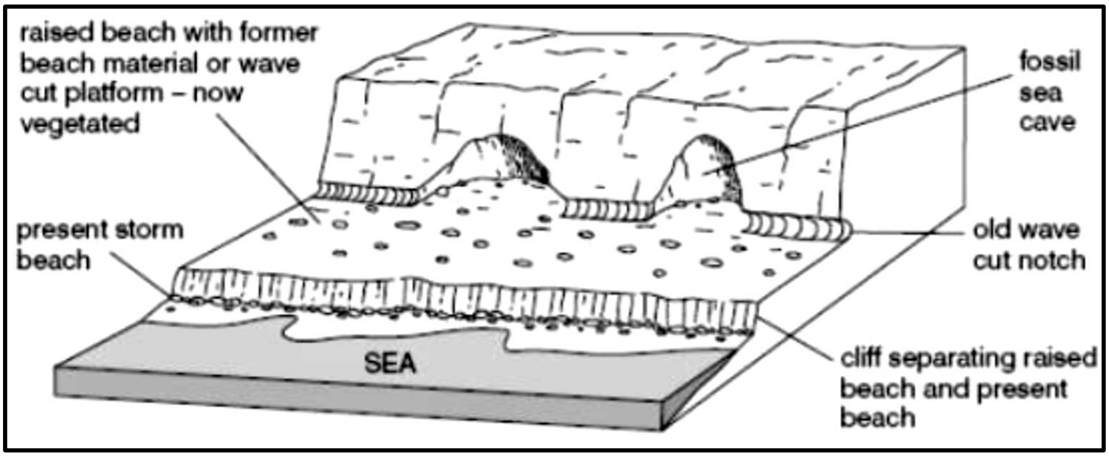
2. **Raised Cliff**: This is ***a steep rock face along the coast left hanging above the present zone of wave erosion***. This is formed when the sea level falls and a new cliff is created at a lower level by wave erosion processes like hydraulic action and solution. The original cliff is left high above the present zone of wave erosion and high tide. Examples can be found at ***Lamu, Malindi, Bagamoyo, Kilwa and Tanga along the East African coast***.



Raised Cliff

3. **Raised Wave-cut Platform or Wave Terrace**: This is ***a gently sloping surface at the base of a raised cliff that is no longer in contact with the water***. This is formed when the sea level falls and a wave-cut platform that was originally submerged is exposed while a new wave-cut platform is formed at the current sea level.

4. **Raised or Exposed Caves**: This is ***an exposed cylindrical tunnel-like opening at the base of the raised cliff formed due to wave erosion by hydraulic action and abrasion processes during the period of contact with the sea water***. Such caves were previously covered or submerged by water and are now visible after a fall in sea level.

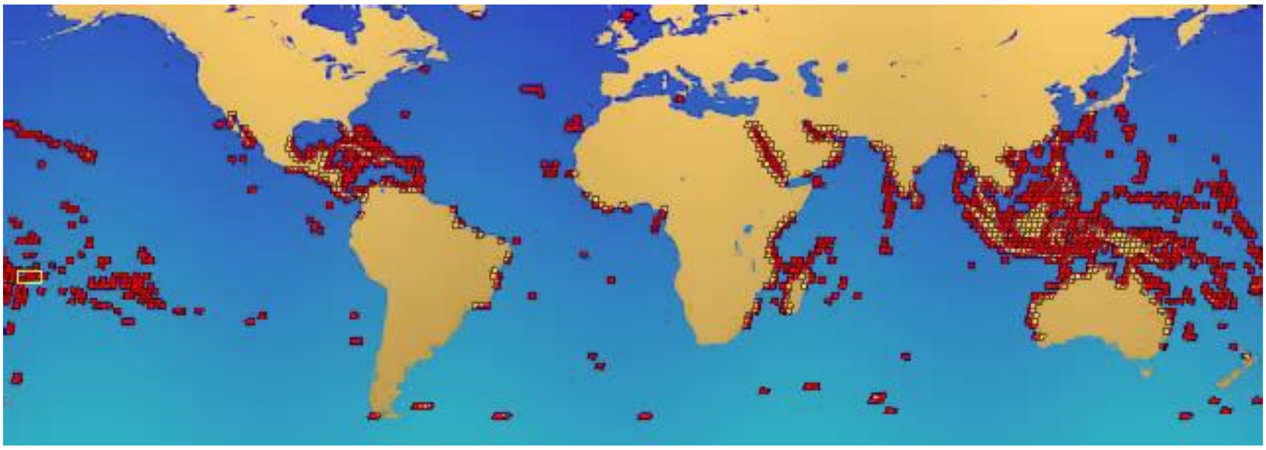


5. **Waterfalls**: Sometimes if the river was pouring its waters into the sea (mouth) before a fall in sea level, when there is a fall in sea level a waterfall is formed since the land is raised and the water pours over a cliff into the sea, for example Robe falls in Cameroon.

CORAL REEFS

A coral reef is ***an underwater/offshore structure/platform composed of limestone or calcium carbonate from the skeletons or shells of tiny sea organisms called coral polyps***. Coral reefs are colonies of tiny living animals found in marine or sea waters formed as a result of the deposition and accumulation of shells or exoskeletons of dead coral polyps. Polyps are tiny marine organisms that live in colonies at shallow depths in sea water. When they die, their exoskeletons which are made of calcium carbonate are deposited and accumulate on the continental shelf, over time there is compression, compaction, consolidation and cementation of the shells to form coral reefs or coral rocks. The process of cementation is facilitated by other organisms such as algae. The nature of coral landforms formed depends on the position and shape of the landmass on which coral rock have accumulated. There are three distinctive types of coral reefs, namely fringing reefs, barrier reefs and atolls.

Coral reefs are the most diverse of all marine ecosystems providing a home for 25% of all marine species. Coral reefs are most commonly found at shallow depths in tropical waters, such as off the coast of East Africa and in the Indian Ocean islands.



Coral reef locations

Conditions favoring the growth and development of coral reefs

(a) Warm temperatures between 20-30^0 C ideal for growth of coral polyps. This means that reef-building corals are only found in tropical and sub-tropical waters within 30^0 North and South of the equator. Extensive corals are found on the eastern side of land masses where warm ocean currents flow, such as the warm Mozambique current along the East African coast.

(b) Salty sea water with salinity between 27 to 40 parts per thousand. This is because coral polyps develop hard exoskeletons from the calcium extracted from the salty sea water.

(c) Shallow water depth less than 25m to allow penetration of sunlight and oxygen to support photosynthesis by the symbiotic algae (***zooxanthellae***) that provide nutrients to coral polyps.

(d) The water must be clean, clear, silt or sediment free, calm or stable and well oxygenated to enable penetration of sunlight for photosynthesis to take place for the survival of symbiotic algae/planktons on which coral polyps feed. Silt may also block the mouths of corals, preventing feeding. Consequently coral reefs do not locate near the mouths of sediment-filled/silty rivers.

(e) Presence of abundant coral polyps from whose exoskeletons coral landforms are created.

(f) Presence of a solid bed rock such as, continental shelf, oceanic ridge or volcanic island on which corals grow.

(g) Absence of strong currents which would prevent the deposition, accumulation and compaction of coral polyps, i.e., the water must be relatively stable.

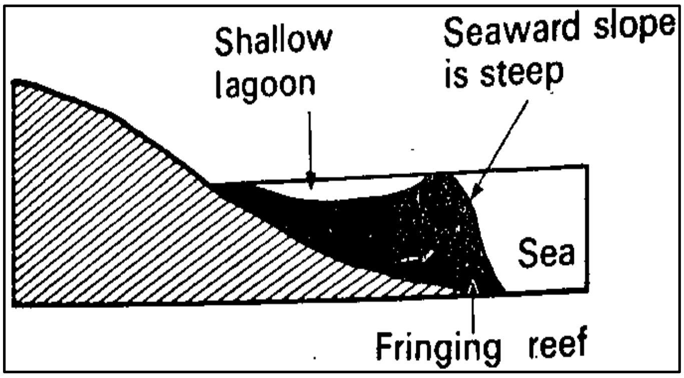
(i) Abundant supply of planktons which act as food for coral polyps.

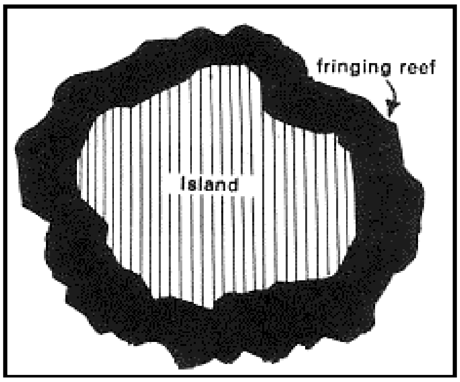
TYPES OF CORAL REEFS

Coral reefs begin to form after coral larvae attach to submerged edges of islands or continents. As the corals grow and expand the reef begins to take on one of three characteristic structures – fringing, barrier, or atoll.

FRINGING REEFS

This is the most common type of reef. They are located or formed very close to land, and often separated from the coast by a ***narrow and shallow lagoon***. They are formed by gradual build-up in the border of the shallow offshore zone until they reach sea level. The top of the reef is usually flat. This type of coral reef is the most common type of reef found in the Caribbean and Red Sea; others can be found along the East African coast at ***Kilifi, Tanga and Mombasa***.

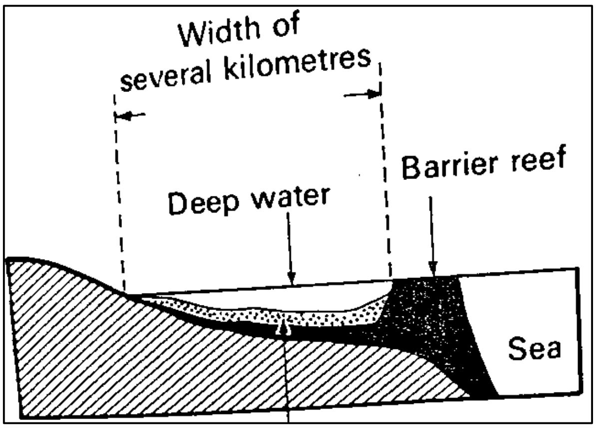


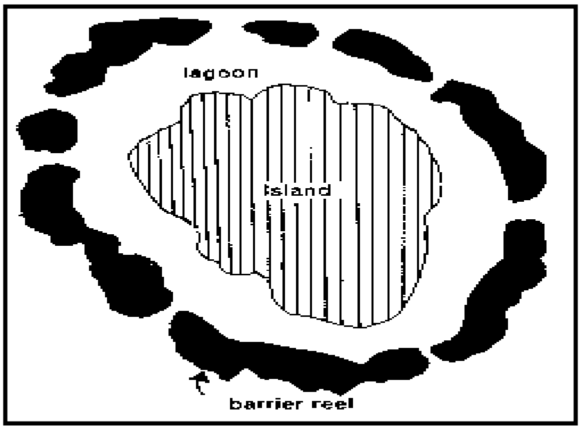


Fringing reef off the coast of Eilat, Israel

BARRIER REEFS

This type of reef is separated from a mainland or coast by a ***deep and wide lagoon***. It's formed much further from the coast and can be much bigger than a fringing reef. There are narrow gaps at intervals along barrier reefs, through which excess water from breaking waves is returned from the lagoon to the open sea. Examples include ***Mayotte in the Comoros Islands of Mozambique; Grant Reef of Tulear in Madagascar; the Great Barrier Reef of Australia***.

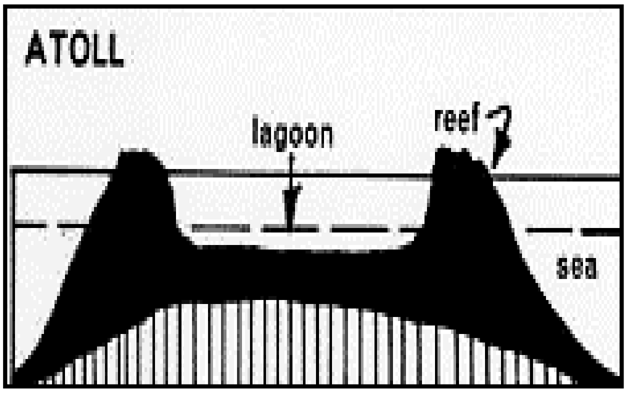


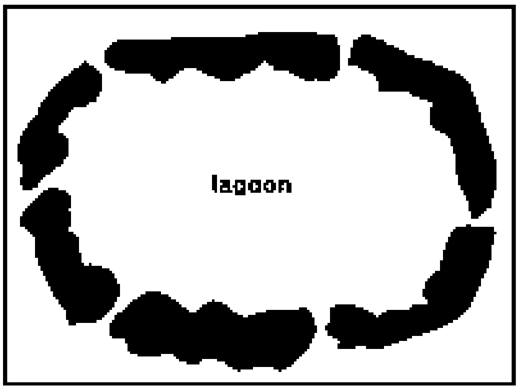


Barrier Reef

ATOLL

These are circular or horseshoe-shaped reefs encircling or surrounding a ***fairly deep lagoon*** but generally broken in places by narrow channels. Atolls have no land inside. Most atolls are rings of coral growing on top of old, sunken volcanoes in the ocean. They begin as fringe reefs surrounding a volcanic island, then, as the volcano sinks, the reef continues to grow, and eventually only the reef remains. Examples include ***Aldabara atoll 700km from the East African coast in the Indian Ocean; most of the world's atolls are in the Pacific Ocean (with concentrations in the Tuamotu Islands, Caroline Islands, Marshall Islands, Coral Sea Islands, and the island groups of Kiribati, Tuvalu and Tokelau) and Indian Ocean (the Atolls of the Maldives, the Laccadive Islands, the Chagos Archipelago and the Outer Islands of the Seychelles***.





Atoll

THEORIES OF CORAL REEF FORMATION OR GROWTH

Many scholars have put forward theories in an attempt to explain the mystery surrounding the formation of coral reefs.

Darwin's Theory of Subsidence:

In 1842, Charles Darwin hypothesized an evolution of reef formation. He suggested that, reefs develop around a volcanic island and as the island itself gradually subsides due to isostatic re-adjustments, coral reefs grow upwards and outwards keeping pace with the rate of subsidence and maintain themselves at the water surface. Thus according to his theory, a fringing reef forms first, and starts growing in the shallow waters close to a tropical volcanic island. Over time, the island subsides due to loss of isostatic equilibrium due to a volcanic eruption, the coral was able to keep pace in terms of growth and remained in place at the sea surface, but farther from shore as a barrier reef. Eventually, the island disappeared below the sea surface, leaving only the ring of coral encircling the central lagoon as an atoll. Darwin speculated that underneath each lagoon should be a bed rock base – the remains of the original island. Subsequent drilling into atolls proved this prediction true.

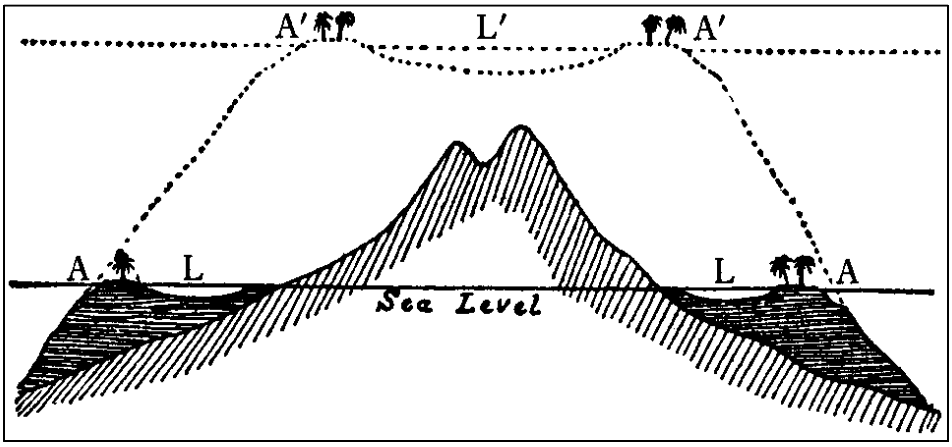


Diagram showing the formation of an atoll during subsidence. (After C. Darwin) The lower part of the figure represents a barrier reef surrounding a central peak.

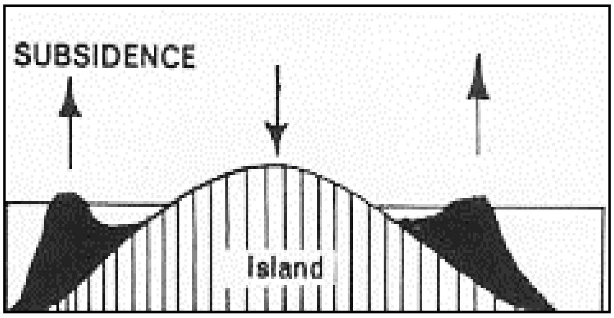
A, A, - outer edges of the barrier reef at the sea-level; the coconut trees indicate dry land formed on the edges of the reef.

L L - lagoon channel.

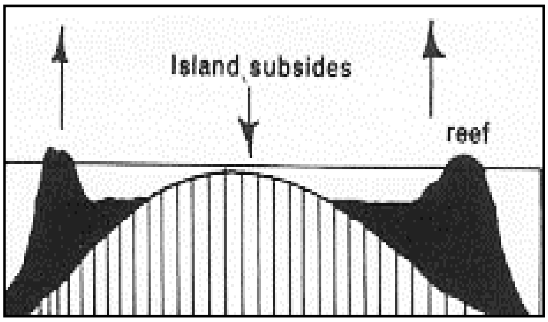
A', A', - outer edges of the atoll formed by up growth of the coral during the subsidence of the peak.

L' - lagoon of the atoll.

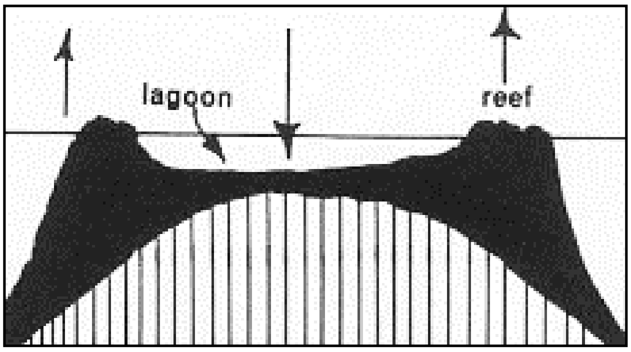
The vertical scale is considerably exaggerated as compared with the horizontal scale.



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.

Relevance of the theory

The theory is relevant in that;

a) There was actual submergence of the East African coast evidenced by the presence of rias at Mombasa, mudflats, and Dalmatian coast along the coastal areas of East Africa.

b) The presence of volcanic islands off the East African coast in the Indian Ocean with coral reefs for example at Aldabra.

c) The presence of coral shorelines all at different stages of developments along the East African coast is a proof for Darwin's theory.

d) Coral reef thickness increases downwards supporting the view of coral reef formation along the subsiding base of submarine plat form.

e) Coral reefs form on a solid sea bed especially where volcanic platforms exist as suggested by Darwin's theory.

f) The existence of lagoons partly indicates subsidence of a coral base if the base was stable, it would get filled up by deposition of sediments.

Daly's Theory of Glacial Control:

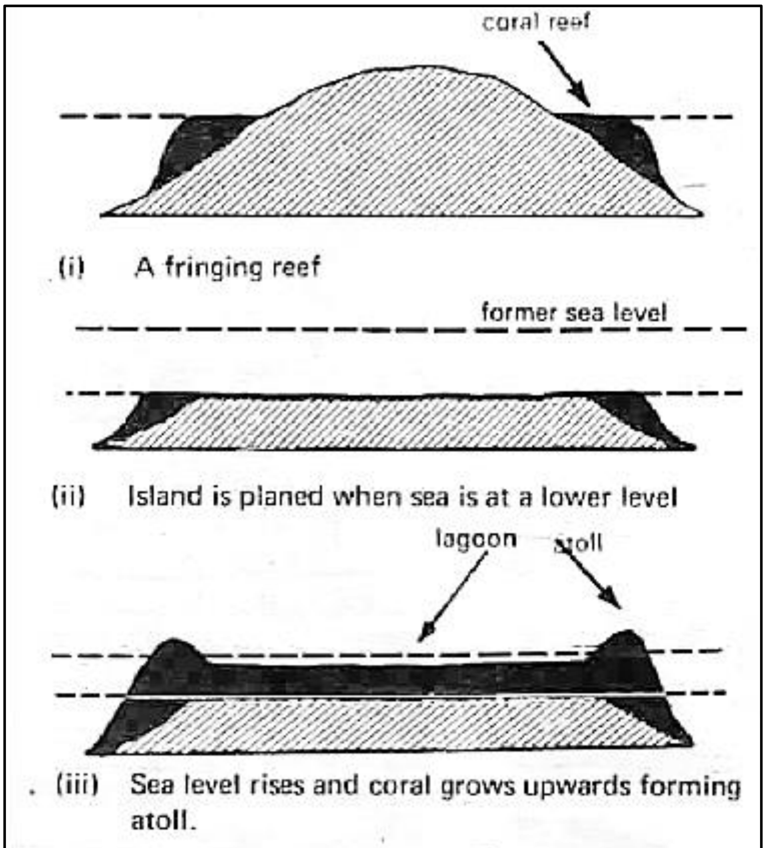
Reginald A. Daly based his theory on glaciation and changes in sea level. During an ice age the sea level was greatly lowered due to a lot of water being locked up in glaciers and also cold waters prevented growth of new reefs. With the absence of a coral barrier, waves eroded and lowered the islands and reefs forming flat and gently sloping submarine platforms. After the end of the ice age and the melting of the glaciers, the sea level rose and coral reefs began growing once more on the flat, planed surfaces. Thus the reefs started out as fringing reefs and continued growing upwards and outwards keeping pace with the rising water level, transforming into barrier reefs and finally atolls.

Relevance of the theory

❖ Existence of coral reefs on continental shelves with fairly deep lagoons (atolls) is a proof for the upward and outward growth for coral reefs during the sea level rise.

❖ Most old coral reefs along the East African coast were eroded by wave action to the level of the sea during a fall in the water level.

❖ Most coral reefs along the East African coast were formed during the post – glacial period as explained by Daly's theory.



Daly's Glacial Control Theory

John Murray's Antecedent Theory:
Sir John Murray (1874-1876) advanced the view that there existed a stable submarine platform on which pelagic or marine (oceanic) deposits including corals accumulated at a depth of not more than 60 meters. Later fringing reef corals started growing on these platforms upwards and outwards. As the reef was growing it was pounded by waves such that masses of coral fragments accumulated on the seaward side or edge where they were cemented and consolidated into hard reefs on which other corals grew while corals on the inner side died due to lack of food and their skeletons were dissolved thus forming a lagoon inside the reef. In the process the fringing reef transformed into a barrier reef and finally into an atoll.

Relevance of the theory
▪ John Murray's theory is relevant because it helps to explain why barrier reefs and atolls are found in deep water over 60 meters deep.

IMPORTANCE OF CORAL REEFS

Coral reefs are favorable sites for accumulation of petroleum deposits. Thus coral reefs are of much importance to oil industry.

Coral reefs support a phenomenal diversity of fish species that provide irreplaceable sources of food. About six million tons of fish are taken each year from coral reefs.

The coral reefs serve as habitats for many plants and animals like sponges, mollusks, echinoderms, fishes etc. Some coral islands are used as habitation by man as well.
Some corals are highly prized for their decorative value. Large quantities of corals are shipped every year for the curio trade. As such healthy reefs contribute to local economies through tourism. Diving tours, fishing trips, hotels, restaurants, and other businesses based near reef systems provide millions of jobs and contribute billions of dollars all over the world.

Coral reefs form natural barriers that protect nearby shorelines from the eroding forces of the sea, thereby protecting coastal dwellings, agricultural land and beaches. Coral reefs break the power of the waves during storms, hurricanes, typhoons, and even tsunamis. Many small islands would not exist without their reefs to protect them.

Coral reefs have been used in the treatment of numerous diseases, for instance the red coral and organ pipe coral are used in some indigenous system of medicine in India. Already coral reef organisms are being used in treatments for diseases like cancer and HIV.

Coral skeletons serve as raw material for the preparation of lime, mortar and cement because of their calcium carbonate and magnesium carbonate content.

Coral reefs serve as good nursery grounds for commercially important fishes, and thus provide revenue for local communities as well as national and international fishing fleets.

Coral are very important in controlling how much carbon dioxide is in the ocean water. You read earlier about how the coral polyp turns carbon dioxide in the water into a limestone shell. Without coral, the amount of carbon dioxide in the water would rise dramatically and that would affect all living things on Earth.

Coral also weather down to form soils suitable for various crops such as clove, coconuts and cashew nuts, for example at Zanzibar and Pemba islands.

Coral rocks are quarried to make aggregate and blocks for constructing houses.

Negative Importance:

Coral rocks are an obstacle to navigation especially during high tides when they are submerged they lead to ship wrecks.

Soils weathered from coral rock don't support crop growing for a long period of time, that is, they lose fertility very fast.

Coral rocks are a hindrance to fishing activities since coral rocks may tear fish nets thus disrupting fishing activities.

REVISION QUESTIONS:

1. Examine the process responsible for the formation of erosional features on the EA coast.

Approach

- *define waves*
- *Identify and explain the processes of wave erosion*
- *Identify wave erosional features and explain their formation in relation to the processes identified above*
- *Draw diagrams and give relevant examples.*

2(a) Outline the causes of sea level changes.

(b) Describe the coastal landforms associated with sea level changes.

Approach

- *Define sea level change and state the types of sea level changes*
- *In part (b) Identify and describe the formation of both submerged and emerged coastal landforms in highland and lowland areas*
- *Draw diagrams and give examples where applicable from EA and outside EA.*

3. Account for the formation of coral landforms along the East African coast.

Approach

- *Define clearly coral landforms*
- *Describe the process of formation*
- *Identify the types*
- *Explain conditions which favor their formation in EA*
- *Explain the theories put forward to explain the formation of coral landforms*

4. Account for the formation of major deposition features on the coast of EA.

Approach

- *Describe the process of wave deposition.*
- *Explain the landforms that are formed due to wave deposition*
- *Draw diagrams and give examples.*

5. Assess the importance of coral landforms along the East African coast.

6. Examine the relevance of Darwin's theory to the understanding of the formation of coral landforms in EA.

Approach

- ***Define clearly coral landforms***
- ***Describe the process of formation***
- ***Identify the types***
- ***Explain conditions which favor their formation in EA***
- ***Explain the formation of coral reefs with reference to Darwin's theory.***

SOILS

Most of Earth's land surface is covered by an unconsolidated layer of **regolith**, a collective term for sediment, regardless of how it was deposited, as well as layers of pyroclastic materials and the residue formed by weathering. Only some of this regolith is **soil**, which by definition is made up of weathered rock, air, water, and organic matter and supports vegetation. Nearly all land-dwelling organisms depend on soil for their existence. Plants grow in soil from which they derive their nutrients and most of their water, and animals depend directly or indirectly on plants for sustenance. ***Thus, soil refers to the top most material on the earth's surface and constitutes the outer most layer of the earth's crust, OR the layer of less consolidated materials naturally occurring on the earth surface and capable of supporting plant life, OR the thin layer on top of the earth crust that is composed of organic and inorganic material and able to support plant life.***

Soils result from the interaction and interrelationship between several physical, chemical and biological processes of weathering all of which vary according to natural environments. The weathered material may then be modified by other soil forming processes to give a wide range of soil types. Soil is composed of mineral particles (inorganic matter), organic matter, living organisms, water and air.

FACTORS INFLUENCING SOIL FORMATION

1. **The Nature of the Parent Rock or Material**: This is the rock material that breaks down to form soil particles. Over time, weathering processes soften, disintegrate, and break bedrock apart, forming a layer of ***regolith***. The influence of parent rock is discussed below;

(a) **Rock Hardness**: Hard parent rocks such as granite limit the rate of weathering resulting in the formation of thin shallow or skeletal and immature soils. On the other hand relatively soft parent rocks such as sandstone, pumice and mica are easily broken down into soil particles resulting in a higher rate of soil formation, forming deep and mature soils.

(b) **Rock Jointing**: Well-jointed rocks allow easy penetration of water and gases thus accelerating chemical weathering to form deep and mature soils. On the other hand, parent rocks that are poorly jointed are not easily weathered therefore the rate of weathering and soil formation is slow thus producing shallow or thin or skeletal, coarse and immature soils.

(c) **Rock Color**: The colour of the parent rock also influences the rate at which weathering processes occur through thermal expansion and contraction. Bright coloured or shiny parent rocks are more resistant to weathering because they reflect much heat thus forming skeletal or thin immature soils. On the other hand dark coloured rocks encourage high rates of physical weathering through thermal expansion and contraction or exfoliation hence forming deep mature soils.

(e) **Rock Permeability or Porosity**: Permeable or porous rocks encourage chemical weathering because they allow water and air to seep through them which accelerates the breakdown of rocks forming deep and mature soils. On the other hand impermeable rocks hinder water percolation hence limiting the rate of chemical weathering processes and leading to the formation of thin or shallow and immature soils.

(f) **Rock Mineral Composition**: The mineral composition of the parent rock determines the nature of the soil nutrients or soil fertility. Some minerals found in rocks like iron and aluminium are

easily weathered by chemical processes such as oxidation and hydrolysis leading to the formation of reddish and stony lateritic soils that are thin/skeletal.
Basic igneous rocks are not easily weathered forming shallow or thin or skeletal soils. Rocks containing limestone breakdown to form soils with high calcium content or rich in lime.

2. **Climate**: Climate is the single most important factor influencing soil type and depth. Climate influences soil formation through affecting weathering that leads to the formation of soil. This is done mainly through the elements of temperature and rainfall as discussed below.

In hot humid areas (tropics or equatorial regions), heavy rainfall and hot temperatures accelerate chemical weathering processes resulting in the formation of deep and mature soils (***pedalfers***) that support dense vegetation, such along the northern shores of Lake Victoria in Mukono, Jinja and Mayuge.

In addition, the heavy rainfall promotes leaching, which is the downward removal of soluble soil materials by water, leading to the formation of an impoverished A-Horizon of the soil. The high rate of leaching forms lateritic soils that are thin or skeletal found on most hills of Buganda region.

In arid and semi-arid areas hot temperatures and low rainfall enable soil formation through physical weathering processes like exfoliation. This results in the formation of shallow or skeletal, coarse soils such as ***pedocals,*** which contain little organic matter and support few plants. This is evident in areas of Moroto, Kotido and the Chalbi desert in northern Kenya.

In cold climates like mountain tops with very low temperatures soil forming processes such as frost action are very slow thus forming thin or skeletal and immature soils. This is common in highland areas such as Kilimanjaro, Rwenzori and Kenya.

Climate also determines the action of living organisms which contribute to soil formation. Humid areas have abundant plant and animal life hence soils are deep and fertile with a high organic matter content for example around Mabira forest.

3. **Relief or Topography**:

Relief influences soil formation by forming various slopes that control the rate of erosion, transportation and deposition as well as the nature and depth of soils.
Along steep slopes rapid erosion and transportation of regolith results in the formation of thin or skeletal soils. However the rate of soil formation is high because erosion exposes fresh parent rock to further weathering but the resultant soils are thin or skeletal and immature due to rapid rates of erosion.

Gentle slopes have a relatively slower rate of erosion and promote deposition hence soils tend to be deep, mature and with a well-developed profile, for example loam soils around Lake Victoria areas of Mukono, Lugazi, and Wakiso.

Lowlands or valleys or flatlands support extensive deposition of regolith forming deep or thick soils found along river valleys. However such soils tend to have low organic matter content due to impeded/poor drainage or water logging. In addition the poor drainage in the valleys results in partial decomposition hence forming gleysols such as clay.

4. **Living Organisms (Biota)**:

This involves the action of plants, animals and man in the formation of soils. When plants and animals die they decompose and add humus to soil forming deep soils. In addition decaying soil organisms further breakdown or decompose parent rocks to form deep mature soils rich in organic content, e.g. areas of Mabira forest along the northern shores of Lake Victoria.

Dense vegetation cover reduces the rate of soil erosion encouraging rapid accumulation of organic and inorganic materials thus leading to the development of deep and mature soils, especially around Mabira forest areas.

Plant roots physically breakdown parent rocks as they grow into the ground. In addition they release or secrete substances that chemically decompose rocks. All this results in the formation of deep and mature soil.

Soil microorganisms such as bacteria aid in the breakdown or decomposition of organic matter to form humus which is an important component of deep and mature soil.

Burrowing animals such as squirrels, earthworms, centipedes, millipedes constantly churn and mix soils and their burrows physically breakdown the parent rock as well as providing avenues for gases and water which chemically react with the parent rock thus enabling formation of deep mature soil.

Human activities also influences soil formation through activities like mining or quarrying, application of chemical fertilizers and digging among others which promote physical or chemical weathering of the parent rock to form deep and mature soils.

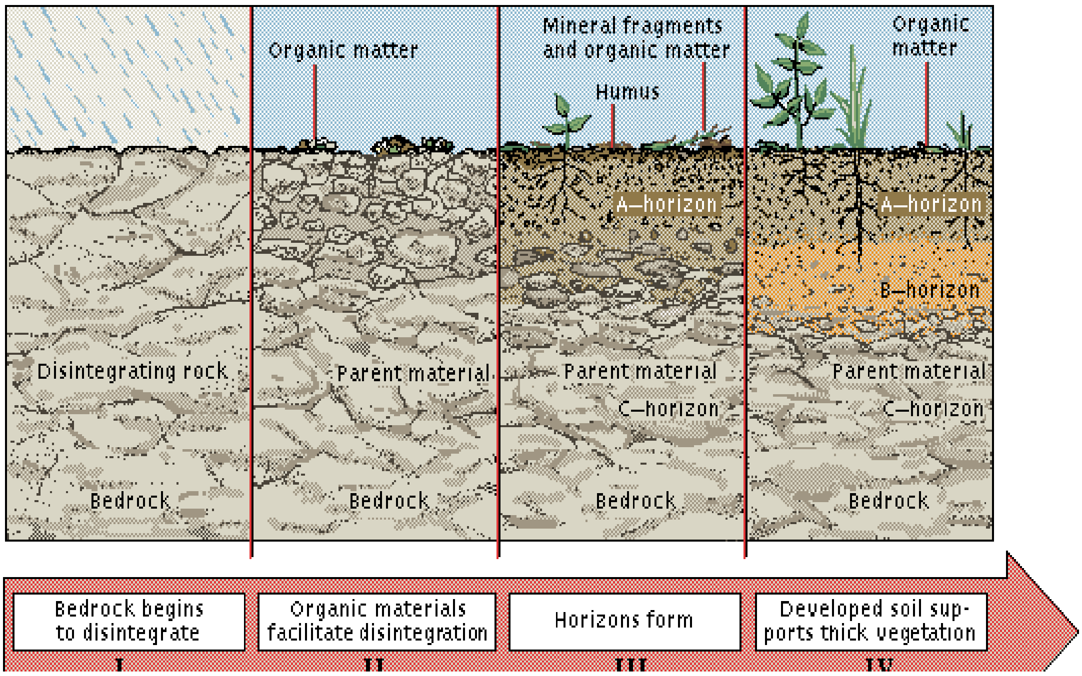
In conclusion therefore, areas with an abundance of living organisms and where man's activities are dominant, the soils are mature and deep while in areas with less or no living organisms the soils are less developed and thin or skeletal.

5. **Time**:

This refers to the duration of the interaction between soil forming processes and factors. If the time of interaction is short, shallow, thin or skeletal and immature soils will develop while if the time of interaction is adequate then deep and mature soils are formed.

N.B. It takes up to 400 years for 10mm of soil to form and between 3000 and 1200 years to produce sufficient depth of mature soil for farming.

Stages of soil formation



Processes of Soil Formation (Pedogenesis) & Soil Profile Development

These are the activities which take place to produce soil from the parent rock. They include;

1. **Weathering**; this is the physical disintegration or chemical decomposition of rocks. Rocks break down through various physical and chemical processes leading to soil formation. High rates of weathering result into deep and mature soils or a mature soil profile, e.g. around the Lake Victoria basin with heavy rainfall and hot temperatures. On the other hand low rates of weathering lead to formation of shallow soils or soils of poorly developed profiles, e.g. areas of Kotido due to limited chemical weathering as a result of low rainfall.

2. **Leaching**; refers to the removal by water of soluble mineral nutrients from the upper layers of the soil profile to the underlying layers i.e. minerals like salt and carbonates dissolve in water in the top soil and move in solution from top to the sub soil. Leaching results into an impoverished A-horizon of the soil profile while B-horizon is enriched with nutrients especially in areas that receive heavy rainfall.

3. **Eluviation**; this involves the movement of soil material (colloids) in solution or suspension horizontally or vertically within the soil. Eluviation generally leads to formation of impoverished soils of the A- horizon since most of the nutrients are washed to deeper layers or horizons.
[Cheluviation is the process in which the minerals are dissolved and transported downwards under the influence of chelating agents. Chelating agents are the organic acids produced after the decomposition of organic matter. Cheluviation is one of the processes of soil formation. Cheluviation process is similar to leaching in that it involves downward movement of materials from upper soil to lower soil layer but they differ in how what causes the process. In cheluviation plant acid are involved in causing the movement while in leaching water alone is involved in causing the movement.]

4. **Illuviation**; this involves the precipitation and accumulation of the leached and eluviated material in the B-horizon of the soil profile i.e. eluviated and leached materials concentrate in the B-horizon. Illuviation is responsible for the dark color of the B_2 layer of the soil profile due to maximum accumulation (deposition) of colloids.

5. **Humification**; this is the process through which organic matter is decomposed to form humus which is then mixed with inorganic matter. It is common in wet, warm and densely vegetated areas such as equatorial or moist tropical regions with hot temperatures and heavy rainfall to speed up chemical reactions. This process influences the development of the A_O and A_1 layers of the A-horizon or the O-Horizon giving it a dark color. Soils produced are fertile with high humus content and are usually referred to as black loam or cotton soils.

6. **Mineralization**; occurs under extreme conditions whereby organic matter is further broken down into mineral substances/elements e.g. carbon dioxide, salts, water and silica. This mainly occurs in the A-horizon but it can take place anywhere provided organic matter is present thus leading to the formation of mature soils or soil profile.

7. **Calcification**; this is a soil forming process which takes place in dry or arid areas as a result of upward movement of capillary water. Due to excessive evaporation in arid areas, water containing dissolved calcium carbonate moves upwards by capillary attraction/action and on reaching the surface it evaporates leaving behind deposits of calcium and other salts in the A-Horizon. The soils formed comprise of a lot of calcite or calcium compounds and are called ***pedocals***. Calcification leads to the development of shallow soil profiles. This process is common in areas with limestone geology in East Africa such as Tanga, Nyakasura, Tororo, etc.

8. **Laterisation**; this involves weathering under hot and wet tropics where chemical weathering occurs at a fast rate. In this process silica is leached out of the A-Horizon leaving behind iron and aluminum compounds in the top horizons to form a lateritic crust with reddish brown or bright orange soils that tend to be sticky when wet and harden when exposed to the dry atmosphere. In East Africa, laterite is commonly known as murram. They are common along the hill slopes of central Buganda.

It is important to note that the formation of laterites is favoured by some conditions which include the following;
(a) Heavy rainfall that encourages chemical weathering and consequent leaching of silica.
(b) Hot temperatures to encourage deep chemical weathering.
(c) Clearing of vegetation (deforestation) i.e. man's influence that exposes the soil to the full force of rain and heat.
(d) Dry conditions that then enable the Laterite to harden.

9. **Gleization or Gleying**; this soil forming process involves the partial or incomplete decay of organic matter due to cold conditions and impeded drainage (water logging) i.e. in swamps or wetlands, resulting in the formation of shallow or immature soils or profiles. The resultant soils are very sticky, e.g. clay and peat, sometimes known as hydro orphic soils. This process is common in areas of Kajjansi and Lweza along the shores of Lake Victoria.

10. **Podsolization**; this process occurs under cool moist climatic conditions i.e. temperate climatic conditions. It involves the removal of iron and aluminum oxides known as ***sesquioxides*** due to intense leaching and deposited in the lower horizon. It results into soils with an impoverished A-horizon and distinct dark sub-surface layers (B-horizon). Such soils include podsols found in upland heaths and moors.

11. **Salinization**; this is the process by which soils are enriched with salt. In some low areas, soils are often enriched with salts dissolved in ground water. When this salt-rich water evaporates, the salts are deposited and build up forming a hard crust. Salinization may also be induced by man through intense irrigation. Salinization gives rise to a poor A-horizon. This process is common in the semi-arid areas and dry irrigated regions.

SOIL PROFILE

As a book cannot be judged by its cover, so soils cannot be evaluated at the surface only. Most soils have distinctive horizontal layers that differ in physical composition, chemical composition, organic content, or structure. This is known as ***soil profile***. Soil profile refers to the ***vertical arrangement of the various soil layers from the top layer down to the parent rock or bottom layer***. Or, ***a vertical section through the soil horizons extending into the parent material or the bedrock***. Or, t***he vertical section through the soil from the earth surface to the underlying bedrock showing distinct layers or horizons***.

The different layers are referred to as ***horizons***. These layers or horizons do not have characteristic demarcations but can nevertheless be identified on the basis of color, texture and mineral composition. A fully developed soil profile comprises of four main horizons namely: A horizon, B horizon, C horizon and D horizon. Each horizon has different physical and chemical properties, which result from various soil forming processes such as weathering, introduction of humus and movement of minerals.

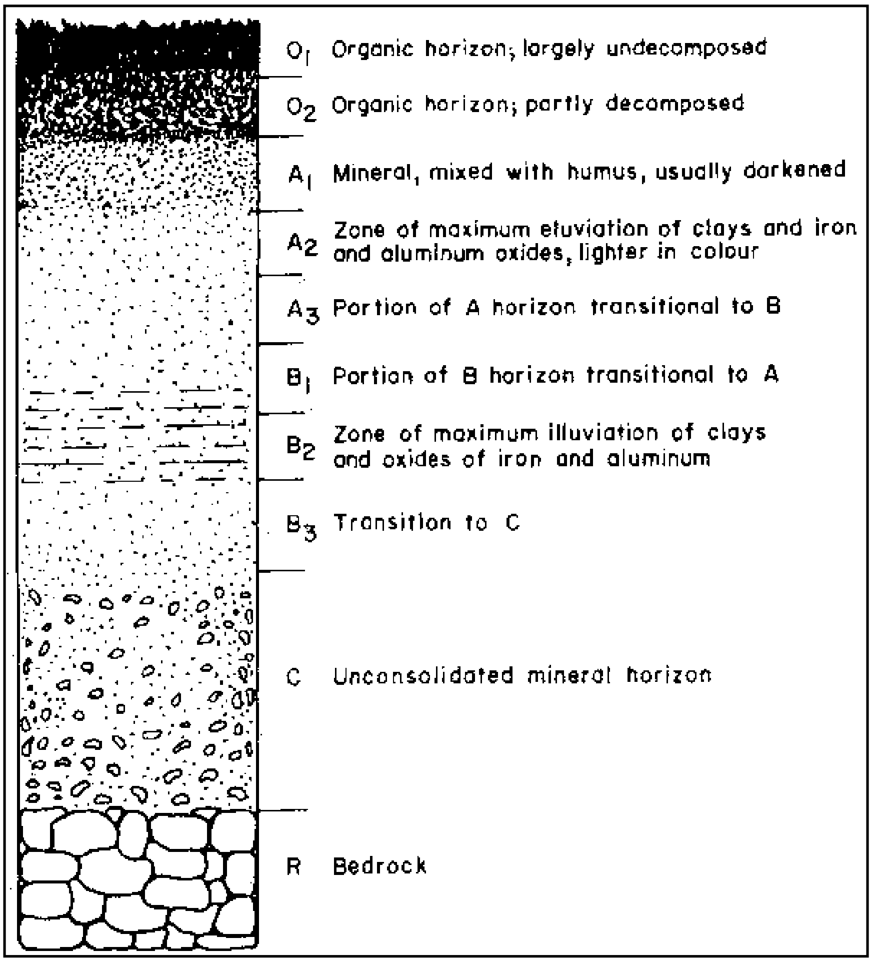
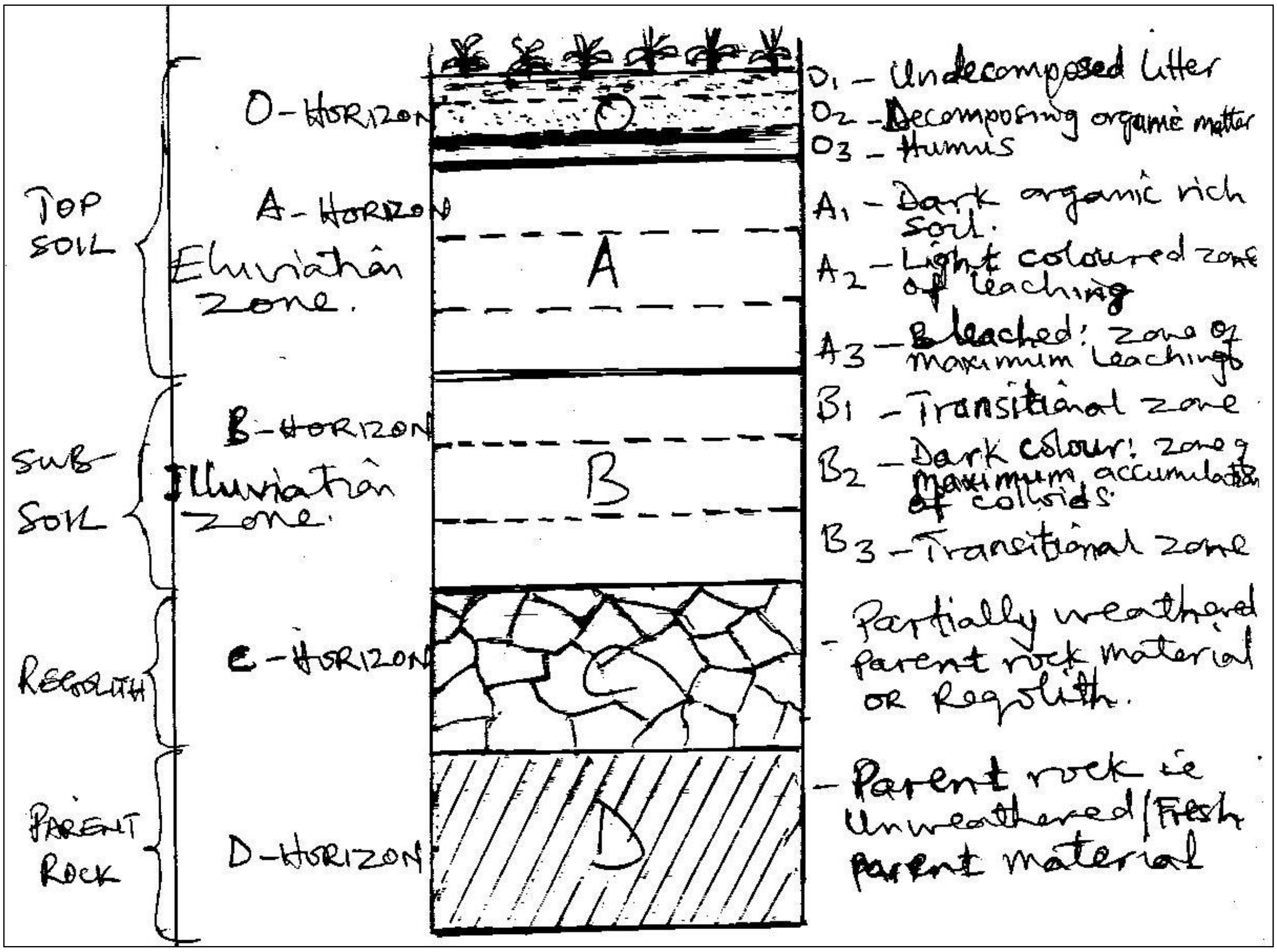


Diagram of an Idealized Soil Profile



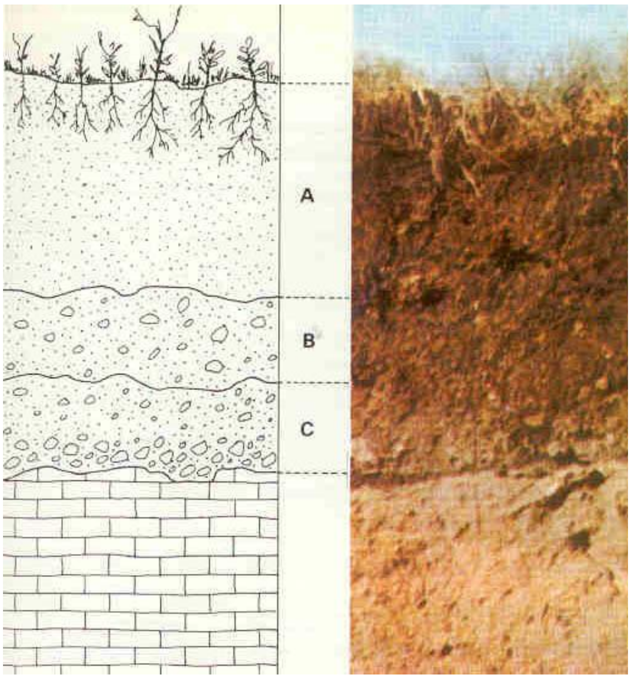
O-HORIZON - This is the top most or surface layer of the soil. This layer is composed of un-decomposed litter of vegetation and dead animals, decomposing organic matter and humus. (***The letter O stands for Organic***). This layer is often dark or dark brown in color because of the high organic matter content. It is common in areas with dense vegetation.

A-HORIZON (Surface soil) - This is the top layer also known as the topsoil and it is rich in organic matter giving it a dark colour. It is comprised of layers **A_1** which has a high humus content giving it a dark color; **A_2** and **A_3** which are poor in nutrients due to the effects of leaching and eluviation giving it a light/bleached color.

B-HORIZON (Subsoil) – This is the zone where nutrients and materials removed from the A horizon through leaching and eluviation accumulate or are deposited in a process known as **illuviation**. This horizon may also be characterized by hard pans due to the accumulation of large quantities of clay and other nutrients. This zone is also richer in nutrients than zone A and darker colored due to accumulation of colloids. A and B horizons constitute true and mature soils.

C-HORIZON - This consists of partially/recently weathered rock and immature soils, this is because weathering and other soil forming processes may not effectively operate at this depth.

D-HORIZON (R (Rock)-Horizon or Bedrock) - This consists of the solid parent rock or bedrock or fresh parent material. It has no soil particles but has potential for future soil formation.



SOIL PROFILE DEVELOPMENT

The nature of the soil profile may be such that it is fully developed or partially developed implying that soils may be deep or skeletal or soils of medium depth. Soil profile development is influenced by a number of factors namely:

1. **Nature of the parent rock or material:**

The parent material is the nature of rock upon which weathering and other soil forming processes operate to create to create soil. In the first place the parent material provides the basis for soil profile development. It influences soil profile development in the following ways;

(a) **Hard or resistant rocks** like granite are not easily weathered leading to the development of thin soils with poorly developed soil profiles. On the other hand **soft rocks** like limestone are easily weathered and acted upon by other soil forming processes leading to the formation of deep soils with a well-developed profile.

(b) **Rocks with lines of weakness or joints** have facilitated weathering and other soil forming processes leading to the formation of deep soils with a well-developed soil profile while **poorly jointed rocks** form shallow soils leading to incomplete soil profiles.
(c) **Dark colored rocks** respond to heat absorption easily hence are easily weathered to produce mature soils with well-developed soil profiles, while **light/bright colored rocks** such as sandstone are not easily weathered leading to shallow soils and immature soil profiles.
(d) Young parent material has led to poorly developed soil or poor soil profile while older rocks have had enough time to be weathered and to develop into well-developed soil profiles.
(e) **Permeable or porous rocks** have enabled the easy infiltration of agents of weathering resulting into deep weathering by chemical processes to produce mature and deep soils with a well-developed profile unlike **impermeable rocks** produce shallow and thin soils leading to incomplete or immature soil profiles.

2. **Climate**:
Rainfall and temperature determine the nature and rate of weathering and soil forming processes. Hot-wet conditions promote chemical weathering leading to development of mature soils and well-developed soil profiles. Tropical climate with alternating wet and dry seasons leads to fairly deep soil profiles. Arid and semi-arid areas with hot and dry conditions promote physical weathering leading to formation of thin skeletal soils with immature soil profiles. Frost conditions in mountainous areas experience mechanical weathering forming shallow soils with incomplete soil profiles.

3. **Living organisms**:
A thick vegetation cover enables deep weathering to occur due to presence of organic matter that promotes chemical weathering processes resulting in formation of mature soil profiles. Areas with scanty vegetation cover have thin skeletal soils and poorly developed soils profiles due to soil erosion.
Plant roots promote physical weathering and formation of soil hence mature soil profiles are formed in areas with thick vegetation.
Thick vegetation also decays and leads to formation of humus which is added to horizon A of the soil profile.
Living organisms such as bacteria, ants, termites, earthworms and rats easily break down rocks as they make passages underground and help to churn the soil leading to development of deep soils and complete soil profiles. In addition, rain water takes advantage of the burrows created causing deep weathering leading to formation of deep soils with well-developed soil profiles.
Human activities such as cultivation, mining, quarrying, construction works among others interfere with the A horizon leading to removal of the top soil hence immature soils hence incomplete soil profiles. However human activities can also accelerate chemical and physical weathering processes leading to formation of deep soils with mature soil profiles.

4. **Topography/Relief**:
The nature or shape of the earth’s surface influences the depth of soil horizon in a soil profile. Steep slopes tend to have less developed or immature soil profiles unlike areas of gentle slopes. This is because the rate of erosion is greater on the steep slopes and this removes the topsoil resulting into shallow or skeletal soils with immature profiles. On the other hand, in the gentle slopes and generally flat lands the soil forming processes act for a long time, soil erosion is slower, deposition and deep chemical weathering lead to mature soils hence soil profile tends to be more developed. In the valleys and lowlands constant deposition of weathered materials and percolation of water encourage formation of mature soils with well-developed soil profiles. However the water-logged conditions at the valley bottoms limit the rate of decomposition leading to shallow and immature soils hence incomplete soils profiles.

5. **Time**:
It takes time for the soil profile to be fully developed. A typical or well developed profile of soil requires adequate/ample time to form, therefore the longer the time to which the rocks are exposed to weathering and other soil forming processes, the more developed the soil profile. Young rocks normally yield skeletal soils i.e. with poorly developed profile.

SOIL CATENA

This is the ***horizontal arrangement or sequence of differing soil types along a slope from the hill top (summit) to the valley bottom***. This sequence varies with relief and drainage though it may be derived from the same parent material e.g. the soils at the valley bottom are likely to be different from those of the hill top. It occurs on hill slopes where the geology is uniform and there is no marked difference in climate from the top to the bottom of the slope. The Buganda landscape has features of a true and typical catena. Soil catena may be due to factors like relief, climate, living organisms and time.

Diagram illustrating soil Catena

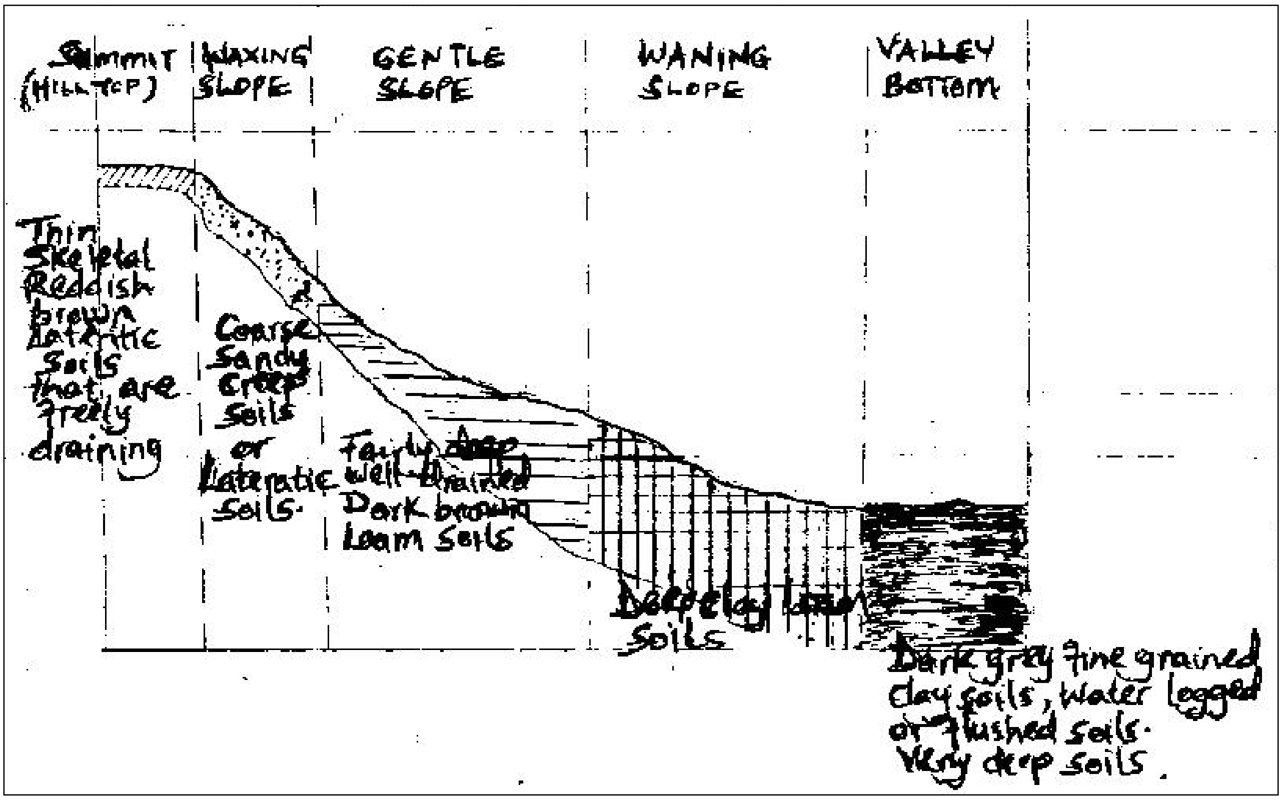
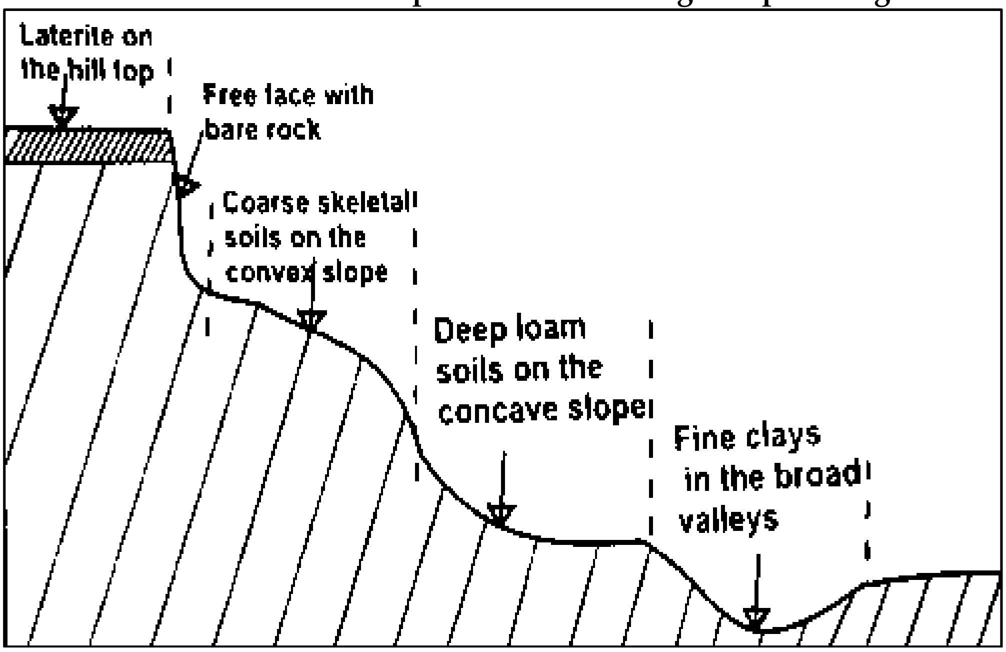
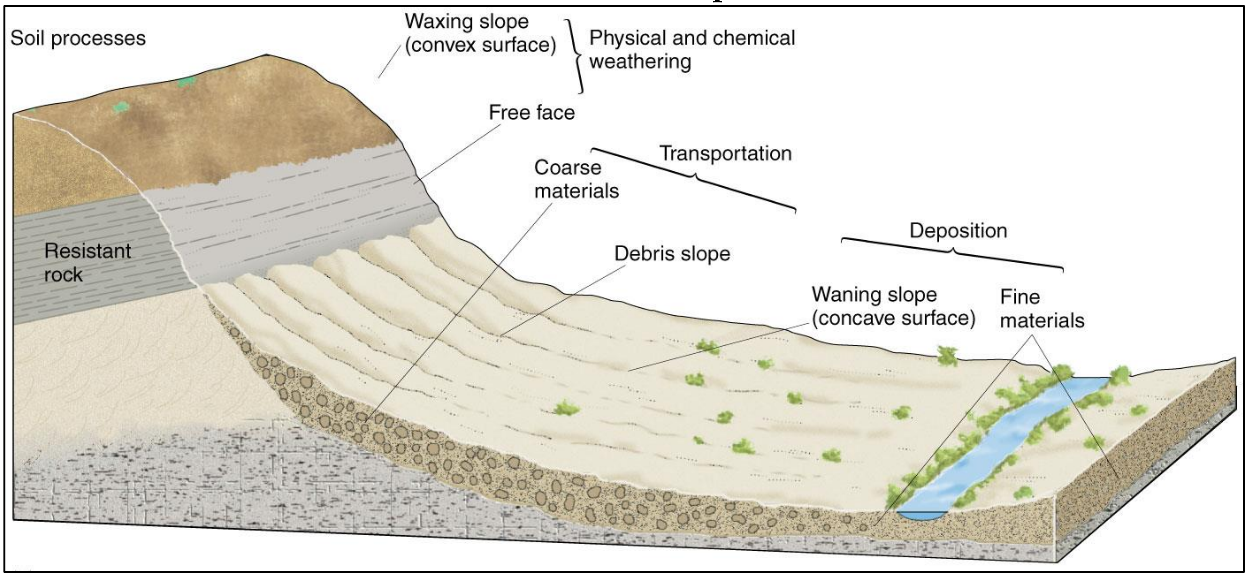


Illustration of a well-dveloped soil catena along a slope in Buganda



Profile of a slope



On the **hill top** there are lateritic soils/lateritic capping characterized by reddish brown thin or skeletal soils due to leaching of the lateritic duricrust. Immediately after the hill top downwards, there is a **vertical slope or free face** which is very steep and largely composed of bare rock and hardly any soils due to excessive erosion along the steep slope. Further down along the slope is the **waxing or convex slope** characterised by coarse, stony, skeletal soils due to excessive erosion. Next is the **waning or concave slope** which is fairly gentle with deep mature loam soils due to deposition of regolith eroded from the upper slopes. Lastly is the **valley bottom** with fine grained clay soils that are deep due to high rate of deposition.

The factors influencing the development of soil catena:

1. **Relief**: The physical appearance (morphology) of the landscape affects or influences the development of soil catena in such a way that differences in relief affect the nature or soil type due to the fact that they influence erosion, deposition and human activities.

- **Hill tops** have lateritic capping with thin/skeletal reddish brown lateritic soils due to intense leaching.
- The **very steep slope/free face** has very little or no soil i.e. has bare rock with little soil due to excessive erosion thus hindering the development of a true soil profile.
- The **waxing/convex slope** is characterised by coarse, stony, creep soils due to high erosion.
- The **waning/concave slope** has fairly deep clay loam soils because deposition exceeds erosion hence soils accumulate to form a true soil profile.
- The low lying area/**valley bottom** has fine particles of clay that are deep and poorly drained. It is generally a zone of deposition or illuviation i.e. zone of accumulation.

The steep slope encourages erosion and hence has shallow soils. The gentle slopes are well drained and experience some down slope translocation of soil particles while the valley bottom experiences much deposition hence accounting for the deep soils.

2. **Climate:** Influences the development of soil catena in the following ways:

- Heavy rainfall encourages erosion on the upper slopes (waxing slope) forming thin skeletal soils and deposition on the lower slopes and valley bottom to form deep loamy mature soils.
- Heavy rainfall also encourages leaching leading to the development of lateritic soils along the hill top and waxing slope.
- Heavy rainfall also leads to flooding in the valley bottom and lower slopes resulting into water logged clay soils or grey soils.
- In arid areas due to the scarcity of rainfall, soil forming processes are very slow hence the failure to develop a mature soil profile; in addition, the scarcity of plant cover means that there is no organic matter (humus) hence the soil profile consists of stony and sandy soils of yellowish to reddish brown color with no humus.

- In very cold regions or tundra, the cold temperatures results in frozen sub-soils or permafrost layer which hinder soil forming activities hence an immature soil profile.

3. **Drainage**: The moisture content of the soil influences the development of the catena as soil changes along the slope.

- Well drained mature soils are found along gentle slopes that are well drained with a high rate of water percolation while thin, stony, dry and immature soils are found along steep slopes with limited water percolation/infiltration.
- Clay soils are found in valley bottoms that are waterlogged because such areas experience partial decomposition hence forming grey soils.

4. **Living organisms**: These include plants, animals and man.

- Well vegetated areas slow down the rate of erosion thus hindering the development of soil catena while areas without vegetation or with limited vegetation encourage a faster rate of soil catena development since the rate of erosion is faster.
- Man's activities like deforestation and cultivation encourage erosion thereby leading to thin soils especially on the steeper slopes while on the other hand encouraging deposition on the lower slopes and the valley bottom hence forming deep soils.

5. **Nature of the parent rock:** The differences in the soil types along the slope could be as a result of them having developed from different parent materials. Hard parent rocks lead to formation of a vertical slope or free face with bare rocks and thin or skeletal immature soils due to high rates of soil erosion. Soft rocks on gentle slopes and in the valleys form deep mature soils and fine clays due to deep chemical weathering and high rate of soil deposition

6. **Time:** The development of soil catena needs ample time. The processes involved take long and therefore the longer the geological time scale, the more developed of soil catena of an area for example the lateritic soils on the hill tops develop after a long time that enables leaching to occur, as well as the deep loamy soils along the gentle slopes and fine clays in the valley develop after a long period of time that enables deposition and accumulation of regolith.

Difference Between Soil Profile and Soil Catena

Soil profile is largely influenced by climate through weathering while soil catena is influenced by relief and gradient.

Soil profile is influenced by vertical changes in attributes such as colour and mineral constituents while soil catena is influenced by changes in surface soil types.

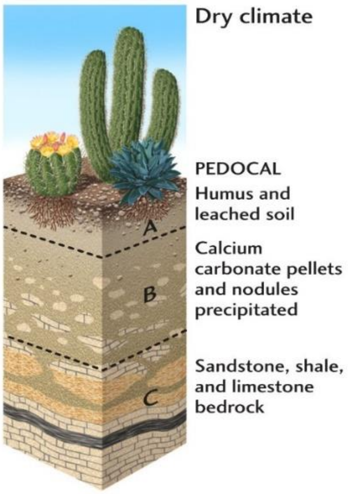
CLASSIFICATION OF SOILS (SOIL TAXONOMY)

Geographers have classified soil in terms of their areal distribution over the earth's land surfaces which are linked with the climates, parent materials etc. As we know, under similar climatic conditions similar soil types develop. There is a much simpler and recognized existence of three orders of soils namely zonal, intrazonal, and azonal soils.

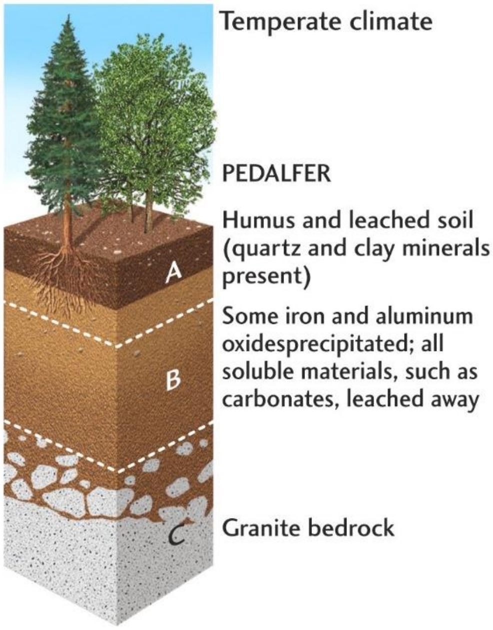
Zonal soils (Climatic soils);

These are by far the most important and widespread soils. They are mature with a well-developed soil profile due to prolonged action of climate and vegetation. They develop on gently sloping or flat landscapes that are well drained and from parent rocks that have remained in the same place for such a long time to have been affected by various soil forming processes. They are neither very acidic nor very alkaline. Zonal soils are mainly categorized into two groups namely;

(a) **Pedocals;** these are soils rich in calcium carbonate with a low organic matter content and tend to develop under conditions of low rainfall (arid and semi-arid areas) e.g. chernozems, chestnut or brown soils, red desert soils, sierozems etc.



(b) **Pedalfers;** these are soils rich in aluminium and iron and have low calcium carbonate content mainly due to extensive leaching (ped=soil; Al=aluminium; Fe=Iron). Pedalfers usually occur in humid areas with abundant vegetation (forests) and heavy rainfall. Such soils include podsols, latosols, tropical brown soils, temperate brown soils and prairies soils.



Generally, zonal soils tend to be restricted to certain latitudinal regions for instance;

(i) In low latitude areas or tropics, the hot humid conditions give rise to latosols and tropical black earths (Basisols), e.g. around the Lake Victoria basin. They're rich in humus

(ii) In mid latitude climates, humid conditions are associated with the development of podsols and brown earths.

(iii) In areas of seasonal rainfall chernozem soils develop e.g. on the Canadian prairies.

(iv) In semi-arid and arid conditions chestnut coloured soils develop, e.g. red desert soils. These are common in North Eastern Uganda and North Western Kenya regions.

(v) High latitude climates lead to the development of tundra and arctic brown soils, e.g. on top of Mt. Rwenzori and Kenya.

Azonal soils;

These are young soils (immature) without a clear soil profile because they have not been exposed to soil forming processes for long so as to develop mature characteristics, or due to location on very steep slopes which prohibits soil profile development. They tend to be skeletal with an underdeveloped (immature) soil profile. They also tend to show characteristics of their original parent rock material. They are derived from unconsolidated material such as alluvium, sand and volcanic ash. Most are formed over steep soils which do not offer enough time for soil formation processes. Examples of azonal soils include the mountain soils on steep soils (lithosols), alluvial soils, glacial soils, windblown soils (regosols), organic soils which develop on peat bogs, and recent volcanic soils.

Factors influencing the formation of Azonal soils;

- Weathering of the parent rock leads to the formation of screes on the mountain slopes. These soils normally show characteristics of their original parent material and resist change. Are commonly found on Mt. Kilimanjaro and Mt. Kenya

- Volcanic activity leading to the extrusion and deposition of lava resulting into the formation lava/ash soils, cinder and pumice found in areas of Kisoro, Kabale, Mbale and Kapchworwa.

- Materials eroded are transported and deposited through agents such as;

- Wave action leading to formation of mudflat soils/marine clays (alluvial soils), e.g. along the coast of East Africa at Mombasa.
- Wind action leading to the formation of windblown soils like loess, e.g. in North Eastern Uganda and North Eastern Kenya.
- Glacial action (fluvio-glacial action) resulting into the formation of glacial soils such as till and gravel found in the lower slopes of Mt. Rwenzori and Mt. Kenya.
- River action leading to the formation of alluvial soils, e.g. along the courses of majors rivers like the Nile, Tana in Kenya and Rufigi in Tanzania.

- Climate influences azonal soil formation in the following ways;

- Heavy rainfall results into river floods that lead to the formation of alluvial soils in the lower course of a river e.g. along river Ngaila in Kenya.
- High rainfall causes erosion on steep slopes and deposition in the lowlands leading to the formation of alluvial soils.
- Temperature changes on the mountain slopes influences physical weathering thus leading to the formation of rock screes, e.g. on Mt. Rwenzori and Kenya.

- Relief: Steep slopes influence erosion of screes on the mountain slopes and their subsequent deposition hence forming new soils.

- Human activities like quarrying and mining lead to the breaking of parent rock into simpler particles leave alone dumping of rock waste material leading to the formation of azonal soils. In addition deforestation, bush burning and overgrazing expose the parent rock to weathering processes that lead to the formation of young soils.

- Time lapse: Azonal soils are immature soils because the time involved or entailed in their course of formation is short.

Intrazonal soils;
These are mature soils that result from particular conditions and are not restricted to latitudinal zones like the zonal soils. Their structures or properties are determined by local factors such as relief and the parent material. These soils have unique or special characteristics and profiles due to the special local factors which determine their formation, i.e. soils which develop in a particular environment irrespective of climatic conditions. Examples of intrazonal soils include;

(i) Saline soils (halomorphic soils) – These form under conditions of hot temperatures and high evaporation rates which encourage accumulation of salts near the surface to form saline soils. They widely occur in arid and semi-arid regions of East Africa such as NE Uganda and NW Kenya. (They're developed through the process of salinization)

(ii) Bog/Peat/Wetland soils (hydromorphic soils) – These are located in waterlogged areas or swamps. Such conditions limit decomposition of organic matter or plant decay thus forming dark grey or black soils that are very acidic.

(iii) Tundra soils – These develop in areas of heavy rainfall and low temperature. They often have shallow profiles with a lot of undecomposed organic matter at the top.

(iv) Meadow soils – These are found in flood plains with silt and mud. They're rich in humus, are black and have a better soil profile.

(v) Calcareous or Calcimorphic soils – These have a high calcium content and are mainly found in limestone regions such as Nyakasura and Tororo. They're mainly of two types namely;
- Terrarosa – these are red soils formed in limestone areas under conditions of heavy seasonal rainfall with some periods of dry conditions (semi-arid areas).
- Rendizina – these are dark colored soils associated with limestone rocks and formed under wet conditions (heavy rainfall).

Factors for the formation of intra-zonal soils

Climate, equatorial climate that is characterised by heavy and reliable rainfall of about 1500mm per annum and hot temperature of about 27^0C – 30^0C lead to the formation of meadow soils. Areas with semi-arid climate with low rainfall lead to the formation of saline soils and terrarosa soils.

Relief, areas with lowlands that are water logged lead to the formation of meadow soils and peat soils.

Nature of the parent rock, mineralogical composition of the rock having calcium carbonate that contains limestone lead to the formation of terrarosa and rendizina soils

Vegetation, areas with scanty vegetation helps water to penetrate into the soil and dissolve limestone forming calcareous soils.

Drainage, areas that are poorly drained lead to the formation of peat soils and meadow soils. Flat lands that are well drained facilitate the formation of saline soils.

LATERITE SOILS / LATERITIC SOILS

Laterite soils; these are reddish brown soils containing iron, Aluminium and are formed through the process of leaching

Characteristics of laterite soils
- They consist of iron and Aluminium
- They are shallow skeletal immature soils
- They are formed in areas with hot temperature and heavy rainfall
- They contain a hard pan called duricast because they have hard minerals.
- They resist further weathering because they are hard
- They are formed in areas with scanty vegetation cover.

Laterite soils are sub-divided into two;
1. **Ferregenous soils** - These are soils that contain iron. They are reddish brown in colour and poorly drained.
2. **Pedalfers/Peddy soils** - These are soils that contain both iron and aluminium.

Process for the formation of laterite soils

Laterites are formed on flat topped hills i.e. Buganda hills like Naguru and around Queen Elizabeth in Western Uganda.

Laterites are formed due to excessive rainfall and hot temperatures which bring about chemical weathering. When it rains silica is leached, iron and aluminium are left behind in concentration in horizon A, the silica will be taken to B horizon and also iron and aluminium are taken to B horizon through eluviation process. When temperatures rise iron and aluminium compounds will be carried to the surface of the soil profile by evaporating water and harden to form a layer known as duricast, the iron and aluminium will be acted upon by chemical weathering through the process of oxidation and they will rust turning into reddish – brown colour to form laterite soils.

Factors for the formation of laterite soils

Climate; Areas with equatorial climate characterised by hot temperatures and heavy rainfall facilitate the formation of laterite soils. Hot temperatures increase the rate of chemical weathering to facilitate rusting in order to allow the formation of reddish-brown soils. Heavy rainfall of about 1500mm – 200mm helps in dissolving of silica and transportation of iron and aluminium that is oxidised and latter acted upon by rusting to form laterite soils.

Relief; Laterite soils are formed in areas with flat topped hills which allow the penetration of water to facilitate leaching from A to B horizon of the soil profile.

Geological time; Laterite soils require long period of time to allow their formation to take place.

Chemical weathering; It must take place through oxidation for laterite soils to form.

Drainage; Laterite soils are formed in flat areas that are well drained

Vegetation cover; Laterite soils are mainly formed in areas with scanty vegetation which allows penetration of water into the ground to facilitate leaching.

Nature of the parent rock; the mineralogical composition of the rock that contains iron and aluminium facilitate the formation of laterite soils.

Rock permeability; Permeable rocks easily allow the penetration of water into the ground to facilitate the process of leaching leading to the formation of laterite soils.

Human activities; such as bush burning, deforestation expose the bear land which allows the infiltration of water into the ground to facilitate leaching leading to the formation of laterite soils

SOIL EROSION

This is the detachment of top soil and its transportation from one place to another by wind, running water, ice and living organisms; OR the removal/washing away of the thin top layer of soil by agents like wind, running water, glaciers, etc. transported and deposited in some other place; OR the removal/washing away of the top thin layer of soil by agents like wind, running water, glaciers, etc. transported and deposited in some other place. Soil erosion is a natural process which usually does not cause any major problems. It becomes a problem when human activity causes it to occur much faster than under normal conditions. Approximately 1.2 billion hectares (3.0 billion acres) of Earth's soils suffer degradation through erosion caused by human misuse and abuse. Topsoil contains most of the soil's **nutrients**, and **organic matter** and soil erosion causes these substances to move also leaving behind soil with poorer structure, lower water-holding capacity, different pH values, and low nutrient levels. ***In East Africa soil erosion is rampant in highland areas of Kigezi, Mbale, Kapchorwa, Ankole-Masaka dry corridor, Karamoja/Kotido region, the Kenya Highlands, Machakos, Nyanza Province of Kenya, slopes of Mt. Kilimanjaro, Turkana region, Kondoa district of Tanzania, central and north eastern Tanzania.***

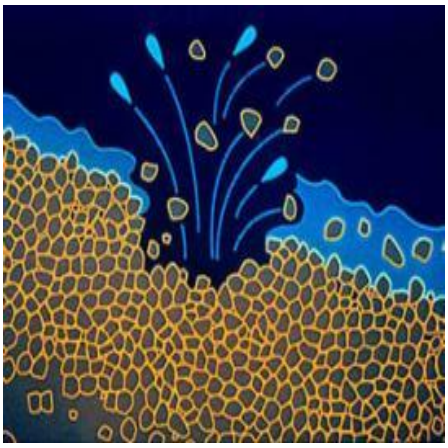
Types of Soil Erosion

(a) **Geological or Normal Erosion** – This occurs under normal conditions where the landscape and vegetation cover have not been disturbed by man's activities. It's a relatively slow process and in most cases, soil formation may keep pace with the removal of the surface soil. Geologic erosion has been taking place naturally for millions of years and it helps to create balance in uncultivated soil that enables plant growth. It's a relatively a slow continuous process that often goes on unnoticed (it's difficult to notice).

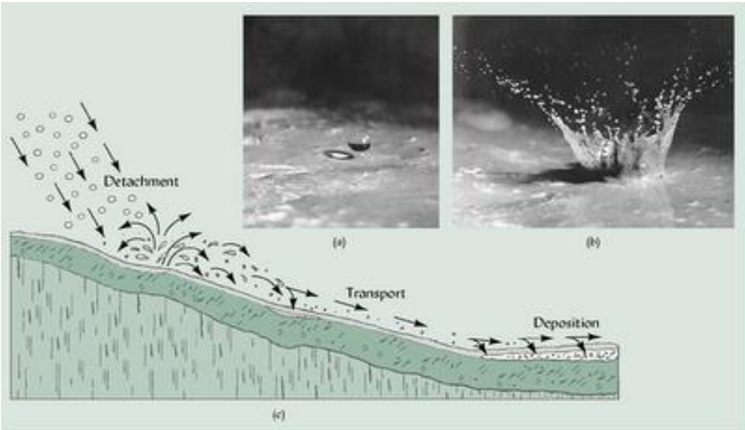
(b) **Accelerated Erosion** – This is the loss of top soil as a result of human or animal activities which directly or indirectly loosen soil. In this case erosion occurs at an increased rate. Accelerated erosion is the most dangerous type and it needs concerted efforts through careful planning and implementation of appropriate control measures.

PROCESSES OR FORMS OF SOIL EROSION

1. **Splash or Rain drop Erosion**: This type of erosion is caused by the impact of falling raindrops which dislodge bare soil particles, rocks and scatter or splash them in several directions. Soil that has been detached by raindrops is more easily moved than soil that has not been detached. Splash erosion is the first stage of the erosion process. It's common in arid and semi-arid areas like NE Uganda and Northern Kenya.



Splash erosion

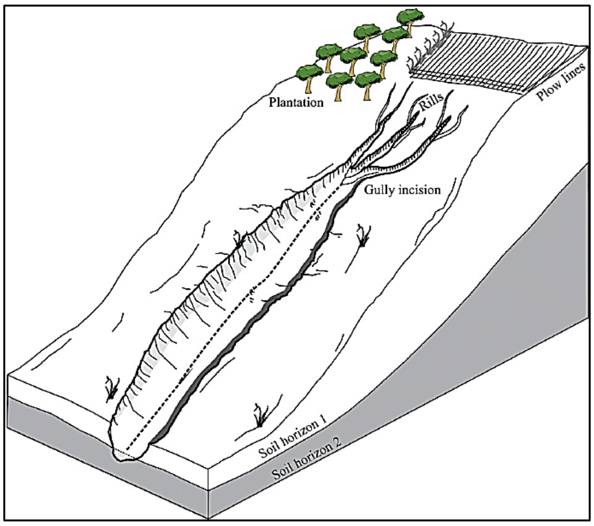


Splash erosion progression

2. **Sheet or Overland Erosion**: This involves the fairly uniform removal of soil in thin layers on a gently sloping slope and flat areas with little or no vegetative cover. Raindrops detach soil particles, which are washed away in solution and transported downstream to a point of deposition (in reality the loose soil merely runs off with the rain). Tilled agricultural fields, construction sites and areas where loose, shallow topsoil overlies compact soil are subject to sheet erosion.

3. **Rill Erosion**: This is the uneven removal of surface soil by running water in small channels or furrows known as ***rills***. This is the most common form of erosion and is visible on the landscape. This type of erosion occurs when the duration or intensity of rain increases and runoff volumes accelerate or increase. It can be removed by normal ploughing. It takes place over gentle and steep slopes.

4. **Gully Erosion**: This is where deep wide channels or grooves are created by running water as soil is washed downslope. The creation of large channels hinders mechanization or vehicle movement. Gully erosion is an advanced stage of rill erosion. Gully erosion occurs when the duration or intensity of rain continues to increase and runoff volumes continue to accelerate. It is common in areas with steep slopes and receive heavy rainfall. It results in the creation of badlands or wastelands.



5. **Wind Deflation**: This involves the removal and deposition of loose soil particles from one part of the earth surface to another by wind. Wind erosion occurs when soils devoid of vegetation are exposed to high-velocity winds. It reduces the productive capacity of soil. It is common in flat arid and semi-arid areas of East Africa such as the Chalbi desert of Kenya.

Causes of Soil Erosion/Factors Affecting Soil Erosion in East Africa

Physical Factors:
(a) **Climate**; The major climatic factors which influence runoff and erosion are precipitation, temperature, and wind. Precipitation is by far the most important. Heavy prolonged torrential rains result in runoff and loss of soil through surface flow while prolonged but gentle rains lead to minimal erosion.
In addition, during drought soil moisture levels at the surface are low increasing the particles to be carried by strong winds. Thus in arid areas where drought is prevalent wind erosion is more pronounced, e.g. Northern Kenya, Chalbi desert and Karamoja.

(b) **Relief**; The topography of the land determines the velocity at which surface runoff will flow, which in turn determines the erosivity of the runoff. Thus steeper slopes (especially those without adequate vegetative cover) in highland areas accelerate the rate of soil erosion causing massive gullies while gentle slopes promote sheet and rill erosion. Flat areas, like Turkana in Northern Kenya however experience wind erosion.

(c) **Vegetation cover**; Vegetation acts as an interface between the atmosphere and the soil. It increases the permeability of the soil to rainwater, thus decreasing runoff. It shelters the soil from winds, which results in decreased wind erosion. The roots of the plants bind the soil together forming a more solid mass that is less susceptible to both water and wind erosion. Thus areas with scanty or no vegetation cover experience high rates of soil erosion by wind and water unlike areas with thick vegetation cover like Mabira.

(d) **Nature of soils**; Poor porous and unconsolidated soils offer less resistance to forces of wind and running water, e.g. young volcanic soils and sandy soils leading to rampant soil erosion. For example areas of Mt. Elgon.

(e) **Presence of strong prevailing winds** especially in areas of very low rainfall and scanty vegetation lead to wind erosion, e.g. areas of Northern Kenya and NE Uganda.

(f) **Prolonged drought** results in scanty vegetation cover hence soils are left bare or exposed to agents of erosion like strong winds and running water. This is common in arid and semi-arid areas of Karamoja, Kotido and Moroto in NE Uganda.

(g) **Biotic factors** like harvester ants common in pastoral and semi-arid areas eat all the grasses leaving behind bare land such that wind or runoff water easily carry away the soils.

Human Factors:

(h) **Overstocking**; This involves the rearing of large numbers of animals than what the land can comfortably accommodate, that is, the number of animals reared is greater than the land carrying capacity. This means that the vegetation (pasture) is cleared at a fast rate creating bare patches of land that are affected by erosion.

(i) **Overgrazing**; This involves the grazing of animals on a specific piece of land for a considerable period of time without rest. Heavy grazing reduces vegetative cover and leaves the soil bare and susceptible to wind and water erosion. The soil can be broken up or compacted by hooves, this makes the problem worse. This is common in the Ankole-Masaka dry corridor.

(j) **Over cropping**; This involves the continued cultivation of crops on the same piece of land for a long period of time without rest. This breaks up soil into finer particles (loss of compaction), leads to soil exhaustion and change in soil structure thus accelerating soil erosion. Over cropping also increases wind erosion rates, by dehydrating the soil and breaking it up into smaller particles that can be picked up by the wind.
(k) **Uncontrolled bush burning**; This is common in pastoral areas to create new pastures for animals. As a result soil is left bare without any vegetative cover to protect it against agents of soil erosion. Thus soil is easily eroded by wind and running water e.g. in the Ankole-Masaka corridor.

(l) **Deforestation**; Deforestation causes increased erosion rates due to exposure of mineral soil by removing the humus and litter layers from the soil surface, removing the vegetative cover that binds soil together, and causing heavy soil compaction from logging equipment. Once trees have been removed by fire or logging, infiltration and erosion rates become high. Severe fires can lead to significant further erosion if followed by heavy rainfall. The loss of permanent vegetation cover in certain locations has resulted in extensive erosion by wind. Loose, dry, bare soil is the most susceptible.

(m) **Monoculture**; This involves the persistent growing of the same crop on the same piece of land year after year without crop rotation. This damages the soil by reducing soil nutrients; the soil becomes dry and easily eroded by wind and water.

(n) **Shifting cultivation**; This is an agricultural system in which plots of land are cultivated temporarily, then abandoned. This system often involves clearing of a piece of land followed by several years of wood harvesting or farming, until the soil loses fertility. This degrades the soil and causes the soil to become less and less fertile.

(o) **Up and down slope cultivation** without using proper methods of cultivation along the slope encourages run-off leading to gulley erosion along slopes.

(p) **Urbanization**; Urbanization has major effects on erosion processes—first by denuding the land of vegetative cover, altering drainage patterns, and compacting the soil during construction; and next by covering the land in an impermeable layer of asphalt or concrete that increases the amount of surface runoff and increases surface wind speeds. Much of the sediment carried in runoff from urban areas (especially roads) is highly contaminated with fuel, oil, and other chemicals. This increased runoff, in addition to eroding and degrading the land that it flows over, also causes major disruption to surrounding watersheds by altering the volume and rate of water that flows through them, and filling them with chemically polluted sedimentation. The increased flow of water through local waterways also causes a large increase in the rate of bank erosion.

(q) Use of pesticide and chemical fertilizers which kill organisms that bind soil together.

(r) **Climate change**; The warmer atmospheric temperatures observed over the past decades are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events. Studies on soil erosion suggest that increased rainfall amounts and intensities will lead to greater rates of erosion. Thus, if rainfall amounts and intensities increase in many parts of the world as expected, erosion will also increase.

(s) **Mining or quarrying**; Mining accelerates the rate of soil erosion because the vegetation cover is removed and land is exposed to agents of soil erosion.

(t) **Construction works** such as road and railway construction lead to exposure of soil to harmful effects of raindrops and wind.

(u) **Growing of poor cover crops** such as cotton and tobacco leave bare land in between the rows that easily encourage soil removal by running water.

Effects of Soil Erosion

Due to the severity of its ecological effects, and the scale on which it is occurring, erosion constitutes one of the most significant global environmental problems we face today. The effects are both positive and negative, they include;

Water and wind erosion are now the two primary causes of **land degradation**; combined, they are responsible for 84% of degraded land area (acreage). This results in loss of valuable fertile soil (land is made barren). The loss of soil fertility due to erosion is further problematic because the response is often to apply chemical fertilizers, which lead to further water and soil pollution, rather than to allow the land to regenerate.

The loss of fertile soil leading to unproductive soils hence low crop yields and famine or hunger.

Soil erosion (especially from agricultural activity) is one of the leading global cause of water pollution, due to the effects of the excess sediments flowing into the world's waterways. The sediments themselves act as pollutants, as well as being carriers for other pollutants, such as attached pesticide molecules or heavy metals.

Soil eroded from the land, along with pesticides and fertilizers applied to fields, washes into streams and waterways. This sedimentation and pollution can damage freshwater and marine habitats and the local communities that depend on them.

In addition, soil eroded by water gets deposited on river beds (siltation), thus increasing their level and causing floods leading to devastating effects such as killing humans and animals as well as damaging various buildings.

Soil particles picked up during wind erosion are a major source of air and water pollution by sand dust. The dust is often contaminated with toxic chemicals such as pesticides or petroleum fuels, posing ecological and public health hazards when they later land, or are inhaled/ingested.

Soil erosion leads to desertification. Desertification refers to increase of desert areas. Desertification can be characterized by the droughts and arid conditions the landscape endures as a result of human exploitation of fragile ecosystems.

Soil erosion creates badlands or waste lands with gullies that hinder transport and communication as well as mechanization, e.g. in Kondoa region of Tanzania.

Soil erosion results in limited vegetation cover because badly eroded soils are unable to support plant growth hence scarcity of pastures for animals.

Dust particles carried by wind are deposited on social infrastructures like roads, railway lines and buildings leading to increased maintenance costs.

Erosion leads to removal of top soil exposing the fresh parent rock to agents of weathering leading to the formation of fresh and new soils.

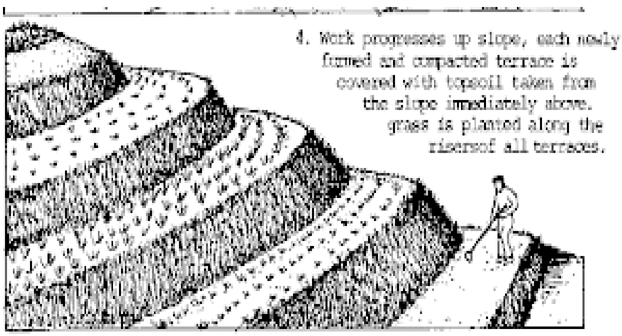
Alluvial fertile soils are transported and deposited in lowlands where they are utilized for agriculture.

Soil erosion exposes minerals that can be mined like granite, and when exported, revenue is earned.

Steps Taken To Control Soil Erosion

Afforestation and Re-afforestation programs; This involves planting trees in areas where they have been cleared. When the land is covered with vegetation, the roots of the plants and trees interlock and interlace to bind the soil particles.

Terracing; Terraces are bench-like channels cut into a steep slope. This slows down the flowing water and allows it to irrigate the crops, as well. This is commonly done in hilly or mountainous areas.



Strip cropping; This is a method of farming used when a slope is too steep or too long. It involves growing of crops in strips, for instance, crops are separated by a row of grass and any other vegetation (alternate strips of crops such as hay, wheat, or other small grains with strips of row crops, such as corn, soybeans, cotton, or sugar beets). Strip cropping helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil.

Using cover crops that are able to grow and spread over the soil, such as beans and sweet potatoes. These cover crops reduce the speed of running water and wing thus acting as breakers to prevent erosion. Cover crops grown are mainly legumes.

Mixed cropping or Crop rotation; This involves growing different types of crops on the same piece of land at different times. This keeps the topsoil covered with vegetation. Rotation of cereal crops with legumes also keeps the soil enriched with nitrogen (from the legumes).

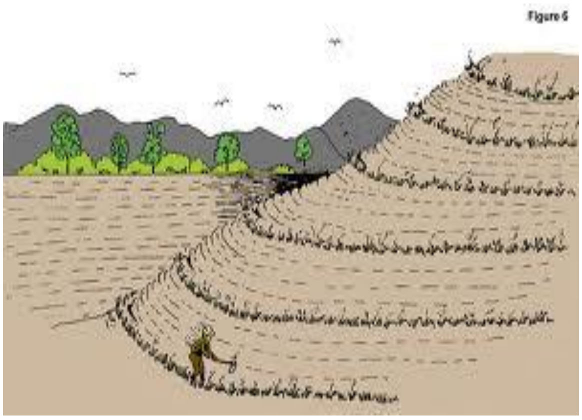
Restricted or Controlled grazing; This involves limiting the number of animals grazed in an area, that is, the number of cattle should balance with the carrying capacity of the land. Grazing should be allowed only on the land meant for the purpose and other areas should be protected from grazing.

Mulching; A mulch is a layer of material applied to the surface of an area of soil. Mulch breaks the fall of rain drops thus reducing the impact of rainfall on bare soil; mulch also interrupts the surface flow of water and increases water infiltration capacity, thus mulch helps conserve soil moisture.

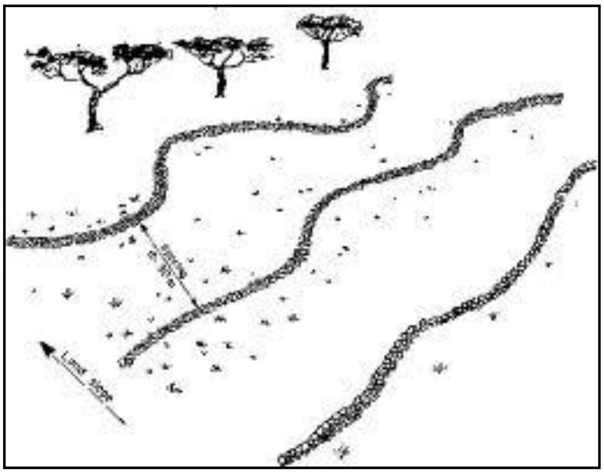
Wind breaks or Shelterbelts; These are rows of trees and shrubs that are planted along the edges of agricultural fields, to shield the fields against winds. They help reduce wind erosion by breaking or reducing the speed of wind. Pine and eucalyptus are some of the suitable tree species planted to act as windbreakers.

Another method of reducing soil erosion is to **leave crop residue** on the field after harvesting. For example, after the corn is harvested, the stalks are left on the field all winter to reduce erosion and soil fertility decline.

Contour ploughing; This is the farming practice of ploughing across a slope following its elevation contour lines. On hilly areas plowing is done across the hill rather than straight up and down. The rows formed slow water run-off during rainstorms to prevent soil erosion and allow the water time to settle into the soil.



Contour bunding; This involves placing stones around the contours of the slope. This helps to capture and hold rainfall before it can become runoff.



Restoring soil fertility; Fertile soil supports vegetation. Loss of fertility results in loss of vegetation and this exposes the land to erosion. Fertility of soil can be increased by addition of natural and synthetic fertilizers.

Building dams; With the dams in place the speed and amount of water flowing can be controlled. This will control the soil erosion of the river banks.

Construction gabions; A **gabion** is a cage or box filled with rocks, concrete, or sometimes sand and soil used for erosion control.

Sand fence; This is a type of fence used to force windblown, drifting sand to accumulate in a desired place. Sand fences are employed to control erosion and to recruit new material in desert areas. Plastic sheets and wood strips are attached to poles and trap windblown sands.

REVISION QUESTIONS

1. To what extent has parent rock influenced soil forming processes in EA?
2. Account for the process of soil formation in EA.
3(a) What is soil profile?
(b) Account for the formation of a well-developed soil profile.
4(a) What is soil catena?
(b) Account for the development of a well formed soil catena.
5. Distinguish between soil profile and soil catena.
6. Account for the extensive soil erosion in EA.
7. Examine the causes and effects of soil erosion in EA.
8. Discuss the causes and effects of soil erosion in EA.
9. To what extent has relief influenced the development of soil profiles in EA?

Approach:

- Define soil profile; describe layers in soil profile; explain role of relief in soil profile development; bring other factors that influence development of soil profile in EA. Give a conclusion by showing the extent to which relief has influenced soil profile development.

10. Account for the formation of lateritic soils in EA.

Approach:

- Identify and describe lateritic soils; locate them in EA
- Give the factors responsible for the formation of lateritic soils; explain the formation process of lateritic soils

11(a) Describe the characteristics of a fully developed soil profile.
(b) Explain the factors which have influenced soil profile development in EA.

Approach

- Define soil profile with aid of a diagram; describe the different layers of soil profile; explain factors the influence soil profile development in EA.

VEGETATION

Vegetation is the term given to all living plants, both trees and grass, of all categories that cover the surface of the earth; OR, a community of plants which cover an area and gives it a distinct character. Vegetation is also known as ***flora*** and includes all types of vegetation both natural and planted. Plant communities include ***trees, grass, shrubs, herbs, thickets and scrub***.

Major plant communities include;
(a) Equatorial forest/tropical rainforest
(b) Savanna vegetation
(c) Swamp vegetation
(d) Mangrove vegetation
(e) Montane/Mountain vegetation
(f) Semi-arid/semi-desert vegetation
(g) Mediterranean vegetation

In Africa, various vegetation types exist as noted above. Globally vegetation is affected by climate. There is a high degree of correlation between the climate and vegetation of an area.

VEGETATION OF EAST AFRICA

1. EQUATORIAL FORESTS OR TROPICAL RAINFOREST VEGETATION

They majorly occur in the Congo basin, Guinea coast of West Africa, Gabon, Cameroon, Nigeria, Ghana, Ivory Coast, and Liberia. In East Africa they cover a small percentage of the total land area and can be found in SW Uganda, windward slopes of mountains, Mabira, Budongo, Kibale, Bwindi, Echuya forests, Kakamega Forest in western Kenya, among others.

Characteristics of Tropical Rainforests

- They contain a great variety of plants which are close together (thick/dense) forming three canopies or layers, namely, bottom, middle and top layers. This is due to the growth of different trees at different intervals or age and sprawl to form canopies as well as the heavy rainfall.
- The forests contain tall trees that grow to a height of about 60m and above as they compete for sunlight.
- Trees are hardwood species, such as, mvule, musizi, mahogany, ebony, greenheart, red heart, iron wood, palms, among others, due to the long gestation period.
- Trees are evergreen shedding leaves at different intervals throughout the year due to the heavy rainfall and sunlight received throughout the year promoting continuous growth.
- Trees have broad leaves because of the hot temperatures and evenly distributed rainfall which enables transpiration and evaporation to remove excess water.
- The forests have little or no undergrowth due to the thick canopies preventing sunlight from reaching the ground.
- Forests have numerous climbing plants and epiphytes that get support from the tall and huge trees.
- There are a variety of tree species growing in mixed or impure stands due to the ample rainfall and hot temperatures, e.g. palms, mvule as well as mahogany.
- Trees have a long gestation period or take long to mature, about 60 years and above.
- Trees have straight and big trunks due to the ample growing conditions provided by the heavy rainfall and hot temperatures throughout the year.
- Most trees have huge buttress roots that give support to the huge and tall trees.
- The forest ground is mainly covered by mosses and ferns due to the heavy rainfall leaving the ground wet and moist.

Conditions favoring the growth of tropical rainforests

(a) Heavy and evenly distributed rainfall of about 1500mm and above throughout the year which provides water for proper tree growth. This explains why the trees grow so tall.
(b) Relief: TRFs are found along gentle slopes of mountains and plateaux, e.g. Mt. Rwenzori forest in Kasese; Mt. Elgon and Mgahinga forests. Other forests thrive in lowland area such as river valleys favoring the growth of riverine forests along rivers like Katonga, Nile and Semliki.
(c) Hot temperatures ranging between 22^0 and 28^0 C which increase humidity in the air hence contributing to rainfall for tree growth. This encourages luxuriant tree growth.

(d) High humidity of about 80% promoting luxuriant growth of vegetation.
(e) Presence of adequate sunshine for plants to manufacture their own food through photosynthesis thus promoting plant growth.
(f) Deep fertile soils along mountain slopes, gently sloping areas and alluvial soils along river valleys and lake shores enable the growth of tall trees.
(g) Drainage: The forests grow in areas that are well drained especially along gentle slopes, mountain slopes and low lying areas. In addition waterlogged areas along the East African coast have promoted the growth of mangrove evergreen forests.
(h) Altitude: TRFs thrive in areas of low altitude of about 1000-2000m above sea level on mountain slopes and low lying areas where there is heavy rainfall, high humidity and hot temperatures.
(i) Man's activities such as afforestation, re-afforestation which involve planting trees and replanting trees where they have been cut has also enabled the growth of TRFs.
(j) Positive government policies of conservation and gazetting of forest reserves and the natural environment has contributed to the growth of TRFs such as Kibale FR, Echuya FR, Mt. Kei FR, Kisii FR in western Kenya, among others.
(k) Existence of pests and diseases as well as damp conditions limit human interference in areas with TRFs, e.g. forests in the Ssese islands.

Revision Questions:
1(a) Describe the characteristics of TRFs.
(b) Explain the conditions which have favored the growth of TRFs in EA.
Approach
- ***Identify areas covered by tropical rain forests in EA***
- ***Give and describe the characteristics of tropical rain forests***
- ***Identify and explain the factors favoring the growth of tropical rain forests***

2. Account for the occurrence of TRFs in East Africa.
Approach
- ***Identify areas covered by tropical rain forests in EA***
- ***Give and describe the characteristics of tropical rain forests***
- ***Identify and explain the factors favoring the growth of tropical rain forests***

3. Account for the distribution of natural forest vegetation in EA.
Approach
- ***Define natural forest vegetation.***
- ***Identify the types of natural forests in EA i.e. TRFs, riverine & mangrove forests***
- ***State the characteristics of each type of forest and where it is found descriptively or by drawing a sketch map.***
- ***Explain the factors influencing the growth of each type of forest***

2. SAVANNA VEGETATION
This vegetation covers almost the entire half of EA. Originally the areas covered by savanna vegetation were once under forest cover but due to man's interference they are now under savanna vegetation. Areas with savanna vegetation lie between tropical rainforest zone and desert areas. This type of vegetation is common in areas with tropical climate, alternating hot and wet seasons. Savanna vegetation comprises of three categories namely savanna woodland, savanna grassland and savanna dry bush, scrub and thicket.

(A) SAVANNA WOODLAND OF TROPICAL WOODLAND

It lies near TRFs. Most common in parts of western and southwestern Tanzania (Miombo woodlands), parts of northern Uganda, Rift valley regions like Lake George and Albert flats; parts of south and eastern Kenya. This is the type of savannah vegetation with more or less continuous cover of trees and shrubs intertwined.

Characteristics of savanna woodland vegetation

- There's a more or less continuous cover of trees because of the moderate water supply, that is, trees are dominant.
- The trees are of medium or moderate height of about 8-16 metres high.
- The trees are moderately spaced.
- There's a dense undergrowth of grass, bushes and shrubs because of the ample sunlight reaching the ground.
- The trees are tropical hardwoods with mixed stands.
- The trees are umbrella shaped with bushy spreading tops, such as acacia.
- Trees are intermingled with xerophytic thorny lianas, cacti and a few hardy shrubs.
- Some trees have swollen trunks or stems such as baobab
- Trees have twisted/gnarled trunks with thick rough bark.
- Trees are drought resistant because of swollen stems and long roots.
- Trees are sometimes fire resistant because of thick bark.
- They tend to have small leaves to restrict water loss through transpiration.
- Dominant tree species are baobab, acacia, miombo, mnondo, zebrawood (msasa) and Isoberlinia.
- Trees are deciduous shedding off their leaves during the dry season.

Conditions favoring the growth of savanna woodland vegetation

(a) Seasonal and moderate rainfall totals of about 750-1050mm per year resulting in trees being deciduous.
(b) Hot temperatures of about 25^0C and above leading to dominance of drought resistant vegetation species.
(c) Moderate humidity of 50% favors growth of a continuous cover of medium sized trees.
(d) Fairly fertile soils with low water retention capacity enable water to drain easily and trees to develop long tap roots.
(e) Low altitude of less than 1000 mm above sea level.
(f) Man's activities involving the clearing of TRFs for settlement, cultivation among others hence degrading forested areas into savanna woodland areas.
(g) Pests and diseases ensuring little or no settlement in areas with woodland vegetation for example the existence of the Miombo woodlands of Tanzania is attributed to the presence of tsetse flies that scare away man thus continuous existence of woodlands.
(h) Government policy creating of national parks and forest reserves for ecological functions has led to protection and regeneration of formally degraded savanna woodlands for example Serengeti national park in Tanzania.

 **baobab tree**

Revision Questions
1(a) Describe the characteristics of woodland (miombo) type of vegetation in EA.
(b) Account for the occurrence or existence of woodland type of vegetation in EA.
Approach
- ***define woodland type of vegetation***
- ***identify areas where woodland vegetation occurs***
- ***describe the characteristics of woodland vegetation***
- ***Identify and explain the explain the conditions favoring the growth of woodland vegetation***

(B) SAVANNA GRASSLAND OR SAVANNA PARKLAND

This type of vegetation lies between woodland and dry thicket bushes. It is dominated by a continuous cover of tall grasses and a few scattered trees. It's found in areas where rainfall ranges between 500-750mm per year. Savanna grassland is common in the Nyika plains of Kenya, rift valley floor of western Uganda (Queen Elizabeth NP, Lake Albert flats), Northern Uganda and areas around Bukoba and Serengeti NP in Tanzania. It should be noted that much of these areas are occupied by pastoral communities and have been gazette as national parks.

Characteristics of savanna grassland vegetation
- Dominant vegetation are tall grasses of about 3-5 m
- Dominant grass species are elephant grass, spear grass and common finger grass
- Grasses from a continuous plant cover
- Grasses grow in compact tufts
- Grasses have long roots which reach down in search of water
- Grasses lie dormant during the dry season and grown again when in the next rainy season
- Grasses dry during the dry season and turn brown or yellow and green during the wet season
- There are a few scattered short trees and bushes amidst the grasses
- Dominant trees species are acacia and baobab
- The trees are umbrella shaped
- Trees are also deciduous shedding their leaves during the dry season
- Trees have tiny or small leaves to reduce water loss through transpiration
- Trees are fire and drought resistant

Conditions favoring the growth of savanna grassland vegetation
- Moderate and seasonal rainfall of about 500-700mm per annum thus deciduous trees
- Moderate humidity levels
- Fairly fertile soils
- Hot temperatures about 27^{0}C and above favor growth of grasses with scattered trees
- Constant bush fires during the dry season thus low density of trees
- Low altitude of less than 1000m above sea level with hot temperatures favoring growth of tall grasses
- High population density thus clearing of tropical forests for cultivation and growth of grasslands
- Soils also should be well drained and not water logged
- Positive government policy of conserving grasslands into conservation areas such as Queen Elizabeth national park in Uganda.

(C) DRY BUSH AND THICKET SAVANNA

Lies near areas bordering tropical deserts. Vegetation comprises of a more or less continuous cover of thorn bushes, thorn trees and low shrubs or scrub intertwined. Its best developed in areas of northern, north western and north eastern Kenya, north eastern Uganda (Karamoja), as well as parts of the Ankole–Masaka corridor, northern Tanzania and some parts of Rift valley.

Dry bush and thicket savanna is characterized by;
- stunted poor vegetation of bushy thorny trees with shrubs and thickets growing in between
- trees are short/stunted about 5-10 meters tall
- trees have small waxy needlelike leaves to minimize water loss
- trees have woody twisted/gnarled stems
- trees have thick bark
- trees are thorny for defense purposes
- vegetation is drought and fire resistant
- trees have deep roots to reach underground water sources
- grasses are very short, more tufted or grow in bunches and widely spaced
- grasses are brown and patched especially during the dry season
- bushes and the shrubs have thorns instead of leaves to reduce transpiration
- bare ground is common in between the scattered thorny bushes

Conditions favoring the growth of savanna dry bush and thicket vegetation

- Low and seasonal rainfall about 250-500mm that is unreliable thus growth of poor and short grasses
- Hot temperatures above 30^0 C encourage growth of dry savanna with drought resistant trees
- Very low humidity levels hence growth of vegetation with small leaves
- Low altitude of less than 1000m above sea level especially low plains promote growth of dry savanna
- Poor infertile sandy soils have encouraged growth of dry savanna vegetation
- Man's activities such as over grazing by domestic and wild animals, bush burning as well as deforestation change the nature of vegetation

Revision Questions

1(a) Describe the characteristics of savanna vegetation.

(b) Explain the conditions which have favored the growth of savannah vegetation in EA.

Approach

- *define savanna vegetation; identify the types of savanna*
- *give and describe the characteristics of each type and where it occurs*
- *Identify and explain the explain the conditions favoring the growth of savanna*

2. Account for the growth and distribution of savanna vegetation in EA.

Approach

- *Describe savanna vegetation and the characteristics of the various types of savanna vegetation and where they are found*
- *Describe the factors/conditions for the growth of each type of savanna vegetation in EA*

3. Account for the decline of savanna vegetation cover in EA.

Approach

- *Identify the three forms of savanna vegetation, their distribution & characteristics*
- *Identify and describe the factors for the decline of savanna vegetation in EA with examples, e.g. human activities like overstocking/overgrazing, crop cultivation, bush burning, deforestation, mining/quarrying, industrialization; prolonged dry seasons, pests & diseases, natural fires, gazetting conservation areas, influence of dry prevailing winds, etc.*

4. Account for the occurrence of the Miombo wood land type of vegetation in EA.

Approach

- *Define Miombo wood land type of vegetation*
- *Identify areas where the Miombo woodland occur descriptively or by use of a sketch map*
- *Describe the characteristics of Miombo woodland.*
- *Identify and explain the various factors that have led to the occurrence of Miombo woodland type of vegetation.*

3. SWAMP VEGETATION

This type of vegetation is majorly comprised of papyrus plants. It's found in low lying areas with poorly drained soils or impeded drainage for example along river valleys of Katonga, Kagera, Rwizi, Tana, Ssezibwa, the Nile and shores of Lakes Victoria and Kyoga. It's also found in shallow waters of low lying areas in central and western Uganda. This type of vegetation is due to impeded soils that give rise to water loving plants such as papyrus reeds, water lilies and hyacinth.

Characteristics of swamp vegetation

- Plants are evergreen due to abundant water supply and sunlight
- Plants have small straight sponge-like stems or trunks
- Plants grow close to each other to increase stability in muddy soils
- They have a uniform canopy
- Have thin thread-like or needle-shaped leaves on top
- Have fibrous roots to hold the plants down in the shallow waters
- Papyrus reeds grow to a height of 3-4 metres tall
- Papyrus reeds have triangular stems
- Sedges have flowering leaves on top of the water
- There are a variety of flowering plants such as lilies
- Swamp grasses have long leaves with sharp blades
- The main plant species are papyrus reeds, water lilies and hyacinth

Factors favoring the growth of swamp vegetation

- Hot temperatures of over 20^0 C which influence high rates of evapotranspiration.
- Heavy rainfall above 1000 mm favouring the growth of broad evergreen vegetation.
- High humidity of 70% favouring the growth of broad and evergreen trees.
- Low altitude of 500m above sea level which are associated with hot temperatures.
- Deep leached alluvial soils ideal for the growth of forests.
- Shallow marine salty soils which at certain points allows the growth of shrubs.
- Poorly drained and heavily logged soils to allow forest growth.
- Government policy of conservation and preservation of swamplands.

Revision Questions:
1(a) Describe the characteristics of swamp vegetation.
(b) Examine the factors leading to the rapid loss of wetland vegetation in EA.
Approach
- Define and identify swamp vegetation – mangrove and swamp/papyrus
- Mention and describe x-tics of swamp vegetation
- Identify and describe the factors for the decline of swamp vegetation in EA with examples, e.g. industrialization; population pressure; over harvesting swamp vegetation; mining of sand and other minerals; wetland reclamation for crop growing; reclamation and draining of river valleys for livestock farming; infrastructural development like roads, buildings & sports grounds; bush burning/natural fires; afforestation in wetlands with eucalyptus trees; prolonged drought; fish farming or construction of fish ponds.

4. MANGROVE VEGETATION

Mangroves are tropical trees that grow along coastal plains of the East African coast such as Lamu, Dar es Salaam, Malindi, the Rufigi delta and the western coast of Madagascar. The vegetation has aerial roots and ion some places they grow close together forming a dense mangrove forest.

Characteristics of mangrove vegetation

- Vegetation is characterized by halophytic or salt loving trees, shrubs and other plants growing in saline tidal waters such as black mangrove, white mangrove, red mangrove, mangrove palm, mangrove apple tree (cork tree) and buttonwood.
- Trees are evergreen due to heavy rainfall and hot temperatures received throughout the year
- Trees have broad leaves to trap adequate sunlight for photosynthesis and get rid of excess water
- Trees grow close together forming a dense or thick forest due to hot and wet conditions
- Trees are of medium height between 8-16m due to ample sunlight
- Trees have aerial or stilt roots kept above the water level for respiration and to support the stout trunks
- Trees have short stumpy trunks in low tidal waters
- Trees are hardwoods that take long to mature since because of the tropical hot-wet conditions
- Vegetation has waxy leaves to reduce water loss through transpiration
- Trees have grey leathery foliage that appears to float on water
- Trees and thick shrubs grow parallel to the coast due to constant supply of silt by waves

Factors favoring the growth of mangrove vegetation

- Very low altitude below 20m above sea level that is associated with hot temperatures and heavy rainfall that support mangrove vegetation.
- Mangrove vegetation grows in a variety of soils such as impervious clay soils, peat soils, mudflat alluvial soils and deep saline soils which enable luxuriant growth.
- Presence of heavy and reliable rainfall about 1000mm and above per year enabling luxuriant growth
- Presence of hot temperatures over 20^0 C leading to growth of luxuriant mangrove forests.
- High humidity levels over 80% which influence formation of rainfall
- Relief: Mangrove vegetation is found along coastal lowlands and broad valleys or creeks which encourage accumulation of silt, mud and alluvial soils that support mangrove vegetation.
- Presence of low tidal range of water that creates marshy conditions which favor growth of mangrove forests.
- Presence of barrier reefs or coral reefs along the coast that prevent alluvial soils from being swept away by high energy wave action hence providing suitable conditions for mangrove forests to grow.
- Government policy: Governments have gazette mangrove forests as conservation areas hence promoting their existence. However, on a negative side, man is encroaching on mangrove vegetation by extracting building materials, cultivation water loving crops as well as coastal recreation developments thus reducing the area covered by mangrove vegetation.

Revision Questions:
1(a) Describe the characteristics of mangrove vegetation.
(b) Explain the conditions that have influenced the distribution of mangrove forests in EA.

5. MONTANE/MOUNTATION VEGETATION

This type of vegetation is dominant on the high mountains of East Africa such as Mt. Rwenzori, Mt. Elgon, Mt. Kenya and Mt. Kilimanjaro. Vegetation comprises of various types that gradually merge into each other as one ascends the mountain. Also the vegetation has no clear cut boundaries. The vegetation types include savanna, tropical rainforest, temperate forests, bamboo forests as we as heath and moorland. The underlying factor influencing this type of zonation is altitude as noted below;

- Between 1000 – 2000m a.s.l, savanna vegetation with its various types is dominant. At its lowest the vegetation is dry bush and thicket savanna characterized by short bushy trees with shrubs growing between them, trees have small waxy or thorny leaves to reduce water loss, trees are deciduous, there are poor and short tuft grasses with bare ground between them, are drought and fire resistant. The dry savanna merges into savanna grasslands characterized by a continuous cover of tall grass, few scattered trees that are drought and fire resistant, trees have tiny leaves and are deciduous, grasses dry up, turn brown during the dry season and turn green during the wet season. This is because at this altitude there is low rainfall, hot temperatures about 29^0 C, fairly fertile soils and human interference like mining, cultivation and settlement. As the altitude rises, grasslands turn into savanna woodland with a continuous cover of umbrella shaped trees, have thick bark, are tropical hardwoods and appear in mixed stands, trees are of medium height about 16-18m, are deciduous, fire and drought resistant, have small leaves to reduce water loss and dominant species is acacia. This is due to conditions such as moderate rainfall about 1000mm p.a., hot temperatures about 30^0 C, moderate humidity and fairly fertile well drained soils.

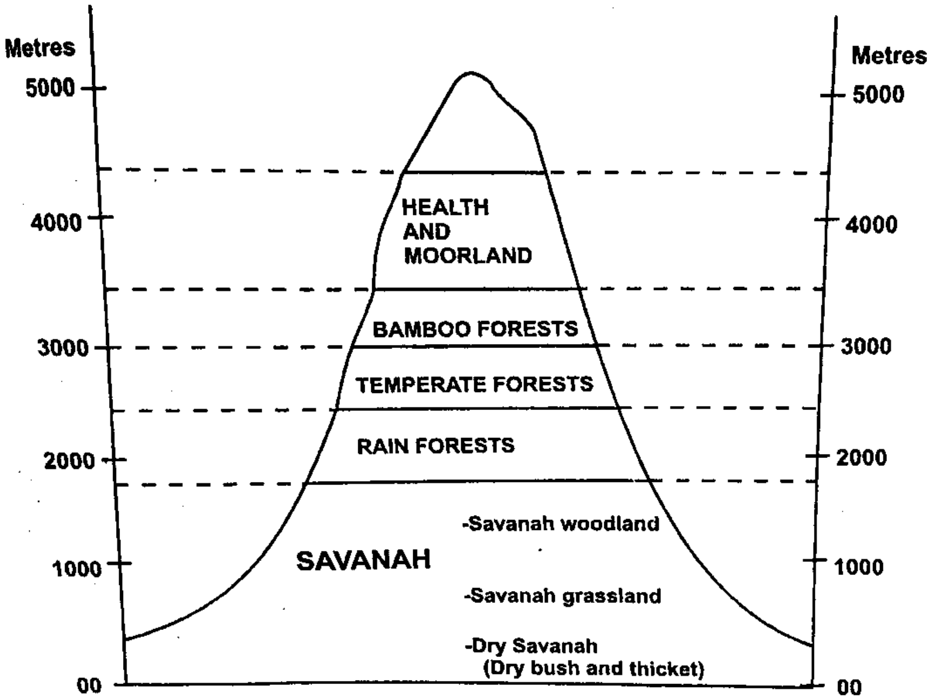
- Between 2000 – 2500m above sea level tropical rainforests emerge characterized by tall evergreen trees with broad leaves, have big and straight trunks, are hardwoods, appear in mixed stands, trees form 2-3 canopies, there is a thick undergrowth of climbing plants and trees have large buttress roots to support their great height and weight. This is due to conditions such as heavy rainfall above 1500mm p.a., hot temperatures about 27^0 C, deep fertile well drained soils as well as less human interference.

- Between 2500 – 3000m above sea level there are temperate forests characterized by dominance of coniferous tree species like cedar, cypress and camphor, trees are evergreen with small leaves, have straight trunks, are conical in shape, grow in pure stands, have needle shaped leaves and no undergrowth. This is due to reducing rainfall totals, cool temperatures, shallow/thin soils and well drained soils.

- At an altitude of about 3000 – 3500m above sea-level, bamboo forests exist characterized by trees with a single layer, trees grow in pure stands, have segmented or reed like stems with hollows inside to minimize water consumption which is relatively scarce at this altitude, have small, tough pointed leaves, trees are evergreen and have prop roots to anchor firmly in the thin soil layer. This is due to the following conditions; cold/cool temperatures, reduced rainfall, thin but well drained soils.

- At an altitude of about 3500 – 4500 meters above sea-level, heath and moorland exist characterized by short grasses, shrubs and alpine flowers. Plants include giant lobelia and giant groundsel that are adopted to the cold climate. This due to the cold/cool temperatures, very little or no rainfall, very thin soils and poorly drained soils due to melting of snow.

Illustration of the vertical zonation of the different types of vegetation along the highland areas.



Factors favoring the growth of montane vegetation

- Moderate rainfall between 500-1000mm and hot temperatures about 25^0 C, especially on the leeward slopes has led to growth of savanna vegetation in the lower slopes of highlands like Mt. Rwenzori in Kasese. On the windward slopes heavy rainfall above 1000mm and hot temperatures about 25^0 C leading to growth of tropical rainforests.
  Higher up the mountain at an altitude of 2500-4000m there is heavy rainfall about 1000mm with warm to mild temperatures giving rise to temperate and bamboo forests. At altitudes between 4000-5000m there are cold temperatures and low rainfall resulting in the growth of heath and moorland.
- Soils: Fertile volcanic soils on the lower slopes support the growth of tropical rainforests and savanna vegetation. The upper slopes are steep and have shallow or skeletal soils that support bamboo forests as well as heath and moorland.
- Relief: On the gently sloping lower slopes savanna vegetation and tropical rainforests thrive while on the upper steep slopes there is bamboo, temperate as well as heath and moorland vegetation.
- Biotic factors: In the lower slopes the destruction of vegetation for timber, firewood, settlement among others has led to degeneration of natural vegetation thus forests turn into woodlands and grasslands. On the positive side, man has influenced the growth of natural vegetation in highland areas where national parks and game reserves have been setup as part of conservation efforts, e.g. Mt. Rwenzori national park and Mt. Elgon national park.

Revision questions:

1. Account for the differences in the natural vegetation zonation in one mountainous area in EA.

Approach

- ***identify any one mountainous area in EA with different natural vegetation***
- ***identify the different natural vegetation zones existing on it***
- ***describe the characteristics of each vegetation type***
- ***explain the factors that have favored each vegetation type/zone identified.***
- ***Draw the diagram showing the arrangement of vegetation types from the top to the base***

2. With reference to any mountains in EA, account for the vegetation distribution.

Approach:
- Identify the mountain.
- Describe the vegetation zonations.
- Describe the characteristics of each vegetation cone and the conditions for each zone.
3. Examine the influence of altitude on vegetation zonation in the highlands of EA.
Approach:
- define vegetation/vegetation zonation; identify highlands of EA then illustrate vegetation zones on highlands of EA
- identify vegetation types, describe their characteristics and explain conditions for their existence at the given altitude

6. SEMI DESERT OR SEMI-ARID VEGETATION

This type of vegetation can be found in the hot and dry areas of East Africa such as parts of Karamoja in North Eastern Uganda, Lake Albert flays in Western Uganda, Ankole-Masaka corridor, Turkana land in Northwest Kenya, and the Chalbi desert in Northeast Kenya. In such areas there is thorny bush trees, scrub as well as stunted grasses. Rainfall in these areas low, temperatures are very hot with prolonged drought.

Characteristics of semi-desert vegetation

- Vegetation comprises of scattered thorny bush trees with a height of 5 – 10m e.g. acacia with very short and coarse grasses growing in between them as well as bushes (thickest or shrubs)
- Vegetation is largely xerophytic, i.e. well adapted to survive the prolonged droughts common in such areas, e.g. baobab, cactus, thorn bushes, coarse grasses, acacia
- Plants shed their leaves during the dry season to reduce water loss through transpiration and bear leaves during the wet season
- Some plants have very few or no leaves to reduce water loss through transpiration
- Seeds of semi-desert plants have a thick layer to protect them against bush fires thus they're fire resistant
- Plants have thick hard bark to control water loss through transpiration
- Most plants have thorns to protect them against animals that would like to eat them
- Also many plants have tiny, thorny leaves to reduce water loss e.g. cactus
- Some plants have waxy leaves and stems to prevent moisture loss
- Plants have deep penetrating tap roots to enable them draw water from underground sources given the limited surface moisture
- Some trees have swollen trunks in which to store water for use during the long dry spell, e.g. baobab
- Plants produce seeds which are dormant for years until a little rainfall is received then they germinate
- Many plants complete their cycle within a few weeks before the soils completely dry up

Conditions influencing the distribution of semi-arid vegetation in East Africa

- Very low, unreliable and highly seasonal rainfall less than 500mm per year that cannot support luxuriant vegetation cover. Thus plants have a short cycle of germination, leafing, flowering and fruiting as well as seed dispersal.
- Very hot temperatures above 30^0 C with dry winds and high evaporation rates favoring growth of short grasses and scattered trees.
- Very low humidity levels of less than 20% due to absence of cloud cover and large water surfaces thus growth of xerophytic vegetation.
- Presence of infertile skeletal sandy soils with low humus content that discourage the growth of luxuriant vegetation. Such soils are also highly porous with low moisture retention capacity giving rise to scattered trees and scanty grasses.
- Relief: Semi-desert vegetation generally grows in low lying areas with relief of less than 1200m above sea level with hot temperatures and limited rainfall.
- Drainage: Due to the limited surface drainage, short thorn bushes and coarse grasses grow in scattered patterns. In areas of slat pans or depressions, halophytic plants, i.e. plants that can grow in salt pans, such as salt bushes grow.

- Biotic factors: Wilds animals feed on and destroy savanna woodlands and grasslands turning them into dry bushes. Termites and locusts destroy grasslands leading to emergence of dry scrubs. Human activities have impacted on the vegetation positively and negatively.
Positively, conservation policies by governments have led to growth of semi-arid vegetation in areas like Kidepo valley in Northeast Uganda. Negatively, activities like over grazing, bush burning, sinking of boreholes, charcoal burning among others have led to reduction of vegetation growth leading to scattered trees and short grasses.



Revision questions:
1(a) Describe the characteristics of semi-arid vegetation.
(b) Explain the conditions that have influenced the distribution of semi-arid vegetation in EA.
2. Account for the occurrence of semi-desert vegetation in EA.

7. MEDITERRANEAN VEGETATION

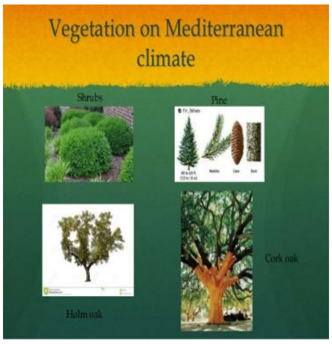
This type of vegetation occurs in the Western Cape Province area of South Africa as well as in north of Algeria, north of Tunisia, north of Libya and Morocco.

Characteristics of Mediterranean vegetation
- Vegetation is comprised of broad leaved evergreen shrubs, bushes and trees such as evergreen oak, cedar, pine, cypress, cork oak and eucalyptus due to the wet winters.
- Trees have small, dark waxy leaves to reduce moisture loss during the hot dry summers (***Sclerophyll vegetation***).
- Vegetation such as vines has long tap roots that can reach the moist rock layers well below the surface during the hot dry summers.
- In addition some plants have large fleshy bulbous roots that can store water for use during the hot dry summers.
- Some plants have thick rough bark to store water during the dry summer months
- There are plenty of sweet smelling herbs and shrubs such as rosemary, lavender, thyme, juniper, olive, myrtle, jasmine, sage as well as oleander.
- Some trees are cone shaped especially pines
- Some trees are short and have flat tops for example cork oak
- A mixed type of vegetation may exist with deciduous trees, coniferous trees, tough grasses, short or dwarf trees and scrub.
- Short grasses are common
- Some plants are fire resistant able to withstand the rampant fires during summer

Conditions favoring the growth of Mediterranean
- Climate: Hot dry summers with temperatures of about 25^0 C limit the growth of luxuriant vegetation while the cool wet winter allow growth of some trees like the evergreen oak. Moderate annual rainfall between 500-700mm supports the growth of scattered trees and bunchy grasses with long tap roots.
- Soils: The ashy Mediterranean residual soils support the growth of plants such as evergreen and cork oak trees. The porous limestone soils that drain easily lead to growth of deep rooted pants so as to reach underground water sources while the poor soils of the drier areas lead to growth of scrubs and poor grasses.

- Altitude: Mediterranean vegetation is mainly found along the coastal areas with low altitude except for the Atlas Mountains and highlands of Cape Province.
- Latitude: Mediterranean vegetation is found between 30^0 N and 45^0 N as well as 30^0 S and 40^0 S of the Equator. Also Mediterranean vegetation is located mainly on the western side of continents because of the suitable maritime conditions.
- Drainage: The poorly drained soils due to excessive evaporation during summer makes plants like vines to develop long tap roots to reach underground water sources while forests develop in areas of well drained soils.
- Biotic factors such as caterpillars have affected the growth of Mediterranean vegetation such as the cork oak trees that attract large numbers of caterpillars and this has reduced their growth.
- Human activities such as logging, over grazing, arable farming, urbanization and introduction of exotic tree species has led to extensive loss of Mediterranean forests as well as extinction of native plants and animals. On the other hand, continued conservation policies have led to preservation and existence of Mediterranean vegetation.
- Many of the Mediterranean plants are ***pyrophytes or fire-loving*** an even depend on fire caused by lightning during the hot dry summers for reproduction, recycling nutrients and removal of dead vegetation thus ensuring the existence of this type of vegetation.





Revision questions:
1(a) Describe the characteristics of the Mediterranean type of vegetation.
(b) Account for the growth of Mediterranean type of vegetation in Africa.
Approach
- ***State where Mediterranean vegetation is found***
- ***Give and describe the characteristics of Mediterranean vegetation***
- ***Explain the factors which have favored the growth of this type of vegetation***

FACTORS THAT INFLUENCE THE GROWTH AND DISTRIBUTION OF NATURAL VEGETATION IN EAST AFRICA

- **Climate**: Influences vegetation growth and distribution through its elements of rainfall, temperature and humidity.

▪ Heavy, reliable and well distributed rainfall over 1500mm per annum and hot temperatures of about 22^0 to 27^0 C encourage the growth of luxuriant natural forest vegetation such as those of Mabira, Ssese, Budongo among others.

▪ Moderate to heavy rainfall of about 760mm-1200mm annually and distributed in one season as well as hot temperatures of about 24^0 C - 30^0 C support the growth of savannah woodland while moderate annual rainfall of about 500mm-760mm and hot temperatures over 30^0 C promote savanna grasslands vegetation.

▪ Low and seasonal rainfall of about 250mm-500mm per annum and very hot temperatures over 30^0 C encourages the growth of scanty vegetation as well as savanna dry bush and thicket vegetation like in Kotido and Moroto in NE Uganda, as well as in Northern Kenya.

▪ High humidity over 80% encourages luxuriant vegetation such as tropical rainforests with tall evergreen trees; moderate humidity of about 50-60% supports the growth of savanna woodlands and grasslands while low humidity of less than 40%supports scanty, stunted scrub vegetation such as savanna dry bush and thicket vegetation as seen in NE Uganda.

- ❖ **Altitude** refers to the height above sea level. Different vegetation types thrive at different altitude because the conditions that influence vegetation growth like climate, soil and drainage change with altitude as noted below;

- Between 0 – 500m above sea level the dominant vegetation type is of swamps like the mangrove vegetation along the East African coast and papyrus swamps in the broad valley and lowlands due to the associated impeded drainage.
- Below 1000 - 2000m above sea level savanna vegetation characterized by woodlands, grasslands and dry bush savanna is dominant, e.g. in central Tanzania, northern Uganda, etc. this is due to fairly fertile soils and moderate rainfall at this altitude.
- Between 2000 – 2500m above sea level there are tropical rainforests characterized by tall evergreen trees with big and straight trunks mainly found along slopes of highlands such as Mt. Rwenzori, Elgon and Kenya. This is due to heavy rainfall as well as the deep fertile soils at this altitude.
- Between 2500 – 3000m above sea level there are temperate forests characterized by dominance of coniferous tree species like cedar and camphor. This is due to moderate rainfall and reduced temperatures at this altitude common on the higher slopes of Mt. Rwenzori and Kenya.
- At an altitude of about 3000 – 3500m above sea-level there are bamboo forests characterized by trees with a single layer, trees grow in pure stands, have segmented or reed like stems with hollows, have small, tough pointed leaves, trees are evergreen and have prop roots to anchor firmly in the thin soil layer. This is due to cool temperatures and thin soils at this altitude.
- At an altitude of about 3500 – 4500 meters above sea-level supports the growth of heath and moorland characterized by plants such as giant lobelia and giant groundsel that are adopted to the cold climate. This is due to the thin/skeletal soils and very cold temperatures found at high altitudes of Mt. Rwenzori, Kenya and Elgon.

- ❖ **Nature of soils present**. The type of soil in terms of fertility, depth and texture influence vegetation growth and distribution in the following ways;

▪ deep and fertile soils such as volcanic on gentle slopes of volcanic highlands, loamy and alluvial soils in low lying areas such as lake shores and valleys have encouraged growth of luxuriant forest vegetation as well as swamp vegetation.
▪ fairly or moderate fertile soils with low water retention capacity have favored the growth of woodlands and grasslands for example in some parts of Northern and NE Uganda, central Tanzania, etc.
▪ Poor infertile sandy soils for example in Karamoja and rift valley regions have encourage growth of scrub vegetation with stunted grasses.
▪ The clay soils in valleys and along water bodies support the growth of papyrus swamp vegetation.

- ❖ **Drainage of the area** influences the moisture in the soil as noted below;

▪ Well drained areas for example gentle slopes of major highlands and basins with adequate supply of steams have favored the growth of forest vegetation like Mabira forest.
▪ Water logged areas have favored swampy vegetation and mangroves at the coast of EA.
▪ Well drained areas without or very limited surface water and streams have encouraged the growth of savanna grassland and scrub vegetation.

- ❖ **Influence of relief** - determines depth and moisture in the soil for example;

▪ Gentle slopes and lowlands such as the coastal plains, lake shores and river valleys have encouraged the growth of both swampy, mangrove and forest vegetation.
▪ Low lying plateau areas have favored savanna wood lands while flat lowlands have favored both savanna grasslands and scrub vegetation.
▪ Steep slopes with excessive water runoff and thin soils lead to growth of temperate, bamboo as well as heath and moorland vegetation.

- ❖ **Biotic factors or living organisms** for example;

▪ Termites, locusts, and elephants have led to destruction of the original vegetation types which are replaced with scrubs or other poor forms.

▪ Animal grazing through nomadism, ranching and dairying leads to disappearance of forests, woodlands and grasslands as well as swamps.
▪ Man's activities such as deforestation, construction, cultivation and mining have led to the destruction of the original forests, woodlands, swamps and grasslands and replacing them with secondary vegetation types. On the other hand, human intervention through environmentally friendly activities such as afforestation, re-afforestation and agro forestry, creation of national parks and forest reserves has led to regeneration of formally degraded natural vegetation such as forests and protection of the existing ones.

Revision questions:

1. With specific reference to EA, examine the factors that influence the growth and distribution of natural vegetation.

Approach

- ***Define natural vegetation***
- ***Identify the various natural vegetation types in East Africa and areas where they occur***
- ***Describe the characteristics of each vegetation type***
- ***Explain the factors that have favored each vegetation type/zone identified.***

2. To what extent has climate influenced vegetation distribution in EA?

Approach

- ***Define natural vegetation,***
- ***Identify vegetation types in EA descriptively or drawing a sketch map***
- ***Give the 1^{st} evaluation and explain the role of climate***
- ***Give the 2^{nd} evaluation and explain other factors that influence vegetation distribution in EA i.e. altitude, type of soil, relief, biotic factors and drainage***

3. To what extent has altitude influenced the distribution of natural vegetation in the highland areas of EA?

Approach

- ***Define natural vegetation***
- ***Identify the highland areas of EA where altitude controls or influences vegetation distribution***
- ***Explain the vegetation zonation with a clear diagram***
- ***Explain the characteristics of each vegetation zone***
- ***Give the 1^{st} evaluation (to a large extent) and explain how attitude influences natural vegetation.***
- ***Give the 2^{nd} evaluation (other factors) that is; climate, type of soil, nature of relief, biotic factors, drainage and human activities.***

4. To what extent has man influence the distribution of natural vegetation of EA?

Approach

- ***define natural vegetation***
- ***Identify and describe the characteristics of natural vegetation types in East Africa.***
- ***State areas where human activities have influenced/ modified natural vegetation in EA***
- ***Give the 1^{st} evaluation (to a large extent) and explain the activities that have influenced natural vegetation***
- ***Give the 2^{nd} evaluation (physical factors)***

5. To what extent has the natural vegetation of East Africa been modified by human activities?

Approach

- ***define natural vegetation***
- ***Identify and describe the characteristics of natural vegetation types modified by human activities***
- ***State areas where human activities have modified natural vegetation***
- ***Give the 1^{st} evaluation (to a large extent) and explain the activities that have modified natural vegetation***
- ***Give the 2^{nd} evaluation (physical factors)***

CLIMATOLOGY

Climate is the average weather conditions of the atmosphere of a given place observed, measured, recorded and processed over a long period of time ranging from 30-35 years. It constitutes the study of weather elements such as temperature, wind speed and direction, rainfall, pressure, humidity, amount of sunshine and cloud cover over a long period of time.
Weather refers to the state of the daily atmospheric conditions of a place at a given time or for a short period of time. Weather can be described as rainy, misty, foggy, sunny or windy.
Climate affects a large area extending for hundreds of kilometers while weather is localized and may change from hour to hour or day to day. Also climatic conditions tend to remain stable over a long period of time through which minor variations occur.

East Africa lies within the tropical latitudes but due to various factors, the region experiences a variety of climatic conditions. The different types of climate include;

A. EQUATORIAL CLIMATE

The equatorial, hot-wet climate is found between 5^0 and 10^0 north and south of the equator. It occurs along a narrow strip of the East African coast in Zanzibar. The high plateau of East Africa interrupts the continuity of a true equatorial climate. However, it's experienced along the Lake Victoria basin at Jinja, Mukono, Entebbe, Bukoba, Kisumu among others and parts of western Uganda e.g. Bwindi, Kamwenge and Bundibugyo.

Characteristics:
- Receives heavy and well-distributed rainfall throughout the year between 1000 and 2000mm p.a.
- Characterized with a double rainfall maxima with peaks in March and November (Bi-modal pattern) where the 1st rain is heavier than the latter.
- There is no clear marked or distinct dry season since rainfall is received throughout the year.
- Rainfall is convectional usually received during morning and evening, often accompanied by thunderstorms and lightning for example around Lake Victoria basin at Jinja, Entebbe and Kampala in Uganda, Bukoba and Mwanza in Tanzania.
- Temperatures are generally hot throughout the year about 26^0 C and above due to heating by the overhead sun experienced most of the year.
- Temperatures are even/uniform throughout the year ranging between 25^0 and 28^0 C on average.
- Annual temperature range is small usually less than 3^0 C.
- Diurnal or daily range of temperature is small between 2^0 and 3^0 C on average.
- Constantly high relative humidity 80% throughout the year due to high rates of evaporation.
- There is dense or thick cloud cover throughout the year due to high rates of evaporation and condensation.
- Equatorial areas are affected by air masses that converge along the I.TC.Z, though there may be long periods of calm and light winds.
- Due to the hot temperatures by overhead sun they are characterized by low pressure (doldrums).

NOTE:
In East Africa due to factors such as altitude, the equatorial climate has tended to be modified. The equatorial climate experienced in much of East Africa is not typical of that in the rest of other tropical regions. That is why most of the areas fringing Lake Victoria are said to experience a modified equatorial type of climate rather than a true equatorial type of climate.

Factors that have led to the occurrence of equatorial climate in East Africa

Latitude: This is the equi-angular distance from the equator, areas lying between 0^0 to 5^0 North or South of equator. Areas within the equatorial belt experience an equatorial climate due to sun's isolation. At this point, the sunrays are more concentrated and strike the earth at right angles leading to hot temperatures and heavy rainfall throughout the year. In addition, the apparent movement of the overhead sun in the equatorial belt leads to hot temperatures and low pressure zone hence convergence of winds (ITCZ) leading to occurrence of heavy rainfall.

Altitude: Refers to height of land above the sea level. Areas below 1000m A.S.L, tend to experience equatorial type of climate i.e. hot temperatures. Generally, the altitude of East Africa especially the plateaux is below 1000m A.S.L, for example Entebbe and Jinja, Kisumu, Bukoba, Kampala leading to occurrence of equatorial climate due to hot temperatures that accelerate evapo-transpiration hence heavy rainfall.

Influence of large water bodies: Presence of water bodies such as Lake Victoria cause microclimate effects through land and sea breezes, increased evaporation which leads to increased rainfall and humidity almost throughout the year around Victoria basin as well as dense cloud cover resulting in convectional rainfall especially in the afternoons.

Influence of vegetation: Thick tropical forests like Mabira, Budongo encourage an equatorial type of climate through enhancing rainfall formation by evapo-transpiration, this leads to high amount of water vapor (humidity), warm temperatures and heavy rainfall accompanied by thunderstorms.

Influence of cloud cover: Thick cloud cover along the Victoria basin i.e. cumulus and cumulo-nimbus prevent heat loss to the space during day and night hence sustaining a small diurnal range of temperature of 8^0 C and annual temperature range of 2^0 C a characteristic of equatorial type of climate.

Air masses or wind systems also account for the occurrence of equatorial climate. In East Africa e.g. when the South East trade winds are on-shore, they bring in heavy rainfall and hot temperature from the Indian ocean hence maintain an equatorial climate particularly along the East African Coast at Mombasa and Dare-es-Salaam as well as the northern shores of L. Victoria.

Human activities shave also contributed to occurrence of equatorial climate conditions through conservation and preservation of forests by gazetting them as protected areas.

Revision Questions:
1(a) Describe the characteristics of the Equatorial type of climate.
(b) Explain the factors that have led to the occurrence of an Equatorial climate in EA.
2. Using specific examples, explain the factors that influence the distribution of Equatorial climate in EA.
Approach:
- Identify areas experiencing equatorial climate in EA
- Describe x-tics of equatorial climate
- Explain factors influencing distribution of equatorial climate in EA

B. TROPICAL OR SAVANNA CLIMATE

It is also referred to as **tropical continental or Sudan type of climate or moist tropical climate**. It is a transitional type of climate found between the equatorial belt and the hot deserts. It is confined within the tropics. In East Africa, it is common in central and western Uganda, parts of northern Uganda southern; western Kenya and parts of parts of southern Kenya; central and southern Tanzania; coastal areas of EA.

Characteristics:
- Receives moderate rainfall ranging between 750mm and 1000mm but the rains are unreliable from year to year.
- Rainfall is seasonal with a single maxima or regime
- There is alternating dry and wet seasons as a result of the apparent movement of the sun.
- Summers are hot and wet while winters are cool and dry
- Rainfall received is largely convectional and the rains are normally short-lived and torrential.
- The length of the rainy season and the annual total rainfall decrease from the equatorial region towards the desert fringes.
- Hot temperatures are received throughout the year usually over 23^0 C.
- The annual temperature range is moderate ranging between 7^0 C and 15^0 C
- The diurnal or daily temperature range is high because of the limited cloud cover
- There is moderate cloud cover during the wet season and limited cloud cover during the dry season.
- Humidity is low during the dry season and relatively high during the wet season

Factors/conditions for the occurrence of savanna climate

I.T.C.Z and apparent movement of the sun. The wet season occurs when the sun moves overhead bringing with it the heat. The I.T.C.Z and the equatorial low-pressure belt bring heavy convectional rainfall for 4-5 moths. The dry season corresponds with the moving away of the I.T.C.Z resulting into little/no rainfall.

Latitude; this is the equi-angular distance from the equator. Savanna climate occurs in areas relatively near the equator between 5^0 – 10^0 North or South of the equator. In this region it's because the sun rays are more concentrated and strike the earth at almost at right angles cause hot temperatures of tropical type.

Influence of trade winds, the trade winds bring rain on certain margins particularly the East African coast at Mombasa, Dar-es Salaam but for much of the interior they are dry winds. North East trade winds for example blow from the Arabian desert bring hot dry air to Northern Kenya, Turkana land, Central Tanzania and Northern Uganda districts i.e. Gulu, Moyo, Kitgum, Kotido.

Distance from the sea/limited water bodies offers limited chances of land and sea breeze or rainfall formation and humidity. For this reason during the dry season, there is no rainfall and areas experience low humidity e.g. Gulu, Moroto, Nakapiripiriti.

Cloud cover; The limited cloud cover allows intense heating during day and at the same time during the night allows loss of heat through radiation cooling resulting into large diurnal temp range of about 15oc in Nakasongola and Northern Uganda as well as central Tanzania
Vegetation; Limited vegetation particularly towards the desert margins offers limited chances of rainfall formation through evapo-transpiration, never the less the equatorial belt favors the little rainfall formation through evapo-transpiration. Such rains are received at Gulu, Lira, and Northern Tanzania.

Altitude, refers to the height of land above sea level. Savanna climate lies below 1000m ASL and such areas experience hot temperatures above 27^0 C for this reason areas like Turkana in Northern Kenya, Central Tanzania experience savannah climate, Northern Uganda i.e. Kitgum, Gulu experience tropical climate.

Influence of the biotic factors such as grazing wild animals have reduced vegetation cover hence limiting chances of rain fall formation through evapotranspiration, human activities like charcoal burning, over stocking, deforestation in Moroto, Trukana region, Tsavo have destroyed natural vegetation leading to little and unreliable rainfall, hot temperatures and limited humidity hence the occurrence of savanna climate.

Revision Questions:
1. Account for the decline of savannah vegetation cover in EA.

C. SEMI DESERT/SEMI ARID & DESERT CLIMATE

This type of climate is found in continental interiors and on the western side of continents along the horse latitude zones 30^0 north and south of the equator. In EA its experienced in Northern Kenya e.g. the Chalbi desert, North Eastern Uganda i.e. Karamoja, semi desert in Southern Kenya i.e. Nyiri desert, North Eastern parts of Tanzania e.g. Masai steppe semi desert. In central Tanzania, in the Eastern parts of Ankole i.e. the Ankole – Masaka corridor. In addition semi desert climate is also experienced in the Western Rift valley region around Lake George and Lake Edward. Semi-arid conditions are also experienced in the rift valley as well.
This type of climate is characterized by the following:
- Low and unevenly distributed rainfall of less than 750mm in semi-desert areas and less than 250mm in desert areas.
- Rainfall is highly seasonal, erratic and unreliable, i.e. periods of extended drought may be experienced and rainfall periods are highly unpredictable.
- Sometimes, occasional storms give heavy downpour within few hours causing flash floods resulting into destruction of human settlements, silting and choking of canals as well as destruction and disruption of means of transport and communication.
- Temperatures are very hot over 30^0 C
- Annual temperature range is high ranging between 17° C and 22° C
- There is a high diurnal range of temperature approximately 10° C and above.
- There's little or no cloud cover especially during the dry season i.e. there are generally open and clear skies partly due to the limited atmospheric moisture required for cloud formation.
- There are high evaporations rates due to the hot temperatures

- There's low relative humidity usually less than 25% due to the clear skies and low level of evapotranspiration.
- A long dry season of about 9 months and a short wet season of about 3 months is experienced.
- The air is dry due to the constant desiccating/dry winds blowing across the area.

Factors/conditions for the occurrence of semi-desert climate

The influence of trade winds such as NE trades which originate from the Arabian desert being hot and pass over the Horn of Africa pick little moisture from the Red sea. On reaching the Ethiopian highlands deposit moisture on the windward side. The leeward side being NE & NW Kenya, NE Uganda receive little or no rainfall and hot temperatures.
Also the SW trades originate from the Indian Ocean where the pick a lot of moisture which is deposited along the EA coast. As the winds proceed inland the amount of moisture deposited decreases hence the arid conditions in central and northern Tanzania. On reaching Lake Victoria they are recharged thereby depositing on the NE shores of Lake Victoria leaving the Ankole-Masaka corridor dry.
Also the westerlies originate from the Atlantic Ocean are moisture laden, depositing moisture on the windward side of Mt. Rwenzori while the leeward areas like Kasese and Lake albert flats are left dry with hot temperatures.

Distance from the sea/continentality. Places adjacent to water bodies (coastal regions) in EA trap moist SE trade winds and deposit rainfall along the coast. As these winds advance further inland and having moved for a long distance on land, lose much of their moisture leaving parts of central and northern Tanzania with hot and dry conditions.

Perturbation. This is where hot temperatures create low pressure in the ocean water, as a result warm moisture or air over the land is diverted to the ocean leaving the onshore areas dry.

Rotation of the earth/Coriolis force. According to Ferrell's law any loose object flowing in the Northern hemisphere is deflected to the right of its path immediately after crossing the equator. This is due to the rotation of the earth. As such, the SE trades are deflected to their right. Also winds blowing across Kenya are deflected towards the Indian Ocean and thus become off-shore winds, which don't bring rainfall to the mainland hence semi desert climate in northern Kenya.

Configuration of the EA coast. NE trades blow parallel to the coast with its moisture thus leaving northern and northeast Kenya with little or no rainfall as well as creating hot temperatures.

Absence of high mountain barriers for example in Turkanaland, Karamoja and Masailand to trap the little moisture has caused semi-arid climate. Winds blow across these regions without rising and cooling therefore without influencing rainfall formation.

Limited water bodies. In some parts of EA such as NE Uganda, NW & NE Kenya have no large water bodies. As such dry winds blowing over the region pass without being recharged and thus continue to bring semi desert conditions.

Scanty/limited vegetation cover. Areas of NE & NW Kenya, Ankole-Masaka corridor, Karamoja, central Tanzania, etc. have scanty vegetation cover therefore resulting in low evapotranspiration rate hence low humidity, hot temperatures and low rainfall.

Human activities have also contributed to the occurrence of semi desert conditions through various ways such as loss of vegetation cover through deforestation, overgrazing/overstocking, mining/quarrying, bush burning, over cultivation, swamp reclamation, etc. All these reduce evapotranspiration rates leading to loss of humidity, less cloud cover and limited rainfall formation hence semi desert conditions.

Global warming, i.e. general increase in temperatures worldwide is gradually leading to dry conditions.

Industrialization results in atmospheric pollution increasing greenhouse gases in the air leading to general rise in temperatures.

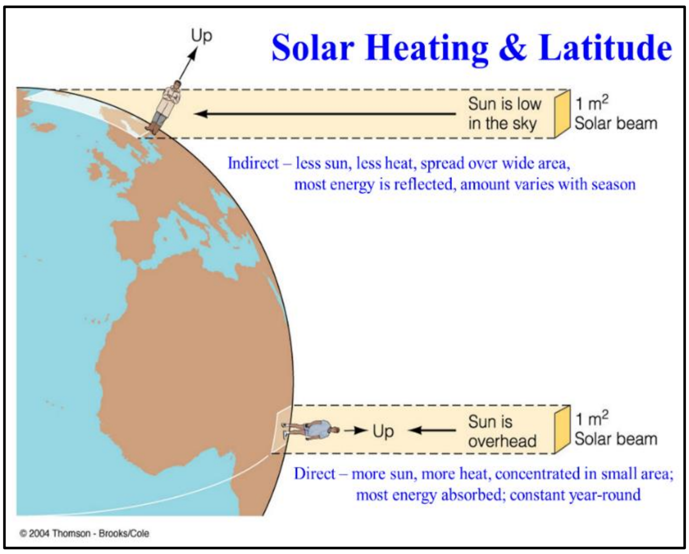
Revision Questions:
1(a) Distinguish between Equatorial and Semi-desert climates.
(b) Describe the factors which have led to the occurrence of a semi-desert climate in EA.
2. Examine the causes and effects of semi-arid climate conditions in EA.

D. MONTANE CLIMATE
This climate may also be referred to as Alpine climate and is experienced on the mountain peaks of EA e.g. high levels of Mt. Rwenzori, Mt. Muhavura, Mt. Kenya, Mt. Elgon, Mt. Meru and Mt. Kilimanjaro.
The distinguishing factor is that there are low temperatures experienced. Snowfall may also be experienced in altitudes above 4800m. The type of rainfall received is relief and is heavier on the windward sides of the mountains while the leeward side experience lower rainfall because of the shadow effect.
Atmospheric pressure in the montane climate conditions tends to be low as a result of rarified air. In addition, the gravitational effect at higher altitudes is lower resulting into the low pressure.

Characteristics:
- Cool or low temperatures about 15^0 to 20^0 C
- Temperature range is low ranging between 1^0 and 2^0 C
- Temperatures reduce with increase in altitude
- Heavy rainfall over 1000mm is received on the windward slopes while leeward slopes get little or no rainfall

FACTORS INFLUENCING THE CLIMATE OF EAST AFRICA
Climate varies from place to place and this is due to the controls or determinants known as climate factors and these include the following;

1. **Latitude**:
This is the angular distance of an area from the equator. Latitude determines the amount of insolation/heat (solar radiation) reaching the earth surface which in turn affects temperatures of a place. In general temperatures decrease from the equator to the poles hence temperatures are always hot in areas around the equator. EA lies astride the equator. Its location explains the generally hot temperatures experienced throughout the year. Areas near the equator experience hot temperatures, heavy rainfall with a bi-modal (double rainfall) pattern, low atmospheric pressure and high humidity due to the effect of the overhead sun twice a year leading to equatorial climate e.g. around the Lake Victoria basin. On the other hand, areas far from the equator such as Northern Uganda experience a mono modal/single rainfall pattern due to the distance away from the equator.



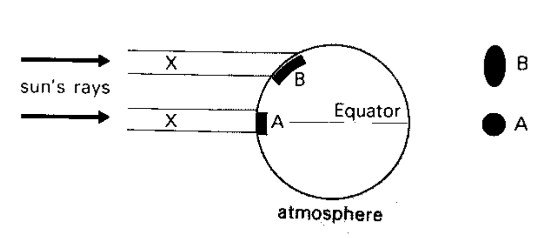


Fig. 14.2 More insolation reaches the earth's surface when the angle of the sun's rays is 90° than when it is less than 90°. The sun's rays pass through a greater thickness of atmosphere to reach B than to reach A. You can see that the surface area of B is oval-shaped and is larger than the surface at A.

In addition, hot temperatures create a low pressure zone (doldrums) in which winds converge known as the inter-tropical convergence zone (ITCZ). Winds within the zone get heated, rise into the atmosphere, cool rapidly and condense into convectional rainfall. The ITCZ follows the apparent movement of the overhead sun thus EA receives hot and wet climate as a result.

2. **Altitude**:
This refers to the height of the land above sea level. Altitude is a major factor affecting or determining temperature of a place. High altitude areas especially highlands like Mt. Rwenzori, Mt. Elgon, Mt. Kenya and Mt. Kilimanjaro experience cool temperatures because temperatures decrease with increase in altitude at a rate of 6.5^0 C per 1000m ascent (normal lapse rate). This is because the air is rarefied at high altitudes and contains less water vapor and dust resulting in rapid loss of heat and the air remains cool. On the other hand, low altitude areas such as the rift valley region, the foothills of mountains and coastal areas experience hot temperatures due to excessive impurities in the air such as dust particles, water molecules and carbon dioxide which trap heat that is radiated in the low altitudes. This explains why Mombasa is hotter than Nairobi.

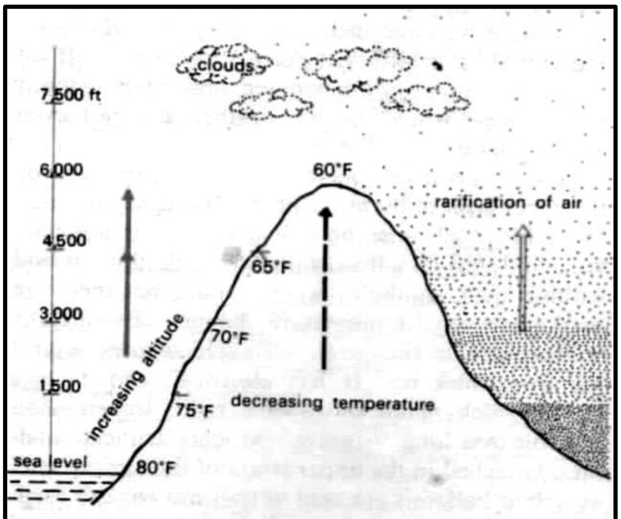


Fig. 108 The lapse rate. The effect of altitude on mean annual temperature in a tropical area

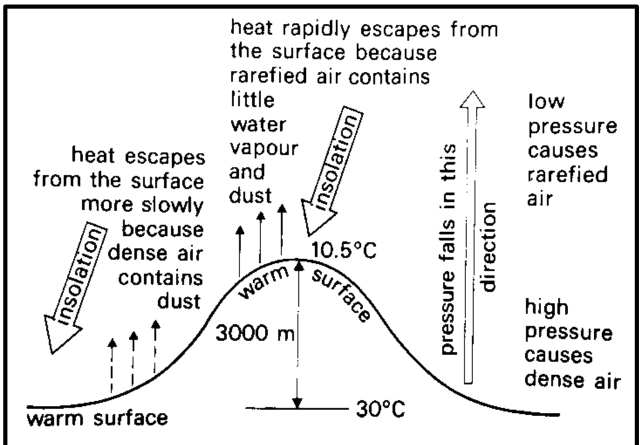
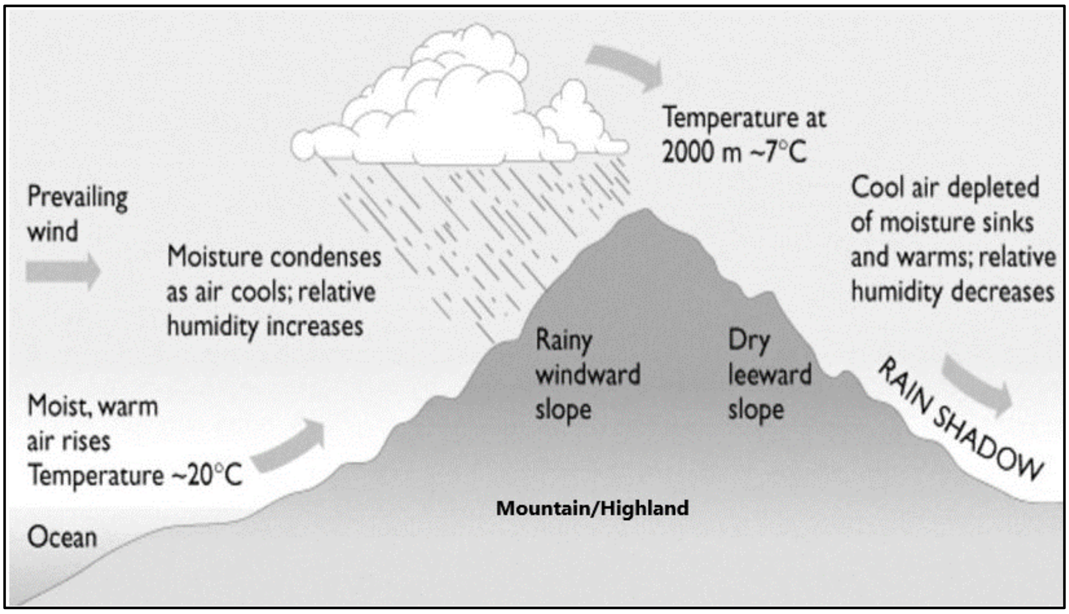


Fig. 14.3 A diagram to show the effect of altitude on temperature. What would the temperature be at the top of Mount Cameroon (4070 m) if the temperature at sea level were 30°C?

Equally, high altitude areas experience low pressure because pressure reduces with an increase in altitude. This is due to a small column of air pressing down on the earth's surface. Low altitude areas experience high pressure because pressure increases with a decrease in altitude. This is because of a big column of air pressing over the earth's surface.

High altitude areas experience low humidity due to the cool temperatures while low altitude experience high humidity due to the high rates of evapotranspiration as a result of hot temperatures.

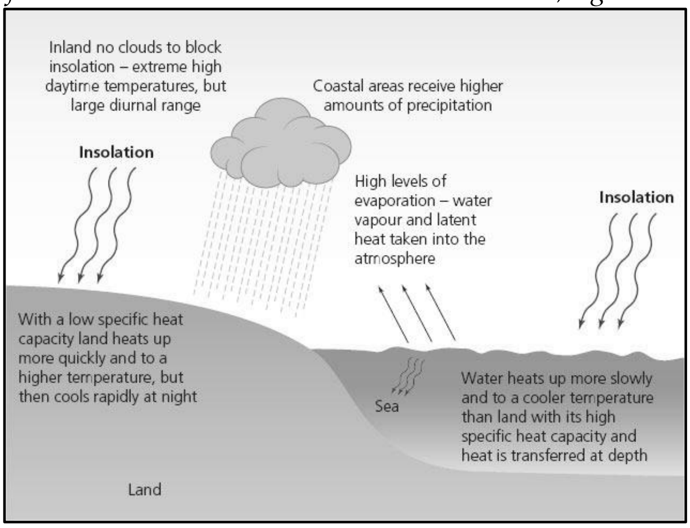
3. **Relief**:
Relief is the general appearance of the landscape. Relief mainly affects rainfall. Highland areas such as Mt. Rwenzori, Mt. Kenya and Mt. Kilimanjaro experience heavy rainfall and cool temperatures on the wind ward sides while dry conditions are experienced on the lee ward sides. This is because mountains act as barriers that force moist winds to rise, cool and condense forming clouds that lead to orographic or relief rainfall on the windward side while the descending dry winds resulting into dry conditions on the leeward side that is in the rain shadow. For instance Masailand in Tanzania lies on the leeward side of Usambara and Pare mountains; Kasese and the Lake Albert flats lie in the rain shadow of Mt. Rwenzori and northern Kenya lies in the rain shadow of the Ethiopian highlands hence these areas experience arid conditions.



4. **Continentality/Distance from the sea**:
Areas near the sea (water bodies) such as the coastal areas of EA and Lake Victoria basin experience heavy rainfall and high humidity unlike areas far from large water bodies. This rainfall decreases as moist air moves further inland because the air loses moisture as it moves further inland. This partly explains why parts of central and northern Tanzania are dry as opposed to the coastal areas. Water bodies also recharge the atmosphere with moisture through evaporation resulting into heavy rainfall in the adjacent areas e.g. the northern shores of the Lake Victoria basin. Areas far away from water bodies like north eastern Uganda and central Tanzania are hot and dry due to the absence of water bodies.

In addition, large water bodies have a moderating effect on temperatures of adjacent landmasses. Water bodies absorb and release heat from the sun more slowly than land surfaces hence coastal areas like Mombasa and Dar-es-Salaam tend to have low temperature ranges or uniform temperatures.

NOTE: *Climates whose temperatures are greatly influenced by the sea are called **Maritime/Oceanic/Insular Climates**, e.g. coastal regions, while climates whose temperatures are influenced by remoteness from the sea are called **Continental Climates**, e.g. continental interiors.*



5. **Vegetation**:
Climate determines the type of vegetation of an area and in turn vegetation effects the climate of a place. There is a definite difference in temperature between forested regions and open ground. Places with luxuriant vegetation cover such as dense forest cover like Mabira, Budongo and Bugoma experience heavy rainfall, high humidity and moderate temperatures throughout the year. The thick foliage (leaves) of the forests cuts off in-coming insolation hence in many places

sunlight never reaches the ground keeping such areas cool or lowering environmental temperatures. Also during the day trees lose water by evapo-transpiration so that the air above is cooled. Relative humidity increases and mist and fog may form. Areas with limited or scanty vegetation cover on the other hand experience low rainfall totals, low humidity and hot temperatures in areas like Turkanaland and Ankole-Masaka corridor.

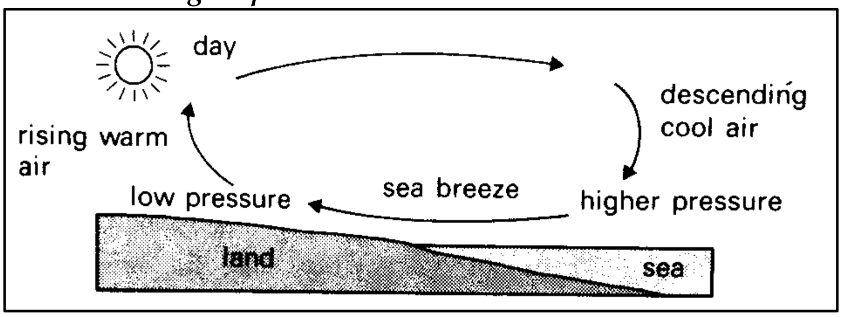
6. **Prevailing winds/trade winds or air masses**:
These are defined as local winds which blow from sub-tropical areas of high pressure to areas of low pressure in the tropics. The winds are either moist or dry, cool or warm thus influencing the rainfall and temperature conditions of the areas where they flow to. The climate of EA is mainly influenced by four (4) main wind systems, they include;
(a) **North East trade winds**. These originate from the Arabian Desert, are dry and hot bringing arid conditions to parts of EA. As they blow towards EA, they pick moisture from the Red sea which is later lost on the windward slopes of the Ethiopian highlands. The winds later continue into EA as cool dry winds causing low rainfall and low humidity in areas like North eastern Uganda and Northern Kenya in general hence semi-arid climate.

(b) **South East trade winds**. They originate from the Indian Ocean hence they are warm and moist. They flow towards the EA coast thereby bringing heavy rainfall and high humidity. They later continue on their eastward journey towards the interior of EA as dry winds causing dry conditions in parts of central and northern Tanzania. They are later recharged with moisture after crossing Lake Victoria consequently causing heavy rainfall on the northern and north eastern shores of Lake Victoria basin.

(c) **Westerlies** are warm moist winds originating from the Atlantic Ocean. They blow over the Congo basin leading to heavy rainfall on the western slopes of Mt. Rwenzori. They however continue towards the leeward slopes with areas like Kasese and the rift valley region of western Uganda (Lake Albert flats) as dry winds leading to semi-arid climate.

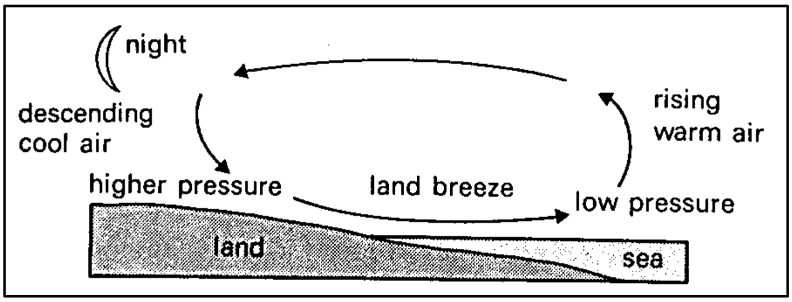
(d) **Local winds or breezes**. Breezes are winds that develop in areas with large water bodies such as Lake Victoria. They include land and sea breezes. They mainly affect areas adjacent to the water bodies such as Jinja, Entebbe, Mukono, etc. The factors influencing these local winds include;
- Differences in specific heat capacities of land and sea, i.e. land heats up and cools down faster than the sea or lake.
- Mobility of water compared to solid land
- Heat transfer through transparent water as opposed to opaque land
- Differences in reflecting capacity of land and water

❖ Sea breeze: During day, the land gets heated up much faster than the sea or lake. Air over land becomes warm and rises forming a region of local ***low pressure***. The sea or lake remains comparatively cool with a ***higher pressure*** so a ***sea breeze*** blows in from sea to land.



Effects of sea breeze
- It lowers temperatures on land especially in the afternoon
- Leads to formation of fog or mist on land resulting in poor visibility
- Onshore rainfall is formed usually received in the early morning and afternoon
- Results in violent thunderstorms
- Brings about high humidity on land
- There is formation of dense cloud cover over land

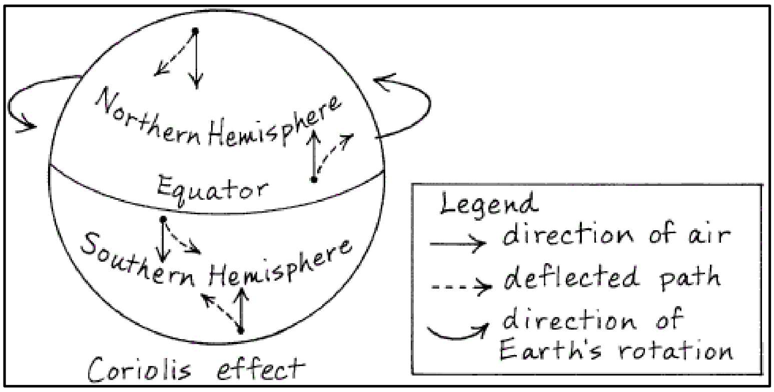
❖ Land breeze: At night as the land cools much faster than the sea, the cold and heavy air creates a region of local ***high pressure*** over land. The sea conserves its heat and remains quite warm and its ***pressure is comparatively low***. A cool ***land breeze*** blows out from land to sea to replace the warm rising air.



Effects of land breeze
- Lowers temperatures over the sea
- May lead to formation of fog or mist over the sea hence poor visibility
- Offshore rainfall is formed over the sea due to warm rising air over the sea which condenses into clouds hence heavy rainfall.
- The land experiences dry conditions of little or no rainfall
- It results in high humidity over the sea
- There is formation of dense clouds over the sea

7. **Ocean currents**:
These are large scale movements of surface water in an ocean/sea in a fairly defined direction. Ocean currents are either warm or cold hence they influence the temperature and rainfall conditions of the coastal areas. The warm ocean currents such as the Mozambique current transport hot temperatures and heavy rainfall to the adjacent coastal areas of EA e.g. the equatorial climate between Mombasa and Dar es Salaam is due to the effect of the warm Mozambique current. Cold ocean currents such as the Benguela current lead to low temperatures, low humidity and low rainfall in coastal areas such as Namibia.

8. **Coriolis force or Rotation of the earth**:
This is the apparent deflection of objects such as wind, ocean currents, airplanes and missiles moving in a straight path relative to the earth surface. This apparent deflection is called the Coriolis force or effect and is the result of the earth's rotation. As air or wind moves from a high pressure zone to a low pressure zone in the northern hemisphere, it is deflected to the right by the Coriolis force while in the southern hemisphere, air moving from a high to low pressure zone is deflected to the left by the Coriolis force. The SE trade winds are therefore deflected to the right as they cross the equator into the northern hemisphere thus causing heavy rainfall (equatorial climate) on the north eastern shores of Lake Victoria and dry conditions (semi-arid climate) in the Ankole- Masaka corridor.



9. **Human activities**:
A variety of man's activities have modified the climate of EA through activities such as deforestation, swamp reclamation, bush burning, overstocking and over grazing resulting in reduced rainfall amounts and hot temperatures. That is why semi-arid climate is experienced in North eastern Uganda, North western Kenya and in some parts of Central Tanzania. On the other hand, man's activities such as afforestation and re-afforestation, agro-forestry as well as forest conservation have restored vegetation cover resulting into increased rainfall amounts in areas such as Mt Elgon slopes, Kigezi highlands and Kenya highlands.

Revision questions:
1. To what extent has altitude influenced the climate of EA?
2(a) Distinguish between weather and climate.
(b) Explain the factors which influence the climate of EA.
3(a) Distinguish between weather and climate.
(b) Describe how any two elements of weather are measured at a weather station.

ARIDITY

Aridity is a climatic condition characterized by very low rainfall usually less than 250mm per year which is largely seasonal and unreliable, hot temperatures above 30^0 C with a large diurnal temperature range, low humidity as well as little or no vegetation cover. In EA arid conditions are found in Northern Kenya around Lodwar, parts of Eastern Kenya, North Eastern Uganda, the Ankole - Masaka corridor, parts of North Eastern Tanzania, Central Tanzania, parts of southern Kenya and parts of the western and the Eastern rift valley e.g. along Lake Albert, Lake Edward and Lake George.

Characteristics of arid areas

- Low and seasonal rainfall is experienced. Drought is a common phenomenon in such areas.
- Rainfall is unevenly distributed and unreliable
- Very hot temperatures are experienced i.e. temperatures of 30°C and above.
- High diurnal range of temperature normally more than 15°C i.e. during the day it is very hot and during the night is cold.
- There is generally low humidity. Relative humidity tends to be less than 20%.
- There is a limited cloud cover. Much of the year is characterised by clear skies.
- There are high transpiration rates and evaporation rates.
- There is unreliable or unpredictable rainfall.
- There is occurrence of strong winds and occasionally dust storms are experienced.
- There is limited plant cover, this is because of the low rainfall such that the vegetation tends to be adapted to low rainfall conditions e.g. there are generally drought resistant species such as steppe savannah grasslands, thicket, thorn bush, cactus, scrub, as well as patches of bare land.

Causes of aridity in East Africa

Physical factors:

1. **Coastal configuration**:
The alignment of the East African coast in the northeast to southwest direction forces the NE monsoon winds to blow parallel to the coast thus the rain bearing influence is not carried farther inland. This leads to arid conditions of low humidity and low rainfall in the interior areas central and northern Tanzania such as Iringa, Morogoro as well as parts of Kenya like Wajir.

2. **Prevalence of dry/desiccated winds**:
Some areas in East Africa have been affected by dry winds for instance the N.E trade winds which originate from the Arabian Desert. As they cross into Africa they pick up moisture from the Red sea which is deposited in the Ethiopian highlands. As they descend into East Africa they are dry and do not bring rain. They even absorb the little moisture that exists in the regions in which they blow. This explains the dry conditions experienced in parts of NE Uganda and Northern Kenya.

3. **Coriolis force**:
This is a drag force as a result of the earth's rotation that deflects moving objects such as wind or air masses. Winds are deflected to the right in the northern hemisphere and to the left in the southern hemisphere. This force accounts for the prevalence of arid conditions in the Ankole - Masaka corridor and other parts to the NW of Lake Victoria. This is because when the S.E trade winds blowing through Tanzania cross the Equator, they are deflected eastwards i.e. to the right leaving the NW parts of Lake Victoria without moist winds hence the arid conditions experienced.

4. **Perturbation**:
This is a situation where low pressure conditions due to hot temperatures are created over the Indian Ocean and as a result winds from the interior of EA are drawn towards the ocean causing heavy rainfall over the ocean while parts of the East African mainland such as eastern Kenya are left dry.

5. **Continentality or distance from the sea**:
Areas far away from large water bodies like North eastern Uganda, North western Kenya and Central Tanzania are hot and dry arid conditions due to the absence of water bodies. Water bodies such as the Indian Ocean recharge the atmosphere with moisture through evaporation resulting into heavy rainfall in the adjacent areas. Thus as air moves from the coast to the interior of EA it loses moisture and becomes dry due to the low evaporation rates over land thus bringing arid conditions.

6. **Relief**:
Relief has contributed to aridity in East Africa because of the rain shadow effect produced on the leeward side of mountains. The prevailing winds that continue onto the leeward side from the windward side are desiccated or dry and do not bring in rainfall but
instead may even absorb the little moisture that may exist in the leeward areas. Arid areas in East Africa that are due to the rain shadow effect include Northern Kenya, the Masai steppe on the leeward side of the Pare and Usambara mountains ranges in NE Tanzania as well as the Lake Albert flats in the western rift valley zone area in the rain shadow of the Rwenzori mountains.

7. **Absence of large water bodies**:
Several areas in East Africa that experience aridity such as Northern Kenya and Central Tanzania have no large water bodies that could otherwise contribute to atmospheric moisture through evaporation and recharging dry winds. This therefore results into limited atmospheric moisture in such areas and therefore dry or arid conditions result.

8. **Absence of thick or luxuriant vegetation**:
Areas with scanty vegetation cover such as scrub, thickets and scattered trees have little moisture to recharge the atmosphere or winds therefore experiencing arid conditions, e.g. parts of northern Kenya and NE Uganda.

Human factors:
9. **Deforestation**:
This involves the excess removal of trees faster than regeneration of new one. This has been due to mans' activities in the clearance of forests and other forms of natural vegetation. The main activities involved include cultivation, lumbering, industrialization etc. which have led to the destruction of natural forests that contribute to atmospheric moisture and cloud formation. Destruction of this source of atmospheric moisture and cloud formation results into aridity with little or no rainfall and very hot temperatures.

10. **Overstocking**:
The rearing of a big number of animals more than what the pastureland can accommodate leads to aridity. In case the carrying capacity of the land is exceeded, the pastures are depleted very fast and the large number of animals trample the ground to create bare patches of land and loosening the soils thereby promoting erosion. This results into impoverished and stunted vegetation growth with low levels of evapo-transpiration consequently leading to aridity.

11. **Overgrazing**:
This may be as a result of continuous grazing by herbivorous animals without leaving the land to rest. Overgrazing depletes the vegetation cover and may lead to low rainfall because of limited transpiration.

12. **Industrialization**:
Industrial plants or factories emit fumes containing pollutants such as carbon dioxide, carbon monoxide and sulphur dioxide. Such gases lead to the destruction of the ozone layer thereby contributing to global warming through greenhouse gas emissions. In addition, industrialization leads to destruction of forests which reduces rainfall totals hence promoting aridity.

13. **Swamp reclamation**:
Swamps are reclaimed for cultivation, settlement and other human activities thus lowering the water table and reduction in evapotranspiration rates causing arid conditions of low humidity and low unreliable rainfall.

14. **Bush burning**:
Dry season bush fires and deliberate burning of grass leads to loss of natural vegetation and reduction in evapotranspiration resulting in low humidity and rainfall amounts especially in parts of Masailand steppe.

15. **Unsustainable farming techniques**:
Through inconsiderate farming methods like heavy tilling, shifting cultivation, planting of unsuitable crops and leaving soils exposed to wind and rain erosion, farmers only speed up the process of aridity in exchange. With erosion the ability of the soil to support plant growth is reduced meaning that there would be poor vegetation and consequently low levels of evapotranspiration.
In addition improper irrigation methods, such as canal irrigation often lead to a buildup of salt in soils. Salt buildup on cultivated lands, then, makes it difficult for crops and other plants to grow, further exacerbating degradation of these lands.

16. **Sinking boreholes**:
This is done to provide water in arid areas, however it lowers the water table hence shallow rooted plants fail to access water and gradually die off. This promotes aridity since there is no evapotranspiration from plants to recharge the atmosphere and contribute to cloud formation and rainfall.

Revision questions:
1. To what extent are trade winds responsible for aridity in EA?
2. Describe the factors responsible for arid conditions of EA.

DESERTIFICATION

This refers to the ***development of desert like conditions in an area and more so in a region adjacent to a desert***. It may be expressed as the advancement or extension of the desert. Desertification has been commonly experienced in the Sahel region of Africa. In East Africa desert like conditions have been experienced or developed in parts of Northern Kenya, Central and Northern Tanzania, NE Uganda and the Ankole-Masaka corridor and parts of Western Uganda adjacent to Lake Albert, Lake George, Albert Nile and within the East African rift valley.

Indicators of Desertification
- Decreasing rainfall amounts.
- Rainfall becomes more unreliable i.e. more recurring cycles of drought are experienced.
- Increasing temperatures i.e. temperatures tend to rise.
- Reducing relative humidity i.e. the amount of water vapour in the atmosphere reduces.
- Increasing diurnal range of temperature.
- Reducing thickness of cloud cover i.e. the skies tend to become clearer and clearer with each passing year.

- There is loss of water retention capacity of the vegetation and soils i.e. there are increasing evapotranspiration rates.
- Reduced bio-diversity i.e. there is degradation of the biological productivity of the land i.e. reduced plant and animal species.
- Increasing wind and run off erosion hence consequently resulting into reduced soil fertility.

FACTORS FOR THE OCCURRENCE OF DESERTIFICATION

Desertification is basically caused by environmentally unfriendly human activities. However to a small extent it may be brought about by naturally existing conditions in the atmosphere that may lead to cycles of drought. Such atmospheric systems that result into cyclic changes or occurrences in the atmosphere have compounded the problem of desertification.

Location along the western coast where the ocean water is cold. Influence of cold ocean currents operates in the sense that, when the wind blows from the sea over a cool current on to a heated land aridity sets in and ultimately a desert climate is experienced, benguela Cold Ocean current in South West Africa led to the development of Namib- Kalahari desert.

Latitudinal location. Hot temperatures are located between 15^0 – 30^0 North South of the equator. Namib Desert in Namibia experience maximum insolation leading to hot temperatures over 30^0 C during day.

Cloudless skies for example in the Sahara desert allow maximum heating raising temperatures up to 40^0 C while at the same time during the night there is rapid cooling such conditions limit vegetation growth leading to desert climate.

Influence of dry or drying winds like the local winds such as the trades blow over an extensive land areas i.e. North East trade winds in Turkana and Karamoja.

Absence of water bodies in extensive landmasses accelerates the development of a desert climate e.g. in Karamoja and Turkana there are few and small water bodies like oases, this limits evaporation hence desert climate.

Human activities have accelerated the condition of hot desert and this has led to its extension in regions that never experienced before. They include;
deforestation; overgrazing; overstocking; bush burning; reclamation of wetlands; borehole drilling; industrial activity; poor methods of cultivation; mining/quarrying cultivation; political conflicts/wars. [***Explain each activity in detail – see points on aridity***]

Effects of Desertification

Desertification is associated with a number of negative effects and therefore it is undesirable. This is because of the following:
(a) It may lead to crop failure or low crop yields hence leading to famine and human suffering. In sub – Saharan Africa it has been a major cause of famine. This is because of the prolonged dry seasons and recurring droughts which lead to crop failure and consequently food shortages resulting into human suffering and death due to hunger, starvation and disease.
(b) The resultant decreasing rains may prompt irrigation. Consequently this may lead to salination of the soils, which is also a form of soil degradation.
(c) The high or increasing temperatures are unconducive for human settlement as well as human activities such as cultivation.
(d) The degradation or deterioration of the natural vegetation may cause a decrease in forestry products and a reduction in the ability of the natural vegetation to protect the environment.
(e) It encourages soil erosion and creates conducive conditions not only for run-off water erosion but also wind erosion.
(f) It may lead to the encroachment of sand dunes due to wind erosion and such sand dunes are normally unsuitable for human activities such as cultivation.

(g) It may result into the disappearance of some drainage features such as small streams and wetlands due to excessive evaporation and yet these drainage features play important roles i.e. both protective and productive roles.
(h) Leads to the destruction of the natural habitat for wildlife and hence reduced biodiversity. This is because desertification leads to a change in the physical environment such as reduced vegetation cover, increased temperatures and reduced wetlands. It also destroys the natural habitat for a variety of wildlife.

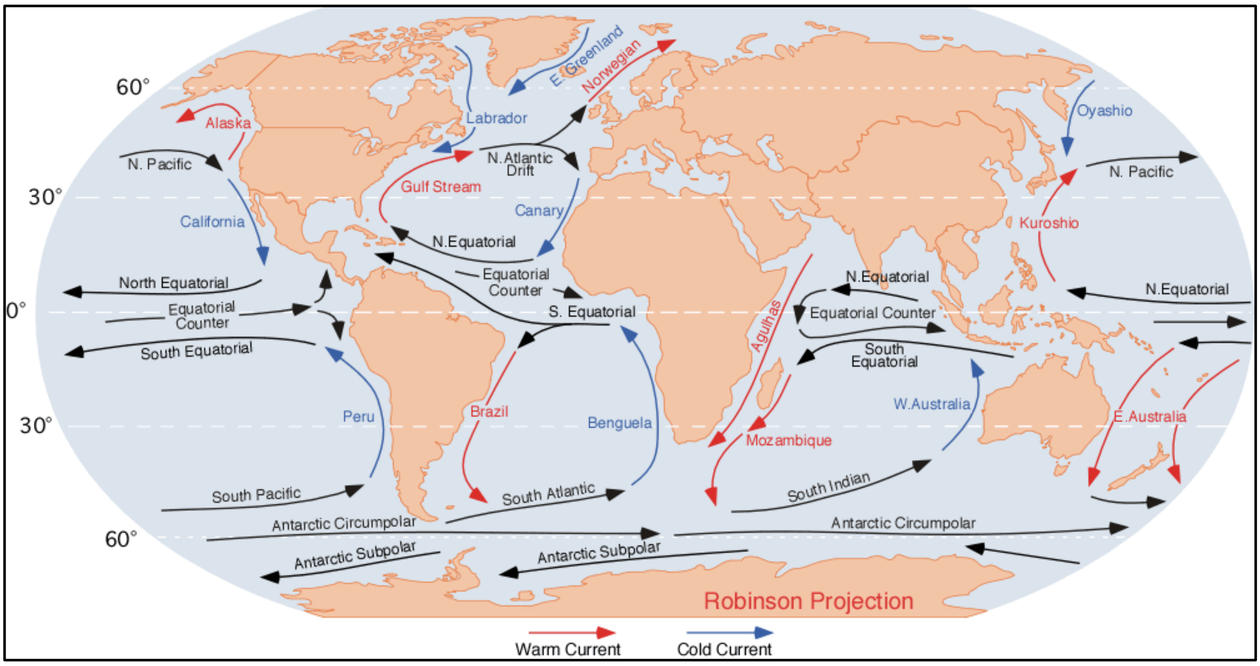
Measures to combat desertification

In East Africa and other parts of Africa, the number of steps has been taken to combat desertification or reverse the trend of desertification. These include;
1. **Legislation against environmental degradation**. Laws have been passed against the destruction of the environment such as wetland reclamation. Most of such vulnerable areas have been gazetted as nature reserves or conservation sites.
2. **Afforestation**: this has involved the campaign to plant trees in order to arrest the effects of desertification. Tree planting campaigns have been conducted by the government, NGO's, environmental/wildlife clubs as well as individuals.
3. **Re-afforestation**: i.e. re-planting of trees where trees have been cut or where deforestation has taken place e.g. Mabira forest, Kibaale forest etc.
4. **Introduction and practice of improved methods of cultivation** i.e. methods that do not harm the environment. This has been mainly through protecting agricultural land by adopting practices that conserve soils e.g. mulching, crop rotation, gully prevention measures, application of manure and fertilizers etc.
5. **Rotational grazing**: This has been facilitated by paddocking. Efforts have also been made to ensure that the carrying capacity of land is maintained in order to avoid overstocking. Rotational grazing also helps to check overgrazing.
6. **Re-settlement of people** adjacent to forest reserves as well as eviction of forests encroachers. Re-settlement of the people is to prevent encroachment upon the forests especially when population is increasing and when land shortage problems are cropping up e.g. encroachers in Kibaale forest reserve were evicted and resettled.
7. **Sensitization of the public** about the role of forests or natural vegetation. This has been through the education of the masses on the dangers of deforestation and also how to utilize the environment sustainably. This has created awareness about environmental issues such as desertification-associated problems. This sensitization has been through a variety of mass media e.g. the press, electronic media, seminars/workshops, schools, Local council meetings, public rallies etc.
8. **Introduction and encouragement of the use of fuel saving stoves** or those that use saw dust such that less biomass is used as fuel. This reduces on the tendency of the destruction of forests for fuel.
9. **Rural electrification** and provision of alternative sources of energy such as solar energy, biogas etc. as an alternative to wood fuel.
10. **Creation or establishment of environmental organizations** to champion or spearhead the fight against desertification through environmental protection and restoration of degraded lands. Some of these organizations are governmental or non-governmental. They may also be international, inter-state, national or local. Some are also voluntary organizations. Examples of these bodies include; NEMA in Uganda (a parastatal body charged with protecting the environment.) Uganda Wildlife Authority (UWA). In addition, there are wildlife clubs, tree planting clubs and anti-pollution clubs. International organizations include; the Kagera Basin Organisation, Inter Governmental Authority on Drought and Development (IGADD), interstate ones like the East African Wildlife Society and others like Karamoja Development Agency
(KDA) to combat desertification and aridity and ensure development of the area.
11. **Encouragement and use of indigenous methods** of protecting the environment and more so natural vegetation and drainage features i.e. through traditional customs and taboos.
12. **Population control** measures through population re-distribution and family planning as well as encouraging late marriages, discouraging polygamy etc. to avoid over population, which would lead to land shortage and deforestation.

Revision questions:
1(a) Explain the causes of desertification in EA.
(b) Outline the steps being taken to control desertification in EA.

OCEAN CURRENTS

Ocean currents are ***continuous general movements or drifts of the surface water of the ocean in a fairly defined direction***. Ocean currents are primarily horizontal water movements and are persistent. Most ocean currents drift very slowly and that is why they are commonly referred to as drifts. Ocean currents flow for great distances and together they create the global conveyor belt, which plays a dominant role in determining the climate of many of Earth's regions. More specifically, ocean currents influence the temperature of the regions through which they travel. For example, warm currents traveling along more temperate coasts increase the temperature of the area by warming the sea breezes that blow over them. Ocean currents may be either **warm** or **cold**.



Causes of ocean currents

1. **Prevailing winds**; winds influence oceanic circulation, this is because as winds blow friction is generated between the wind and water surface causing the water to move in the general direction of the wind. Some winds such as trade winds which almost continuously blow in the same direction cause surface waters over which they blow to move in the direction to which they blow e.g. across the Indian ocean trade winds produce the equatorial currents. In addition trade winds cause upwelling of cold water along the west coasts as they blow surface water away from the land giving rise to currents such as Canary and Benguela in the Atlantic Ocean.

2. **Rotation of the earth/Coriolis force**; the earth's rotation results in the Coriolis force which also influences the direction of movement of ocean currents. It causes currents in the northern hemisphere to be deflected to the right of their intended direction of flow and in the southern hemisphere the currents tend to be deflected towards the left.

3. **Differences in temperature**; ocean currents may be caused by differences in temperature. Such currents are generally referred to as convection currents. In the equatorial belt, temperatures are hot and therefore waters are warm and tend to be less dense, unlike the polar region or high latitude region waters. As a result, the warm waters of the equatorial region drift towards the higher latitudes and vice versa.

4. **Salinity of the waters**; Saline waters (these of high pH/basic waters) tend to be denser than waters of low salinity. It is generally noted that waters of high salinity tend to flow to areas of low salinity e.g. the surface water current from the Mediterranean Sea which enters the Atlantic Ocean is due to difference in salinity while an undercurrent flows in the opposite direction.

5. **Coastal configuration**; the alignment the coast and the existence of submarine ridges is partly responsible for the direction of flow of ocean currents. The shape of the land helps in the direction of moving currents e.g. the North equatorial current tends to be deflected northwards because of the shape of the horn of Africa.

Types of ocean currents

There are three types of ocean currents, namely; warm ocean currents, cold ocean currents and return or compensating or counter currents.

A. RETURN/COMPENSATING/COUNTER OCEAN CURRENTS

Ocean currents may be characterized by under currents. These are return or compensating currents that normally flow within the equatorial latitudes. They flow in the opposite direction from which the opposite currents are flowing. They are also known as counter currents that replace the surface waters that may have moved to another region for instance as warm water flows to the poles it is replaced by cold water from the poles as a counter current.

B. WARM OCEAN CURRENTS

These are ocean currents with warm waters or temperatures and move from regions of hot temperatures to those with cooler temperatures. They flow from the equator to the poles. They include, the warm Mozambique or Agulhas current or south equatorial current in the Indian Ocean, the warm Gulf Stream in the North Atlantic Ocean, the North Atlantic drift, the North pacific current, the Kuroshio Current in the North Pacific Ocean and the East Australia current.

Characteristics of warm ocean currents

- They have warm/higher temperatures i.e. tend to be warm.
- They generally flow on the eastern side of continental landmasses in the low latitudes except the Guinea current.
- They generally flow on the western side of continental landmasses in the mid and high latitudes e.g. the Pacific current and the North Atlantic drift.
- They tend to flow from the lower latitudes to the higher latitudes i.e. flow poleward away from the equator.
- In the northern hemisphere, their circulation tends to be clockwise while in the southern, their circulation tends to be anti-clockwise.
- They generally tend to be of low density/high salinity.
- They flow on the surface but later lose temperatures and become under water currents.

Effects of warm ocean currents on climate

Warm ocean currents have influenced the climate or environmental conditions of the areas adjacent to them in the following ways;

a) They lead to warm conditions, i.e. they tend to raise the temperature of the adjacent area, this is because the winds which blow over them are warmed up and as they blow onshore they bring in warm conditions e.g. Durban on the eastern coast of South Africa has temperatures of 24.4^0 C compared to Port Noloth on the west coast of Africa on the same latitude has temperatures of 15.5^0 C due to effects of the warm Mozambique current and the cold Bengeuela current respectively.

b) Warm ocean currents lead to heavy rainfall conditions on the adjacent coastal lands. This is because over warm ocean currents there is high rate of evaporation and the winds that blow over them (onshore winds) pick the moisture, rise, cool down and condense to form rainfall e.g. along the East Africa coast and along the West African coast there is heavy rainfall because of the warm Mozambique and warm Guinea currents respectively. For instance Beira in Mozambique receives 1,521 mm and Durban receives 1,008 mm of rainfall per annum.

c) They bring about high humidity along the adjacent coastal lands. This is because warm ocean currents have a high rate of evaporation due to the relatively hot temperatures thus increase the humidity of the surrounding areas e.g. the Natal Province of South Africa.

d) Warm ocean currents influence the temperatures of winds and result into warm winds. Winds that tend to originate from areas with warm currents are generally regarded as warm maritime winds.

e) They lead to increased or dense cloud cover over the adjacent coastal lands. This is because of the high rate of evaporation. The water vapour rises, cools and condenses to form dense clouds (cumulonimbus clouds) which later result into heavy rainfall.

Effects of warm ocean currents on human activities along the coastal areas
1. The resultant heavy rainfall experienced has encouraged crop cultivation or rain fed-agriculture. This is common along the East African coast and West African coast where a number of crops are grown, e.g. cloves, sisal, coconut palms and sugarcane along the East African coast. Along the West African coast crops like cocoa are grown in Ghana.

2. The high rainfall experienced encourages the growth of tropical rain forests and people may be involved in forestry activities, e.g. in Gabon, forestry activities such as lumbering are practiced. On the East African coast lumbering is also carried out in the mangrove forests.

3. The hot temperatures or warm conditions along the East African coast are conducive for the growth of coral polyps and the resultant rocks and land forms like coral reefs. These coral rocks have been a potential for the manufacture of cement from the coral limestone e.g. the Bamburi cement.

4. In addition the coral reefs have been a tourist attraction and have promoted tourist activities along the coast of East Africa. Furthermore, the fringing reefs have tended to be a hindrance to deep sea fishing along the East African coast.

5. The heavy rainfall that may result may be associated with thunderstorms which tend to be destructive to the crops and property and also disrupts the economic activities like fishing and shipping.

C. COLD OCEAN CURRENTS
These are ocean currents with waters of low or cold temperature, i.e. the waters are cold. In Africa the main cold ocean currents include; the cold Benguela current along the southwest coast of Africa and the cold Canary current along the northwest coast of Africa. Elsewhere examples include the California current, Peru current, East Greenland current and the West Australian current.

Characteristics of cold ocean currents
- They are characterized by low temperatures, i.e. they have cold waters.
- They tend to flow from high latitude regions to regions of low latitude, i.e. they flow equator wards from the poles or regions with cold temperatures.
- They generally flow on the western side of the continental landmasses in the low latitude regions e.g. Benguela and Canary currents.
- In the mid and high latitude regions, they tend to flow on the eastern sides of the continents e.g. the Labrador current and the Oyashio current.
- In the northern hemisphere their circulation tends to be anti-clockwise while in the southern hemisphere their circulation tends to be clockwise.
- They are characterized by high density or low salinity.
- They are also characterized by up-welling of waters at the coasts.

Effects of cold ocean currents on climate
Cold ocean currents influence the climate and environmental conditions of the adjacent land masses in the following ways;
1. Cold ocean currents tend to lower the temperatures of the surrounding land masses due to the influence of the land and sea breezes. E.g. the Benguela lowers the temperatures of surrounding areas in Namibia e.g. Walvis Bay has temperatures of 16^0 C as compared to Durban's 25^0 C yet they lie at almost the same latitude.

2. Cold ocean currents lead to arid conditions or the formation of marine deserts on the adjacent coastal lands. This is because of limited evaporation and offshore winds that blow over them hardly pick any moisture due to the low level of condensation hence rainfall is low and arid conditions. Examples of marine deserts include the Namib Desert which is due to the cold Benguela current. The Californian desert is due to the cold Californian current and the Atacama Desert due to the cold Peruvian current.

3. They tend to result into low humidity and low cloud cover because of the low rate of evaporation.

4. Cold ocean currents lead to the formation of cold offshore fog or misty conditions as a result of rapid radiation cooling. It may also be due to when slightly warm air blows over the cold ocean currents resulting into steam fog e.g. there are frequent foggy conditions in San Francisco in southern California and in the Labrador region in eastern Canada.

Effects of cold ocean currents on human activities

a) The arid conditions lead to the growth of pastures of short grass which has encouraged pastoralism. It is important to note that pastoralism is common in semi-arid areas such as the Namib Desert and Kalahari Desert.

b) The arid or desert conditions have promoted tourism. Such areas have been gazetted as wildlife conservation sites e.g. Namib Desert.

c) The arid or desert conditions have also provided a conducive environment for the film industry. Film making has been carried out in the arid areas such as the Namib Desert.

d) The cold ocean currents cause upwelling of ocean waters creating conducive conditions for the growth of planktons and this has promoted fishing in these areas, e.g. fishing has been an important activity in the coastal waters of Morocco, South Africa, Angola and Mauritania. This occurs where the cold ocean currents (carrying oxygen) meet warm ocean currents rich in nutrients.

e) Cold ocean currents lead to the formation of fog which tends to reduce on visibility over water and air thereby hindering navigation and aviation.

Revision questions:

1(a) What are ocean currents?

(b) Explain the influence of ocean currents on the climate of EA.

2(a) Describe the characteristics of warm ocean currents.

(b) With reference to specific examples, explain the influence of warm ocean currents on the climate of adjacent landmasses.

3(a) Describe the characteristics of cold ocean currents.

(b) With reference to specific examples, explain the influence of cold ocean currents on the climate of adjacent landmasses.

4. Giving specific examples, examine the influence of ocean currents on the economic activities along the coastal regions of Africa.

TEMPERATURE

Temperature refers to the ***degree of hotness or coldness of the atmosphere over a given place*** **OR** the ***amount of sensible heat or cold with in the atmosphere of a given area*** **OR** ***the balance of heat received from the sun's insolation (solar radiation) and the heat reflected by the earth surface (terrestrial radiation)***.

The major source of heat energy affecting the atmosphere and the earth's surface is ***solar radiation*** which is the heat emitted and transferred to the earth's surface by the sun in a process called ***insolation***. It is transferred in form of short waves and occurs during day time. When this ***solar radiation/solar energy/radiant energy*** reaches the earth surface it is reflected back into the atmosphere and is known as ***terrestrial radiation***. It is transmitted in form of long waves and occurs both day and night. The balance of heat between incoming solar radiation and outgoing terrestrial radiation is what affects temperature.

The temperature of a place is measured using a ***six's thermometer*** which records the maximum and minimum temperature of the day. When the highest and lowest temperature is obtained, the following expressions can be made:

- Daily temperature: It refers to the actual amount of heat or cold that is recorded at a weather station in a day.

- Mean/Average daily temperature: It refers to the average of heat or cold that is recorded in a specific area in a day. It is obtained by;

  Mean daily temperature = $\frac{\text{Maximum Temperature + Minimum Temperature}}{2}$

- Daily (Diurnal) temperature range: It refers to the difference between the highest or maximum and lowest/minimum temperature of the day.

  Daily temperature range = Highest Temperature – Lowest Temperature

- Mean/Average monthly temperature: It is the average temperature of an area obtained when the sum of the mean daily temperatures for a month is divided by the number of days in the month.

  Mean monthly temperature = $\frac{\text{Sum of the Mean Daily Temperature}}{\text{Number of days in a month}}$

- Mean/Average annual temperature: It is the final figure obtained when the sum of the mean monthly temperatures in a year is divided by 12 months

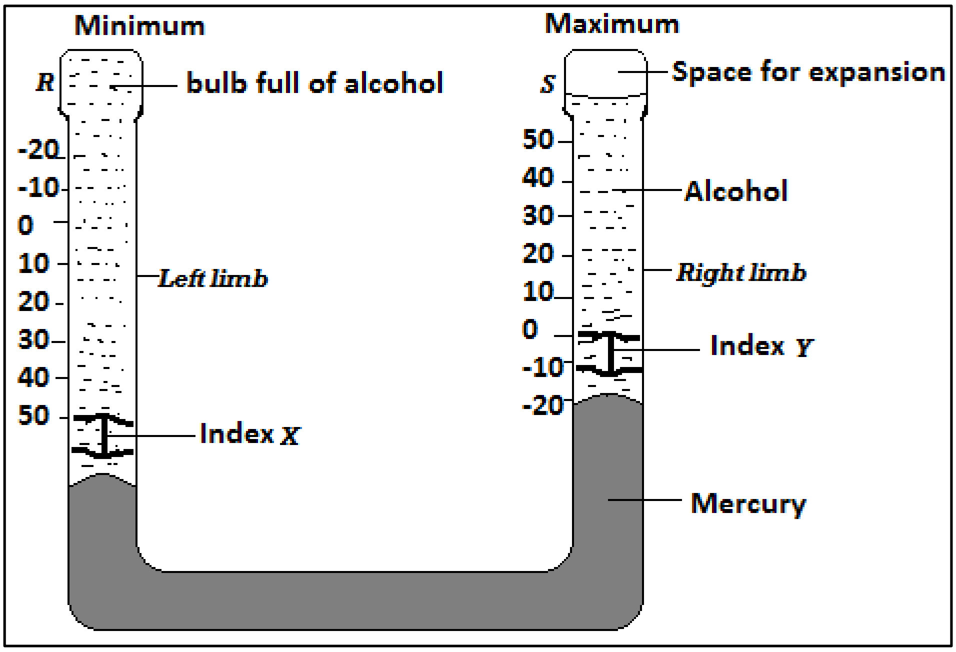
Mean annual temperature = $\frac{\text{Sum of Mean Monthly Temperature}}{12}$

- Annual temperature range: It is the difference between the highest and lowest mean monthly temperature in a year **OR** It is the difference between the hottest month and the coolest month of the year.

  Annual temperature range = Highest Temperature – Lowest Temperature

How temperature is measured at a weather station:
The temperatures recorded in climatic graphs are ***shade temperatures***, i.e. the temperature of ***air***. Precautions are taken to exclude the intensity of the sun's radiant heat by placing the thermometers in a standard meteorological shelter known as a ***Stevenson Screen***.
Maximum and minimum temperatures are measured using the ***maximum and minimum thermometers***. They're either in the form of separate thermometers or joined in a U-shaped glass tube called the ***six's thermometer***.

SIX'S THERMOMETER



When the temperature rises, alcohol in the left-hand limb of the (min) thermometer expands and pushes the mercury down the left-hand limb and up the right-hand limb. The alcohol in the right-hand limb (max) also heats up and part of it vaporizes and occupies the empty space in the bulb. The end of the indicator nearest the mercury gives the reading for the maximum temperature on the right-hand limb.

When the temperature falls, alcohol in the left-hand limb (min) contracts and some of the alcohol vapor in the bulb liquefies. Alcohol from the right-hand limb pushes mercury downwards to left-hand limb, thereby pushing the metal index upwards. The end of the index in the minimum thermometer farthest from the bulb gives the minimum temperature of the day.

FACTORS AFFECTING THE TEMPERATURE OF A PLACE

1. **Latitude**:
This is the angular distance of an area from the equator. Latitude determines the amount of insolation/heat (solar radiation) reaching the earth surface which in turn affects temperatures of a place. Due to the earth's inclination or tilt, the mid-day sun is almost overhead within the tropics but the sun's rays reach the earth at an angle outside the tropics. As the rays of the sun fall vertically on the Equator, the temperature is always hot there. Places within the tropics have the mid-day sun almost overhead, and the temperatures remain hot. Outside the tropics, the sun's rays reach the earth's surface obliquely, and the temperatures are correspondingly lower. There are two similar bands of rays coming from the sun to two different latitudes on the earth's surface. The band of rays falling vertically over the equatorial latitudes heats up a smaller surface, and there the temperature is hot. The band of rays falling obliquely over the temperate latitudes heats a larger area (this is due to the curvature of the earth), and there the temperature is low. Temperatures thus decrease from equatorial regions to the poles.

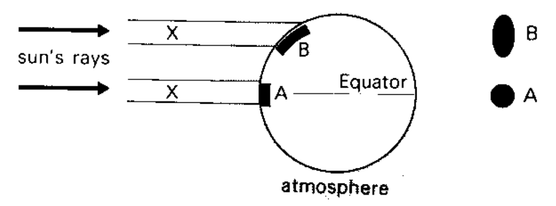


Fig. 14.2 More insolation reaches the earth's surface when the angle of the sun's rays is 90° than when it is less than 90°. The sun's rays pass through a greater thickness of atmosphere to reach B than to reach A. You can see that the surface area of B is oval-shaped and is larger than the surface at A.

2. **Altitude**:
This refers to the height of the land above sea level. Altitude is a major factor affecting or determining temperature of a place especially in highland areas. High altitude areas especially highlands like Mt. Rwenzori, Mt. Elgon, Mt. Kenya and Mt. Kilimanjaro experience cool temperatures because temperatures decrease with increase in altitude at a rate of 6.5^0 C per 1000m ascent (normal lapse rate). This is because the air is rarefied at high altitudes and contains less water vapor and dust resulting in rapid loss of heat thus the air remains cool or cold. On the other hand, low altitude areas such as the rift valley region, the foothills of mountains and coastal areas experience hot temperatures due to excessive impurities in the air such as dust particles, water vapor and carbon dioxide which trap heat that is radiated in the low altitudes. This explains why Mombasa is hotter than Nairobi.

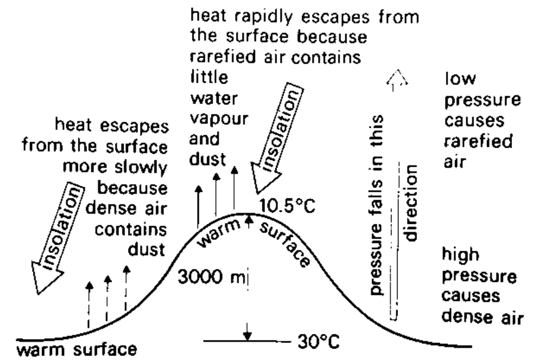


Fig. 14.3 A diagram to show the effect of altitude on temperature. What would the temperature be at the top of Mount Cameroon (4070 m) if the temperature at sea level were 30°C?

3. **Continentality/Distance from the sea**:
Land surfaces heat and cool more quickly that water surfaces such as seas, oceans and large lakes. Thus air temperatures decrease from the coast inland as coastal regions tend to be cooler than inland regions. The cool sea breeze experienced during the day lowers temperatures of the adjacent coastal belt and the warm land breeze experienced at night raises or warms temperatures of the coastal belt.

4. **Winds and Air masses**:
Winds are mechanisms through which global circulation and transportation of heat or temperature occurs. Winds and air masses carry temperature characteristics of their areas of origin to places they're passing or going. Cold or warm on-shore winds cool down or raise temperatures of places they're passing. In EA the major winds influencing temperatures are the SE and NE trade winds. The NE trades are hot and dry winds originating from the Arabian Desert and raise temperatures in areas of NE Uganda and Northern Kenya. The SE trades are warm and moist blowing from the Indian Ocean hence modify temperatures at the coastal belt.

In addition several local winds bring a marked change in the temperature. During the day the land is hotter than the sea. The heated air over the land becomes lighter and rises. This creates a low pressure area over the land. At this time, the air above the sea is cooler. When this air blows towards the low pressure area over the land, it lowers the temperature of the air on land. This is known as Sea Breeze. This sea breeze has a moderating influence on coastal regions. During the night, conditions are just the reverse. At this time, the sea remains warmer than the land. So the land breeze blows from the land to the sea, and relieves the cold of the land. The areas, close to the sea have lower daily and annual ranges of temperatures.

5. **Ocean currents**:
These modify the temperature by transporting heat or cold to the adjacent coastal areas. When the winds blow over them, they get their warmth or cold and affect the temperatures of coastal areas. Warm ocean currents such as the Warm Mozambique current raise the temperatures of the winds blowing around hence causing warm and/or hot temperatures to the adjacent lands such as

Mombasa and Dar es Salaam while cold ocean currents like the Benguela current lower temperatures along the Namibian coast.

6. **Cloud cover**:
The presence of thick clouds in the sky reduces the amount of solar insolation reaching the earth surface as well as the amount of terrestrial radiation leaving earth surface. For this reason, areas with thick cloud cover like the Lake Victoria basin experience a small diurnal range of temperature than areas like Turkana with limited cloud cover that experience a hot day temperatures (more than 38°C) and a much lower night temperatures (less than 21°C).

7. **Humidity**:
The amount of water vapour in the atmosphere determines the atmospheric temperature of a place. High amounts of humidity absorb heat and prevent heat loss from the earth's surface. This explains why areas with high humidity e.g. equatorial regions experience hot temperatures during the day and at night than areas with low humidity which experience cool temperatures during the night due to excessive heat loss.

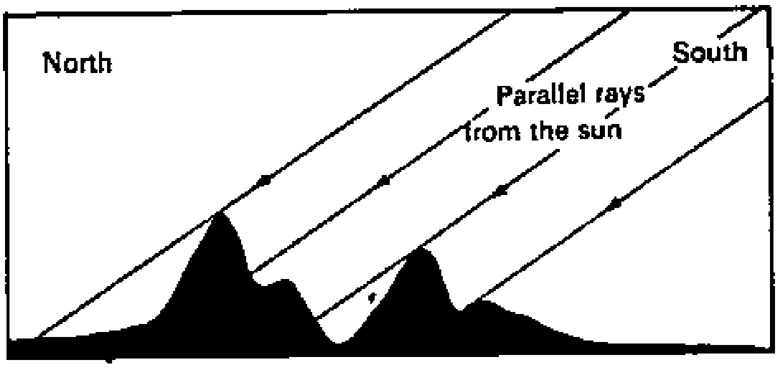
8. **Natural Vegetation**:
There is a definite difference in temperature between forested regions and open ground. Thick vegetation cover has a modifying effect on the temperature of the surrounding areas by reducing the amount of in-coming insolation reaching the ground and also through evapotranspiration so that the air above is cooled. Forested areas have high humidity and relatively low temperatures for instance Mabira and Budongo forest. On the other hand, areas with limited vegetation cover tend to experience hot temperatures e.g. NE Uganda and Turkana land in NW Kenya.

9. **Soils**:
Light soils reflect more heat than darker soils which are better absorbers. Such soil differences may lead to slight variations in the temperature of a region. Dry soils like sand warm up and cool down much quicker than wet soils like clay that retain much moisture and warm up or cool down more slowly.

10. **Apparent movement of the overhead sun**:
The position of the sun influences seasonal variations in temperature. Temperatures are hot in regions where the sun is overhead. When the sun is overhead in the northern hemisphere between June and July, hot temperatures are experienced in the northern hemisphere and low temperatures in the southern hemisphere. When the sun is overhead in the southern hemisphere between December and January, temperatures are high in the southern hemisphere and low in the northern hemisphere.

11. **Nature of the earth's surface (Albedo)**:
The capacity of a surface to reflect the sun's energy is called its **albedo;** a surface with a high albedo has a high percentage of reflection. The more solar energy that is reflected back into space by Earth's surface, the less that is absorbed for heating the atmosphere. Temperatures will be higher at a given location if its surface has a low albedo rather than a high albedo. Surfaces covered by water and snow or ice reflect much of the heat (solar radiation) back into the atmosphere leading to low (cool) temperatures while forested areas have a low albedo leading to warm/hot temperatures.

13. **Aspect**:
It refers to the direction of a hill slope in relation to the position of the sun. It influences temperature in the temperate latitudes where the sun facing slopes of mountains get warmer than the land sloping away from the sun or towards the Poles. In the northern hemisphere the south facing slopes experience warm temperatures than the north facing slopes. In the southern hemisphere on the other hand, the north facing slopes are warmer than the south facing slopes. In the tropics however, the influence of aspect is not experienced because in those latitudes the mid-day sun is always high in the sky, and its rays fall more or less vertically over the whole land.



South-facing slopes are more sunny

14. **Human activities**:
Human beings, too, may be considered "controls" of temperature. Cities represent areas where human activity is concentrated, large densities of population live and work in temperature controlled environments (utilizing heating and air conditioning units), and people develop industries that burn fossil fuels. Rural areas lack the concentration of human population and have no large heat-producing industries. In cities, many thousands of automobiles can add heat to the air, whereas rural areas may experience only limited numbers of farm vehicles. Even the building material of cities (concrete, asphalt, glass, and metal) can heat up quickly (with low specific heat and low albedo values) during the day, as opposed to the grass, trees, and cropland of the surrounding countryside, which react more slowly to insolation. Hence cities are generally warmer than the surrounding countryside. In addition, human activities like destroying forests, draining swamps, or creating large reservoirs can significantly affect local climatic patterns and, possibly, world temperature patterns as well.

VERTICAL DISTRIBUTION OF TEMPERATURE (LAPSE RATE)

Lapse rate refers to the natural fall in temperature with increase in altitude of a rise in temperature with decrease in altitude. The increase in temperature or heat is caused by the compression of the air as altitude falls/decreases while the fall in temperature is due to the expansion of air as ascends.

Types of Lapse Rate

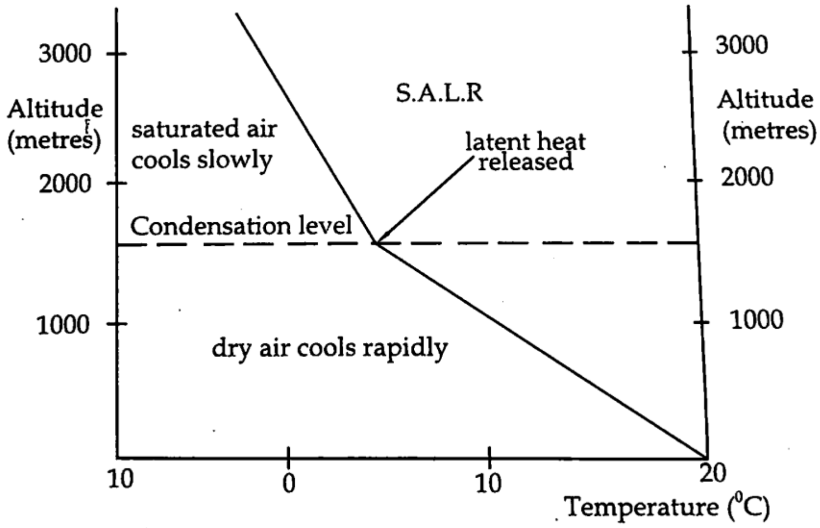
Lapse rate is described in three (3) ways:

a) **Environmental Lapse Rate (ELR)**:
It is the rate at which temperatures change with an increase or decrease in altitude at a given time and location. This describes the vertical distribution of the temperature of a given geographical location at a precise moment in time. The ELR is not fixed and changes from day to day as well as from place to place. The ELR is approximately 6.5^0 C for every 1000m of ascent. ELR is influenced by height, time and nature of surface. ELR is lower nearer the ground level, during the rainy season and over continental surfaces than water surfaces.

b) **Adiabatic Lapse Rate (ALR)**:
This refers to the decrease in temperature when air rises into the upper atmosphere and rise in temperature when air descends to the lower atmosphere. The rise of air results in decrease in pressure as well as increase in volume resulting in a fall in temperature with increase in altitude. On the other hand, descending air is compressed, pressure increases and temperature rises. There are two types of ALR;

(i) **Dry Adiabatic Lapse Rate (DALR)**:
It is the rate at which rising dry air cools without affecting the temperature of the surrounding atmosphere. Dry air cools at a faster rate of 10^0 C for every 1000m of ascent.

(ii) **Saturated (Wet) Adiabatic Lapse Rate (SALR)**:
It refers to the rate at which saturated/wet air cools as it rises to greater heights (higher levels) of the atmosphere or warms when it descends into the lower atmosphere. Saturated (humid) air cools at a rate of 6^0 C per 1000m of ascent. A body of air which starts to rise may first cool at DALR until the condensation level is reached then it cools at SALR.



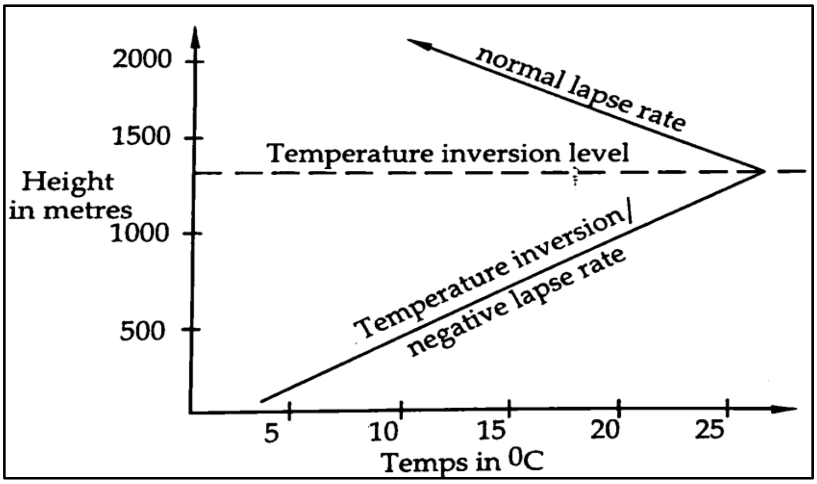
TEMPERATURE INVERSION

Under certain circumstances, the normal observed decrease of temperature with increased altitude might be reversed; temperature may actually ***increase*** for several hundred meters. This is called a ***temperature inversion***. ***It is an atmospheric condition in which air temperatures increase with an increase in altitude in the troposphere***. It is the opposite of the environmental or normal lapse rate where temperatures decrease with an increase in altitude, i.e., the higher you go, the warmer it becomes.

Temperature inversion is temporary and usually lasts for a few hours especially in the morning. It occurs up to a certain level referred to as the temperature inversion level. Beyond this level, the normal lapse rate applies.

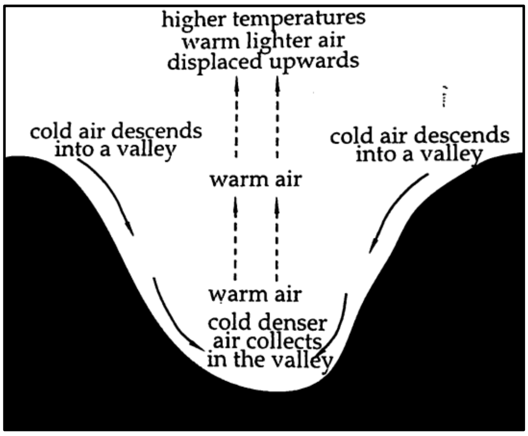
It normally occurs in highland areas due to temperature differences between the hill slopes and the valleys e.g. in the Kigezi highlands, Kenya highlands as well as areas of limited cloud cover marked by air stability or calm weather such as the semi-arid areas.

It happens when surface air is cooled by the descending cold dense air while the warm light air is displaced upwards as illustrated below:

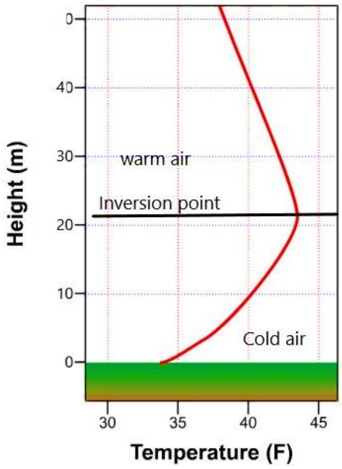


CAUSES OF TEMPERATURE INVERSION

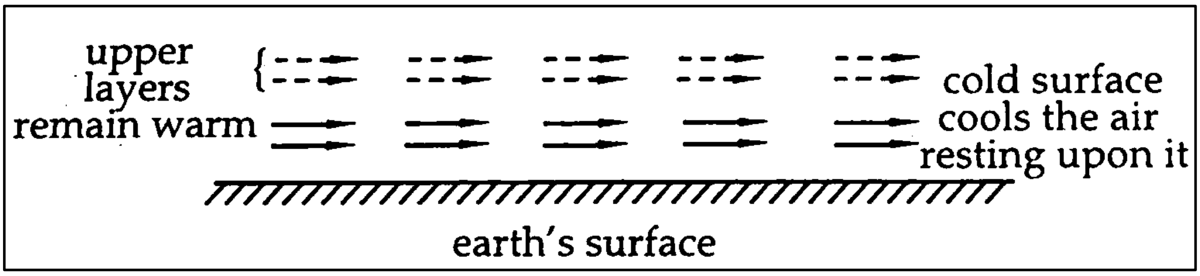
1. Subsidence or sinking of cold dense air in highlands. Due to the rapid cooling of the upper slopes of highlands at night, air cools and becomes dense causing high pressure while the air in the valleys remains warm leading to low pressure. The cold dense air therefore sinks down into the valleys displacing the light warm air upwards hence causing temperature inversion e.g. in the Kigezi highlands.



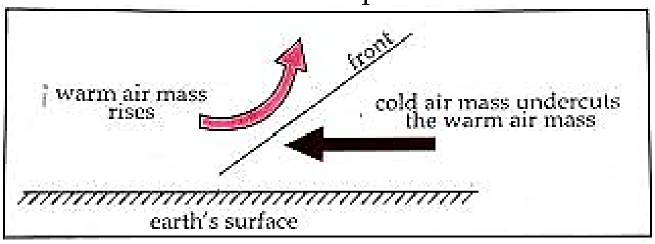
2. Rapid radiation of heat at night. Inversion may occur in the morning hours after a long night of clear cloudless skies and relatively still air. Under this condition the earth surface cools faster at night due to the rapid loss of heat hence causing low temperatures near the ground surface than the air which is far above the ground surface. This normally occurs in the morning thereafter the normal lapse rate returns with the incoming solar radiation and outgoing terrestrial radiation.



3. Movement of warm air over a cold surface. Temperature inversion will occur when a warm air mass passes over a cold surface. As the warm air blows over the cold surface, the lower layers of the air mass will be cooled by the cold surface while the overlying layers remain warmer so that there is an increase in temperature with altitude. This is referred to as advection temperature inversion. It eventually leads to the formation of advection fog by the layer in contact with the cold surface.



4. Frontal convergence of warm and cold air masses. When two air masses with different temperature characteristics meet, the cold air mass which is dense sinks downwards and undercuts the warm light air mass. The cold air mass ultimately lies below the warm air mass leading to temperature inversion called frontal/cyclonic temperature inversion. This occurs in the tropics where air fronts are common i.e. the inter tropical frontal zones in EA.



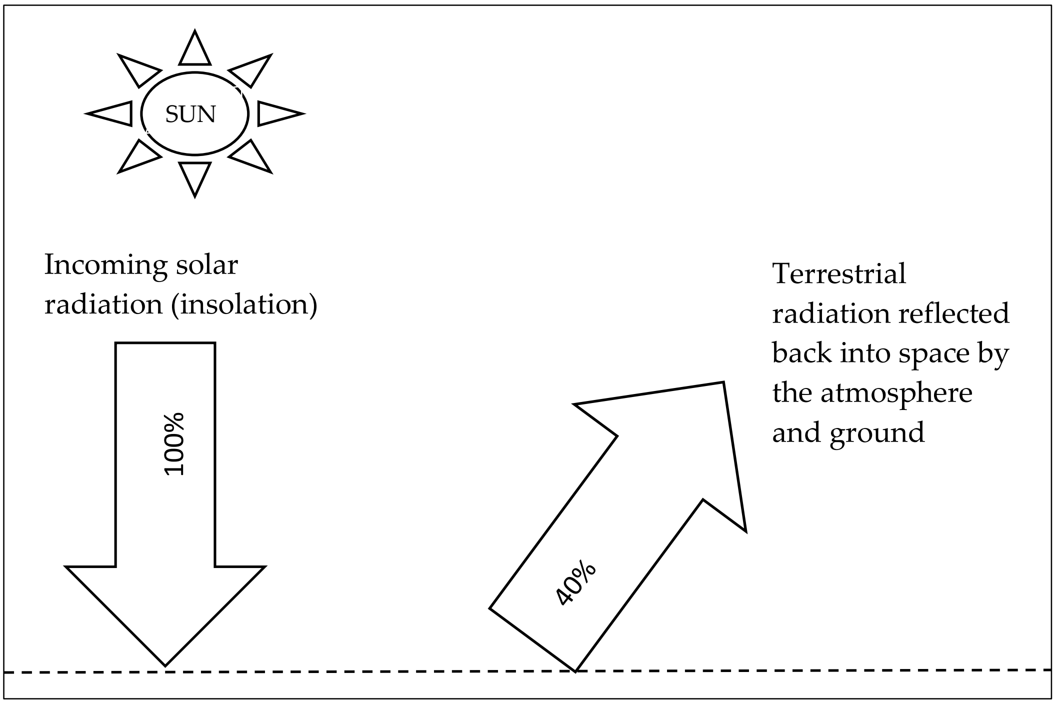
Effects of temperature inversion on weather and human activities
- It limits or retards the vertical movement of air currents creating a stable atmospheric condition which hinders rainfall formation and promoting aridity.
- It leads to premature surface condensation in the lower levels of the atmosphere hence the formation of fog i.e. tiny light water droplets which form over the earth's surface.
- The formation of fog may hinder visibility hence resulting in accidents especially by road and railway.
- It leads to the formation of cold frosty conditions especially in the hilly areas due to the subsidence of cold dense air.
- The cold frosty conditions caused by temperature inversion discourage the growth of some crops such as coffee, tomatoes and bananas
- It promotes atmospheric pollution at higher levels especially in the industrial areas since the industrial carbons are easily spread by the warm air above the earth's surface forming a blanket of smoke or smog.
- The increased industrial pollution may lead to formation of acid rain which is dangerous to man, his property and economic activities.
- The cold frosty conditions which occur in the valleys due to temperature inversion favor the growth of some crops like pyrethrum, tea and sorghum as well as temperate crops like grapes and apples
- It leads to spread of cold related diseases like asthma and pneumonia due to the cold conditions associated with it
- The fog experienced in the morning hours in areas such as Kigezi highlands due to temperature inversion reduces the morning working hours

Revision questions:
1(a) Differentiate between annual range of temperature and diurnal range of temperature.
(b) Account for the variations in temperature experienced in the different areas of EA.
2(a) Differentiate between mean annual temperature and annual range of temperature.
(b) Account for the variations in mean annual temperature over the African continent.
3(a) Differentiate between diurnal range of temperature and mean monthly temperature.
(b) To what extent is the position of the overhead sun responsible for temperature conditions of a place?
4(a) Describe the steps take to record and measure temperature at a weather station.
(b) To what extent has latitude influenced temperature in Africa?
5. Examine the causes and effects of temperature inversion.

TERRESTRIAL RADIATION
It is also known as ***thermal radiation***. This is the energy transmitted or transferred from the earth's surface to the atmosphere. Terrestrial radiation is transferred in form of long waves (electro-magnetic radiation) and it occurs all the time both during day and night time in form of infra-red energy i.e. both light and heat energy. The amount of terrestrial radiation varies with the nature of the surface area and its size e.g. water surfaces emit less radiation than land surfaces. Equally, mountain tops emit less radiation than the lowlands
Air, water vapour and clouds take up a great deal of this energy emitted by the earth thus resulting into the rising of temperature in the atmosphere which is measured and recorded at a weather station. Terrestrial radiation therefore results into **a rise in the temperature** of the atmosphere.

SOLAR RADIATION
It is also known as ***insolation/solar energy/radiant energy***. This is the energy transmitted from the sun to the earth through the atmosphere. It passes in the atmosphere in form of a beam of short wave rays (solar short wave radiation) and reaches the earth as ***solar or radiant energy*** in the process called ***insolation***. This radiation from the sun is made up of three parts, the ***visible 'white' light*** that we see when the sun shines and the less visible ***ultra-violet*** and ***infra-red rays***. Solar radiation is received in a place during the day in form of light and it is converted into heat at the earth's surface. The amount of solar radiation received in a place also varies from time to time. The water vapor, clouds, carbon dioxide and other gases atmosphere absorb some of this energy while dust, clouds and air molecules reflect and scatter the energy into the space. The earth therefore

absorbs only a fraction of the energy emitted by the sun. The nature of the earth's surface (albedo) is used to express the ability of a surface to reflect insolation.



CONDITIONS INFLUENCING THE IN-COMING SOLAR RADIATION IN A PLACE

(a) **Latitude**: The angular distance of a place from the equator determines the distance travelled through the atmosphere the rays of the sun to the earth's surface. Hence, there's always maximum insolation in the low latitudes because the sun's rays strike the earth's surface at right angles and have a short distance to travel through the atmosphere thus there's intensive heating since there's a smaller surface to heat. The sun's rays are however less intensive towards the mid-latitudes and polar regions (high latitudes) because of the long distance they travel through the atmosphere and the oblique angle at which they strike the earth's surface. In addition, the atmospheric gases act to diminish, to some extent, the amount of insolation that reaches Earth's surface. Because oblique rays must pass through a greater distance of atmosphere than vertical rays, more insolation will be lost in the process.

(b) **Rotation of the earth**: Rotation refers to the spin of Earth on its axis, an imaginary line extending from the North Pole to the South Pole. Earth rotates on its axis at a uniform rate, making one complete turn with respect to the sun in 24 hours. The rotation of the earth on its axis causes changes in solar radiation received in a place. Within the tropics when the sun is overhead, high amounts of solar radiation are received. Absence of the overhead sun at the poles, arctic and sub-arctic regions reduces the insolation rates. In addition rotation accounts for our alternating days and nights thus areas experiencing day time receive insolation while those in the dark receive no insolation.

(c) **Revolution of the earth**: As the earth rotates on its axis, it also revolves around the sun in a slightly elliptical orbit. This causes seasonal variation in the amount of insolation received in the different places of the earth. More solar radiation is experienced during the summer season compared to the winter season.

(d) **Length of day**: The length of daylight also affects the amount of radiation that is received. Obviously, the longer the time the sun shines the greater is the quantity of radiation that a given portion of the earth will receive. At the equator, for example, the day length is close to 12 hours in all months, whereas at the poles it varies between 0 and 24 hours from winter (polar night) to summer.

(e) **Cloud cover**: Clouds in the atmosphere absorb, reflect and refract insolation. This reduces the amount of solar radiation reaching the earth's surface hence implying that areas with thick and continuous cloud cover experience less solar radiation as compared to areas with clear skies.

(f) **Aspect**: Areas in the direct path of the sun's rays especially in the mid and high latitudes receive more solar radiation as compared to those areas sheltered from the sun's rays. For instance, in the mid-latitudes of the Northern hemisphere, the south facing slopes receive more solar radiation than the north facing slopes. This is because the south facing slopes are in the direct path of the sun's rays while in the Southern hemisphere, the north facing slopes receive more insolation than the south facing slopes.

(g) **Humidity**: The amount of water vapour in the atmosphere may absorb or reflect solar radiation. It prevents some percentage of the solar radiation from reaching the earth's surface. Areas with a low humid content such as arid and semi-arid regions therefore experience more insolation on their surfaces because direct heat from the sun is received.

(h) **Impurities in the atmosphere**: Impurities such as smoke and dust particles tend to absorb part of the solar radiation reaching the earth's surface. This means that areas with a lot of atmospheric impurities receive less solar radiation as compared to areas with clear atmospheric conditions.

(i) **The sun's hot spots**: The surface of the sun has certain sections which are hotter and emit more radiation. Therefore, sections on the earth's surface that receive heat directly from these hot spots experience greater solar radiation. The reverse is also true.

(j) **Greenhouse effect**: The increase in the amount of greenhouse gases like methane, carbon dioxide, nitrous oxide and carbon monoxide in the atmosphere affects the ozone layer hence triggering off the occurrence of global warming which ultimately increases the amount of solar radiation. On the other hand, areas with limited atmospheric greenhouse gases have an intact ozone layer hence they experience less solar radiation reaching the earth's surface.

Revision Question:
1(a) Distinguish between terrestrial radiation and solar radiation.
(b) Describe the conditions that influence the in-coming solar radiation in an area.

PRECIPITATION

Precipitation refers to ***all forms of moisture which fall on the earth's surface from the atmosphere***. Precipitation occurs when the droplets of water, ice, or frozen water vapor grow and develop masses too great to be held aloft. They then fall to earth as rain, snow, sleet, or hail.
Precipitation forms under the following conditions:

✓ Adiabatic cooling of air which occurs when moist air rises and cools until when the temperatures reach the dew point at the condensation level. The water vapour condenses to form clouds or precipitation.

✓ Air contact with a cold surface. When warm moist air moves over a cold surface, the water vapour is cooled and it condenses into precipitation. This commonly occurs over the sea leading to the formation of fog.

✓ Mixing of air in the atmosphere. When two (2) air masses or wind systems meet in the atmosphere, the warm air is cooled down and it condenses leading to the formation of water droplets.

✓ Terrestrial radiation at night. Rapid loss of heat by the land surface causes rapid cooling which also in turn causes the condensation of water vapour near the earth's surface. This is responsible for the formation of dew especially in the semi-arid areas.

✓ The degree of relative humidity. When air is fully saturated (wet) i.e. with a relative humidity of 100%, any increase in water vapour results into condensation to take place hence forming water droplets.

✓ Presence of condensation nuclei (cloud seeds). These are minute (very tiny) particles in the atmosphere that provide a surface upon which condensation can take place, e.g. dust, pollen, soot, sea salt and sulfate from volcanic activity. Water molecules often form or cling onto these tiny particles suspended in the atmosphere acting as condensation nuclei. These aid in the formation of clouds, rain, dew, haze and fog.

N.B: Condensation in the atmosphere results into the formation of clouds. ***Clouds are defined a collection of very tiny water droplets or ice particles suspended in the atmosphere***. Clouds form as a result of the condensation of water vapour when air carrying the water vapor cools to below the dew point temperature. Cooling occurs when warm air is forced to rise. As it rises, air expands and therefore becomes cooler and condenses at the ***condensation level***. Clouds in the atmosphere affect the weather conditions of a given place in the following ways:
- Clouds lead to low surface temperatures by absorbing radiation from the sun during the day. This reduces the amount of insolation received on the earth's surface.
- Clouds regulate warm temperatures during the night by acting as a blanket that prevents heat loss from the earth's surface. Areas with thick cloud cover e.g. the equatorial region experience a low diurnal range of temperature due to the reduced amount of heat loss at night.
- Dense cloud cover results into dark unclear conditions during day time. Thin cloud cover results into clear sunny day conditions.
- Thick cloud cover is associated with heavy rainfall while thin clouds lead to little or no rainfall at all.
- Low altitude clouds like mist and fog reduce visibility that hinders human activities such as transport thereby causing accidents.

RAINFALL

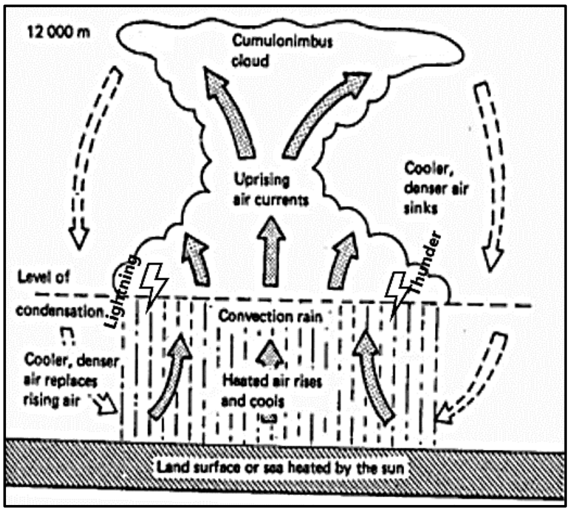
Rainfall is ***liquid water in the form of droplets that have condensed from atmospheric water vapor and then become heavy enough to fall under gravity***. Rainfall is formed when very tiny or minute droplets of water, (which from clouds), join together to produce large drops of water called ***raindrops***. Water droplets then join together around a ***condensation nuclei*** to form raindrops. When raindrops grow in size they eventually become heavy enough to fall to the ground either as a drizzle or rain. Drizzle is very fine rain or small raindrops while rain consists of much larger raindrops.

Types of Rainfall

There are three major types of rainfall.

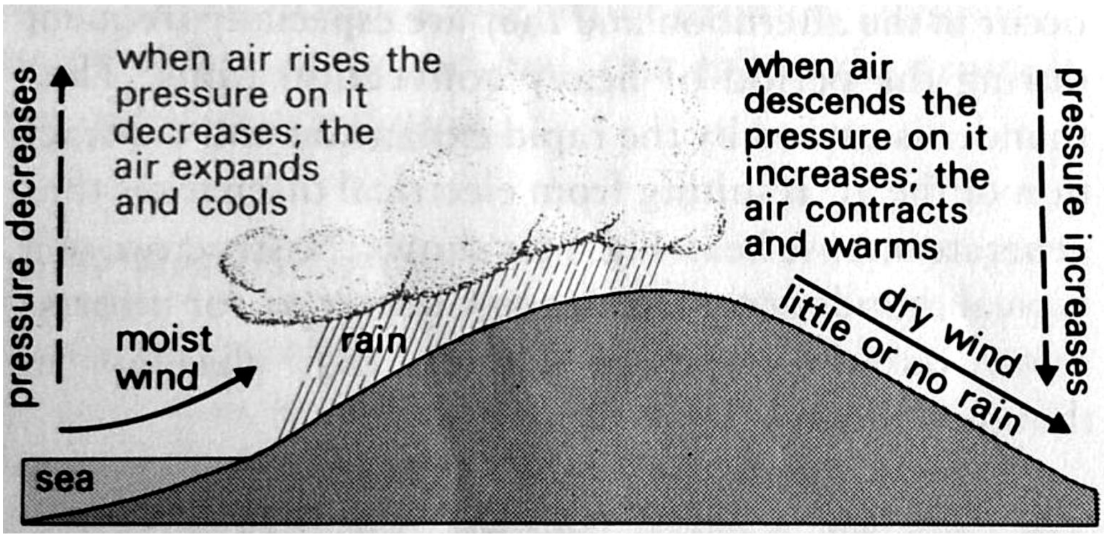
1. **Convectional Rainfall**: This type of rainfall occurs as a result of evaporation induced by heat. When the earth surface is heated the air above it is heated, absorbs a lot of moisture, expands and rises in a convection current. As it rises it cools and condenses to form clouds and later torrential rains develop. This type of rainfall is most common in equatorial and tropical areas as well as continental interiors which experience intense heating almost throughout the year while in the mid-latitudes, it is received during summer. This rainfall is often accompanied by thunder and lightning because large amounts of energy are released when condensation occurs and this provides energy for the thunderstorms. Also this rainfall occurs in afternoon when maximum heating of land occurs.

Characteristics of Convectional rainfall:
- It is experienced in areas with intense heating
- It is associated with prolonged rains covering a wide area
- It is mainly received in the afternoons when maximum heating of land occurs
- Its often accompanied by thunder and lightning
- It involves heavy showers or torrential downpours
- It occurs in summer in the mid-latitudes or temperate interiors



2. **Relief or Orographic Rainfall**: This is a type of rainfall experienced in the mountain ranges, hilly regions, or even the escarpments of plateaus or tablelands. It occurs when prevailing moist winds are forced to rise upwards by a relief barrier such as a mountain (highland) or hill, expands and cools to form clouds and eventually rain on the windward slopes. As air descends on the leeward side the pressure and temperature increase while the relative humidity decreases hence the air is warm and dry resulting into little or no rainfall. This region is called the rain shadow. This type of rainfall is common in the mountainous areas/highlands of Kilimanjaro, Rwenzori, Elgon, Muhavura and Mt. Kenya.

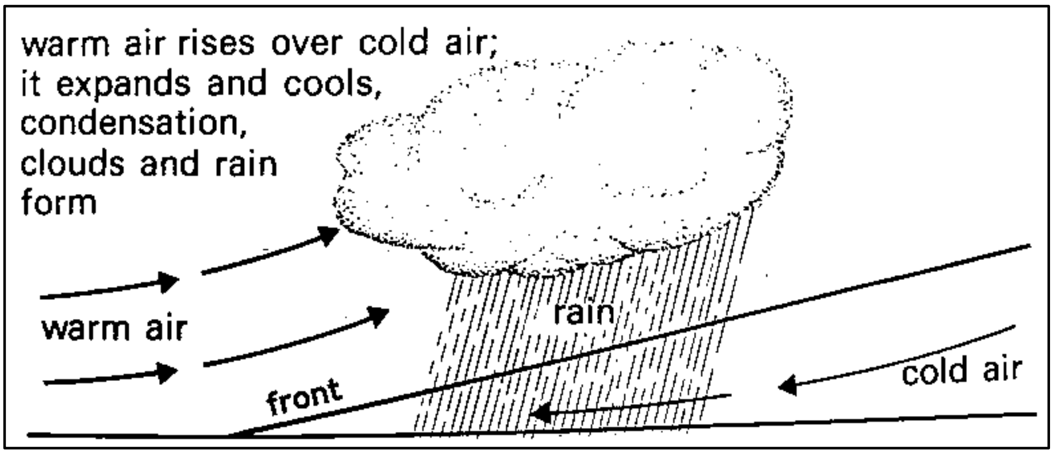
Characteristics of Relief rainfall:
- It is often heavy on the windward side of the highlands
- It occurs as a result of the ascent of moisture laden air over a highland
- It involves prolonged periods of rain or precipitation
- It occurs in proximity to highlands
- Occasional thunderstorms and hail are common



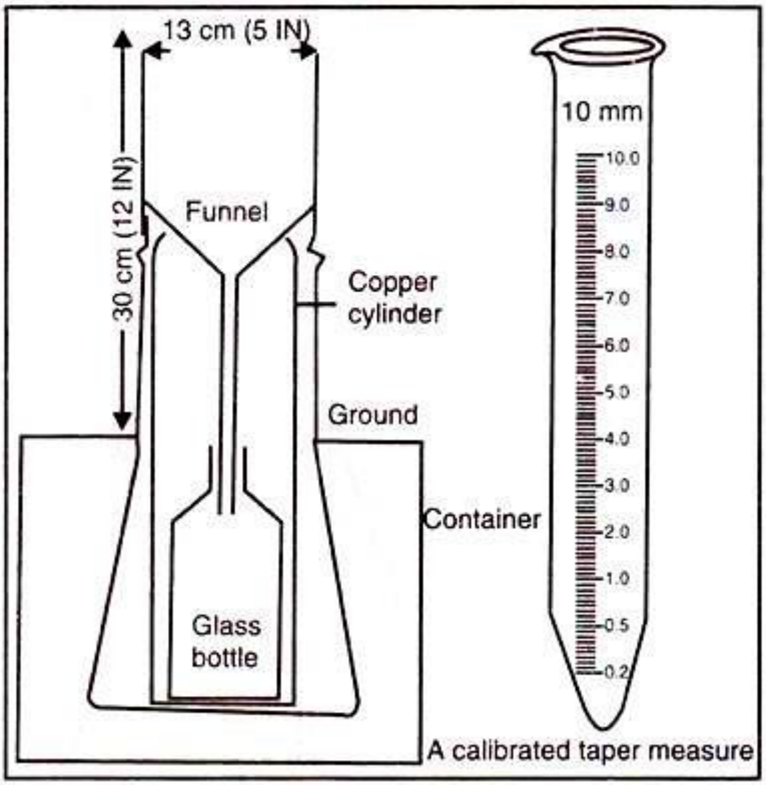
3. **Frontal or Cyclonic or Depression Rainfall**: This type of rainfall which occurs when two air masses of different characteristics meet or converge and the air mixes at a ***front***. The lighter warm air is forced to rise over the cold dense air. As the warm moist air rises, pressure decreases, the air expands and cools, condensation takes place and light showers called ***cyclonic or frontal rain*** occur. The cold dense air mass eventually pushes up the warm light air and the sky is clear again.

Characteristics of Frontal Rainfall
- It is experienced along fronts such as the Inter tropical convergence zone (I.T.C.Z) where trade winds meet
- It involves heavy showers covering small local areas
- It lasts for only a few hours. i.e., it's short-lived

- It involves violent thunderstorms



Measurement of Rainfall
Rainfall is measured using a ***rain gauge***. It consists of a cylindrical copper container with a metal funnel, in which is a smaller copper container and a glass bottle or jar. The gauge is sunk into the ground so that the top of the funnel is about 30cm above the ground level to prevent any rain from splashing up from the ground into the funnel. The instrument is placed in an open space so that no run-off from tress and tall buildings can get into the funnel. Also the outer case is sank into the ground to prevent evaporation of any rain collected in the glass jar. Rain falling over the funnel collects in the glass jar. After 24 hours it is emptied and measured in a tapered measuring cylinder, graduated in millimeters. The tapered cylinder enables very small amounts of rain to be measured accurately. The daily records of rainfall are added at the end of each month to find the total rainfall for that month. The total for each month is again added at the end of the year to find the annual rainfall.



FACTORS INFLUENCING RAINFALL DISTRIBUTION IN EAST AFRICA

Rainfall distribution refers to the pattern in which rainfall is spread over a given area in a specific period of time. Rainfall in EA varies mainly in terms of amount and seasonality. Heavy rainfall of over 1000mm per annum is experienced in areas around the Lake Victoria basin, coastal areas and the highland areas of Mt Kenya, Elgon and around the Kigezi highlands among others. Moderate rainfall ranging between 760-1000mm per annum is experienced in South western Tanzania,

Central and Northern Uganda as well as Southern Kenya. Low rainfall of less than 760mm per annum is received in areas like Karamoja region, Ankole-Masaka corridor, Turkana land, Masai land and the Albert flats.
The variations in the amount of rainfall received in EA are influenced by the following factors:

1. **Apparent movement of the sun (I.T.C.Z)**:
Between May and September the sun is overhead the northern hemisphere, intense heating occurs creating a low pressure belt and the convergence of moist winds which result into heavy rainfall in the north. The same condition is experienced in the southern hemisphere between December and January. The north and south therefore experience a single rainfall maximum due to the apparent movement of the sun. Because the sun is overhead at the equator twice in a year, a double rainfall maxima is experienced in the equatorial areas such around the Lake Victoria basin.

2. **Prevailing winds**:
These have a rainfall effect on the areas over which they blow because they transfer weather characteristics to the areas where they move. The SE trade winds emerge from the Indian ocean when they are moist so they are responsible for the heavy rainfall experienced along the coast of EA as well as the northern shores of Lake Victoria while the NE trade winds are dry winds from the Arabian desert and are responsible for the low and unreliable rainfall in North eastern Uganda and North western Kenya.

3. **Vegetation cover**:
Areas with thick vegetation cover like tropical rain forests experience heavy rainfall due to the high rates of evapotranspiration e.g. around Mabira, Budongo and the coastal areas with mangrove forests. On the other hand, semi-arid areas with scanty and poor vegetation cover experience low and unreliable rainfall e.g. Karamoja region and Turkana land.

4. **Influence of water bodies**:
Water bodies such lakes and oceans recharge the atmosphere with water vapour through evaporation as well as through land and sea breezes. Therefore, areas near water bodies experience heavy convectional rainfall e.g. the Lake Victoria basin and the coastal areas while areas far away from water bodies experience low and unreliable rainfall e.g. in North eastern Uganda.

5. **Relief**:
Highland areas in EA experience heavy rainfall on the windward slopes since they act as barriers towards the movement of the moist winds hence forcing them to rise upwards towards the condensation level thereby forming orographic rainfall while the leeward slopes experience hot and dry conditions with little or no rainfall due to the descending dry winds.

6. **Altitude**:
High altitude areas like mountainous regions experience heavy rainfall due to cool temperatures which induce condensation of moisture bearing winds while areas of low altitude experience low to moderate rainfall due to the limited cooling effect for instance Mt Elgon areas receive heavy rainfall than the rift valley regions.

7. **Ocean currents**:
Warm ocean currents like the warm Mozambique currents increase the temperature of the ocean water and cause an increase in the rate of evaporation. Thus onshore winds pick up moisture when they blow across a warm current, and they give rise to heavy rainfall in the adjacent coastal areas of EA between Mombasa and Dar es Salaam. On the other hand when onshore winds blow across a cold current they lose moisture bringing dry conditions to the adjacent land areas.

8. **Corriolis force/effect**:
According to Ferrell's law, the South east trade winds are deflected to the right of their path as they cross the equator due to the rotation of the earth. This is responsible for the heavy rainfall received around the northern and north eastern shores of Lake Victoria while low and unreliable rainfall is experienced in the Ankole-Masaka corridor.

9. **Perturbation**:
It refers to the development of low pressure belts over the Indian Ocean due to intense insolation. This forces winds from the interior of EA to blow offshore (seaward) resulting into heavy rainfall over the Indian Ocean and dry conditions in north eastern Kenya.

10. **Coastal configuration**:
The north east and south west alignment of the coast forces winds to blow parallel to the coast instead of blowing onshore. This is responsible for the low rainfall received in north eastern Kenya.

11. **Human activities** such as deforestation, overgrazing, sinking of bore holes and swamp reclamation among others reduce the rate of evaporation and evapotranspiration resulting into low rainfall e.g. in the Karamoja region and Turkana land. On the other hand, afforestation and re-afforestation result into increase in the rate of evaporation and evapotranspiration hence increasing the amount of rainfall in the areas where the trees are planted.

Revision Questions:
1(a) Distinguish between convectional rainfall and orographic rainfall.
(b) Account for the variations in rainfall distribution in EA.
2(a) Differentiate between orographic rainfall and convectional rainfall.
(b) Explain the factors leading to the formation of convectional rainfall in EA.
3(a) Distinguish between frontal rainfall and orographic rainfall.
(b) Account for the differences in the rainfall pattern in EA.
4(a) Describe how mean monthly rainfall is obtained at a weather station.
(b) Explain the factors which influence the rainfall patterns in EA.
5(a) Examine the factors which have influenced rainfall formation in EA.
(b) Explain the effect of rainfall on human activities in EA.
6. To what extent has altitude influenced the distribution of rainfall in EA?
7(a) Explain how the I.T.C.Z occurs in the tropics.
(b) Examine the influence of the ITCZ on rainfall patterns in EA.

FOG

Fog is a ***form of precipitation comprising of a dense mass of tiny water droplets which form close to the earth's surface***. It is a meteorological condition where condensation around very small particles of matter, occurs near to the ground surface. For condensation to occur, condensation nuclei such as smoke and dust particles must be suspended in the atmosphere near the earth's surface. Fog helps to sustain vegetation in arid and semi-arid areas. However, fog also is a hazard to modern transportation systems such as air travel, water and road transport, as it greatly hinders visibility which can lead to accidents.

Types of Fog

There are different types of fog which occur depending on the conditions of formation.

(a) **Radiation fog**
This is a type of fog which is formed due to rapid cooling of the earth's surface. It is likely to occur on a cold, clear, calm night. The air near the earth's surface therefore cools to a temperature below its dew point and condenses to form a low-lying fog called radiation fog or ***temperature-inversion fog***. It is common in valleys of mountainous areas and in cool temperate latitudes. Radiation fog is densest at sunrise when temperatures are lowest then burn off during the day when heat from the sun and earth warms the surface and air above it.

(b) **Advection fog**
This type of fog is formed when a warm moist air is cooled as it passes over a cold sea or land surface. When the warm air is cooled below its dew point condensation occurs in the form of fog. Advection fog occurs off the west coast of Africa where warm moist air passes over the cold Canaries current and also off the west coast of Namibia.

(c) **Frontal or Precipitation Fog**
It is a type of fog formed when a warm air mass rides up and over a cold air mass. The cold air mass cools down the warm air mass above it resulting into condensation near the earth's surface. This is so common around the coastal areas and the inter-tropical convergence zone.

(d) **Hill Fog or Upslope Fog**
This is a low sheet of cloud that covers the lower windward slopes of mountains. During early morning hours, a light, moist breeze may ascend a slope and cooled to the dew point leading to premature condensation that results into the formation of hill fog. It is common in mountainous areas which experience cool/low temperatures at high altitude and mountain slopes covered with tropical rainforests.

(e) **Steam or Evaporation Fog**
This is a type of fog formed when cold air passes over a warm land or water surface. The water vapour from the warm surface condenses and easily mixes with the overlying cold air thus forming fog. Steam fog forms rapidly and disappears quickly. [***On a cold day, you may have unknowingly produced evaporation fog. When moist air from your mouth or nose meets the cold air and mixes with it, the air becomes saturated, and a tiny cloud forms with each exhaled breath. Steam fog may also form above a wet surface on a sunny day. This type of fog is commonly observed after a rain shower as sunlight shines on a wet road, heats the asphalt, and quickly evaporates the water. This added vapor mixes with the air above, producing steam fog. Fog that forms in this manner is short-lived and disappears as the road surface dries.***]

HAIL
Hail refers to a ***form of frozen or solid rain/precipitation comprising of balls or irregular lumps of ice***, called hailstones, which fall in showers from cumulonimbus clouds.
It is associated with extreme instability in the atmosphere resulting from uplift of air by convective currents. Hail forms when water droplets are carried upwards by rising air currents to cooler layers of the atmosphere for them to be turned into ice crystals. When these crystals fall, water vapor around them condenses into ice, they become bigger and fall to earth as hail or hailstones. Hail occurs in unstable cumulonimbus clouds and thunderstorms.

Revision Questions
1. Describe the processes leading to the formation of the following:
a) Fog   b) Hail   c) Orographic rainfall
2(a) Distinguish between fog and hailstone.
(b) Explain the conditions which lead to the formation of fog.

WIND
Wind is defined as ***moving air or air in motion or the horizontal movement of air in response to differences in pressure***. Winds are the means by which the atmosphere attempts to balance the uneven distribution of pressure over Earth's surface thus winds often blow from high pressure to low pressure regions. Air usually moves in a definite direction and is therefore referred to as a wind system.

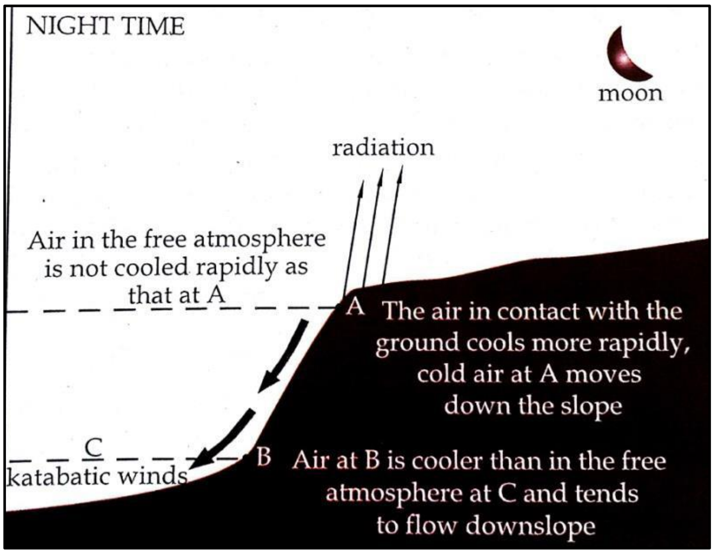
Winds are either local or global. Global winds are generally referred to as air masses and they have great influence on the climate of extensive areas while local winds have micro climatic influence. Winds may also be referred to as **breezes** when they are light.

LOCAL WINDS
These are winds that occur either regularly or periodically, but they only affect localized areas and blow for short periods of time. They are less extensive wind systems.

Types of Local Winds:

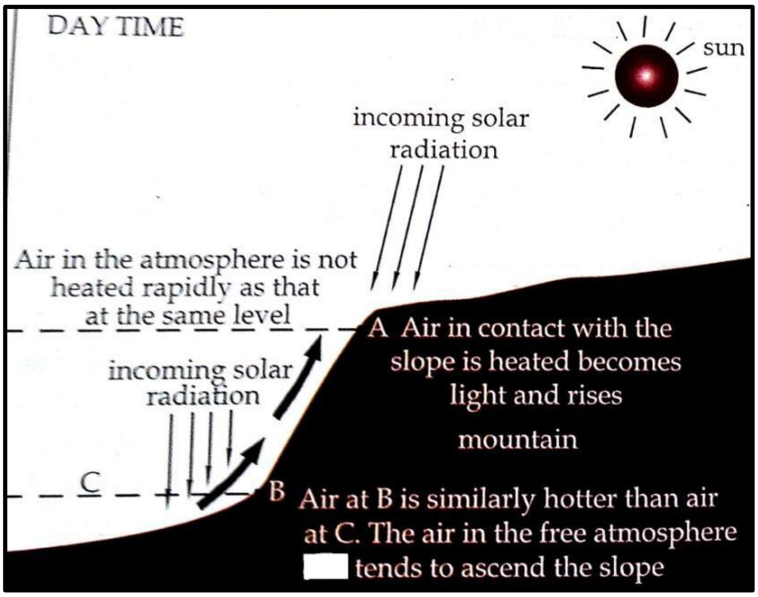
A. **KATABATIC OR DRAINAGE OR FALL OR DESCENDING WINDS**:
These are local winds occurring in mountainous or highland regions. This is a wind that carries high density air from a higher elevation downslope under the influence of gravity. They occur under calm, clear conditions at night when cold, dense air moves down slope under the influence of gravity. Katabatic winds form due to rapid cooling of the highland slopes at night leading to high pressure over the slopes. The upper slopes lose are exposed hence they lose a lot of heat and cool down much faster than the valleys ultimately becoming areas of high pressure. The air on the upper slopes becomes denser than the air in the valleys which is warm and light. The cold dense

air from the upper slopes therefore blows downslope (descends) to the valleys i.e. from a high pressure zone to a low pressure zone forming a katabatic wind as illustrated below;



Katabatic winds normally result into the following weather conditions:
- There's formation of mist and fog in the valleys especially in the morning hours because of the meeting of descending cold air and the warm air in the valley.
- Cold conditions are created in the valleys during the night usually extending to the morning hours.
- Temperature inversion is experienced in the valleys as the cold descending air displaces the warm air upwards thus the air in the valley is colder than the air above it.
- Frost conditions are experienced in the valleys due to rapid cooling caused by the descending cold air.

B. **ANABATIC WINDS OR ASCENDING WINDS OR UPSLOPE FLOW**:
These are warm local winds which blow up a steep slope or mountain side during the day in calm sunny weather. They occur as a result of the differences in the rate of heating between the valley and the upper slopes in highland areas. During the day, the upper slopes are warmed more than the valleys hence, the air over the upper slopes is heated, and it expands, becomes light and rises upwards thereby creating a low pressure zone into which cold dense air from the valley flows. Such winds are called 'anabatic winds' as illustrated below:



Anabatic winds result into the following weather conditions:
- Formation of mist and fog on the upper slopes of the mountains as the ascending cold air moves over a warm surface.

- Orographic rainfall is experienced in the mountainous areas as warm air rises from the upper slopes, cools adiabatically to below its dew point, forms cumulus clouds that produce rain.
- Low clouds are formed in highland areas due to the cooling effect of the ascending cold air at and beyond its condensation level or dew point.
- Cold temperatures are transferred from the valleys to the upper slopes of the highlands

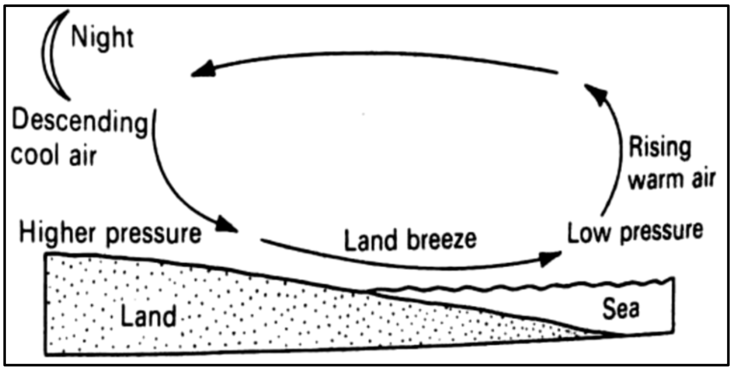
Revision Questions:
1(a) Distinguish between anabatic winds and katabatic winds.
(b) Describe the weather conditions associated with;
(i) anabatic winds (ii) katabatic winds

C. LAND BREEZE

Land and sea breezes are like monsoon winds on a small scale. They differ from most other local winds local winds in that they are diurnal or daily. Both are basically caused by differential heating of land and sea. They operate in coastal areas.

Factors for the occurrence of Land and Sea breezes:
• Differences in specific heat capacities of the land and sea, i.e. land heats up faster and cools down more quickly than water
• Mobility of water compared to the solid land
• Heat transmission through the transparent water as opposed to the opaque land
• Differences in the reflecting capacity of the land and water

Land breeze involves the movement of cold dense air from the land towards the sea. It occurs at night. It is as a result of differences in the air pressure between the land and water surface. At the land cools more quickly than the sea, the cold and dense air over the land creates a region of local ***high pressure,*** than that over the sea. A cold ***land breeze*** blows out from land to sea.



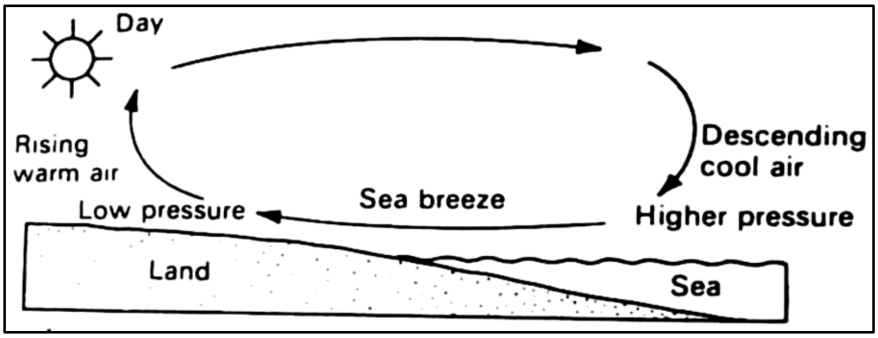
Causes of a Land Breeze:
• Rapid loss of radiation at night. Land therefore cools faster than the water hence temperatures are cooler over the land than the sea which retains much of its heat.
• Water loses heat more slowly such that the air above it remains relatively warm
• Low pressure is created over the warm sea and high pressure over the cold land. Cool air from the land under high pressure blows towards the sea to replace the rising air hence forming a land breeze.

Effects of a Land Breeze:
- It results into lowering of temperature over the sea as cold air from the land blows towards the sea
- Formation of fog/misty conditions occurs over the sea as cold air from the land cools down the warm air over the sea leading to premature condensation as well as poor visibility
- Temperature inversion occurs over the sea as cold air from the land displaces warm air upwards over the sea
- Dense clouds and heavy offshore rainfall are experienced over the sea as warm air is displaced upwards to the condensation level
- It results into dry conditions on the land because little or no rainfall is received
- It results into violent thunderstorms over the sea which a hazard to fishing and transport

- It also causes high humidity over the sea/lake

D. **SEA BREEZE**

Sea breeze involves the movement of cool moist air from the sea towards the land. During the day, the land gets heated much faster than the sea creating a low pressure belt over land while the sea gets warmer at a slower rate creating a higher pressure. As such a cool ***sea breeze*** blows from the sea (high pressure) to the land (low pressure) to replace the rising warm air.



Effects of a Sea Breeze:
- It lowers temperature on the land especially in the afternoons as cool air from the sea replaces the rising warm air
- It is associated with onshore convectional rainfall which is normally received in the early morning and afternoon hours
- It causes violent thunderstorms which are a hazard to fishing and transport
- It results into high humidity over the land
- Thick cloud cover is formed over the land
- It leads to the formation of fog/misty conditions on the land which results into poor visibility

Revision Questions
1. Examine the causes and effects of land and sea breezes in East Africa
2(a) What is atmospheric pressure?
(b) Examine the causes and effects of land and sea breezes in EA.

The movements of the wind also plays a major role in correcting the imbalances in radiational heating and cooling that occurs over Earth's surface. Our global wind system transports energy poleward to help maintain an energy balance. The global wind system also gives rise to the ocean currents, which are another significant factor in equalizing the energy imbalance. Thus, without winds and their associated ocean currents, the equatorial regions would get hotter and the polar regions colder through time. Winds also transport water vapor from the air above bodies of water, where it has evaporated, to land surfaces, where it condenses and precipitates. This allows greater precipitation over land surfaces than could otherwise occur. In addition, winds exert influence on the rate of evaporation itself. Furthermore, natural sources such as wind become increasingly attractive alternatives to fossil fuels. They are clean, abundant, and renewable.

HUMIDITY

Humidity refers to the amount of water vapour in the air. Humidity varies greatly from place to place at different times of day usually ranging between 48% and 80%. Atmospheric water vapour is as a result of evaporation and transpiration. Air absorbs water through the process of evaporation and transpiration which result in water changing from liquid to gaseous state, hence water vapor is formed. Water vapour is significant in the atmosphere because;
- It influences the formation of rainfall through condensation
- It regulates the temperature of the atmosphere through absorbing radiation i.e. solar and terrestrial radiation
- It stores energy in the atmosphere

The humidity of a place can be described as follows:
(a) **Absolute Humidity**:
This is the ***actual amount of water vapour in a given volume of air at a particular temperature***. Absolute humidity varies according to temperature and pressure. When air temperature reduces,

water vapour condenses consequently lowering the humidity and when temperature rises, air is capable of holding more water vapour leading to high humidity. When air can hold no more water it is said to be ***saturated***.

(b) **Relative Humidity:**

This is the ***ratio between the absolute humidity of a given mass of air and the maximum amount of water vapor that it could hold at the same temperature***. **OR** the ***ratio between the actual amount of water vapor and the total amount the air can hold at a given temperature, expressed as a percentage.*** When relative humidity is high the air is moist and when it is low, the air is dry.

$$Relative\ humidity = \frac{\text{Actual amount of water vapour in a given volume of air}}{\text{Saturated water vapour content}} \times 100$$

OR

$$Relative\ humidity\ = \frac{\text{Absolute humidity}}{\text{Saturated water vapour content}} \times 100$$

Example:

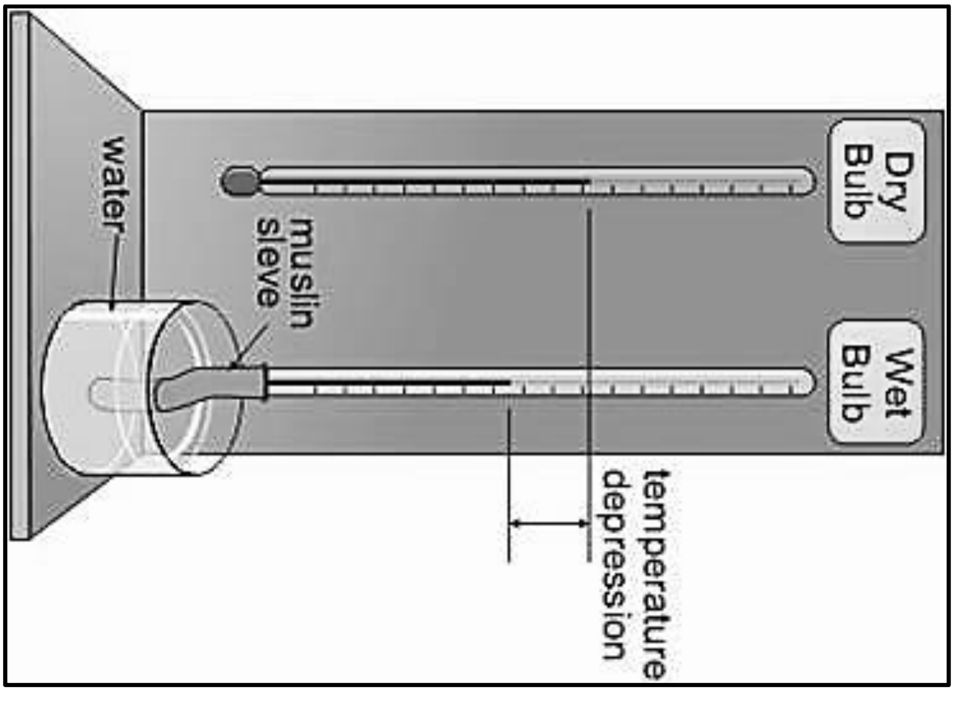
If saturated air at 40^0 C contains $40g/m^3$ of water vapour per $1m^3$, at a time of measurement the volume of air contains $20g/m^3$. Calculate the relative humidity.

$$Relative\ humidity\ = \frac{\text{Absolute humidity}}{\text{Saturated water vapour content}} \times 100$$

$= \frac{20}{40} \times\ 100$ Relative humidity = 50%

Measuring Humidity at the Weather Station

Two ordinary thermometers, called a ***hygrometer*** are used to measure the humidity, and both are kept in the Stevenson Screen. One thermometer has its bulb wrapped in thin muslin (or a wick), that dips in a container with distilled water. This is known as the ***wet bulb thermometer***. The other thermometer has no muslin and is known as the ***dry bulb thermometer***. When the air is not saturated, water evaporates from the muslin and this cools the bulb of the wet thermometer causing its mercury to contract. The bulb of the dry thermometer is not affected in the same way, so the two thermometers show different readings, i.e. the wet bulb thermometer shows a lower reading. The difference between the readings is used to calculate the relative humidity by using a set of prepared tables. Normally a large difference indicates a low relative humidity, a small difference shows a high relative humidity and if both have the same readings or no difference relative humidity is 100%, i.e. the air is saturated.



Factors which influence the humidity of a place

▪ **Temperature**

Temperature controls or determines the rate of evaporation and transpiration. Hot temperatures lead to high rates of evaporation hence increasing the amount of water vapour in the atmosphere while cool temperatures reduce evaporation rates resulting into minimum condensation hence lowering the humidity of a place.

▪ **Altitude**

Since temperatures decrease with increase in altitude, high altitude areas like mountain tops experience low humidity as water vapour condenses while areas of low altitude like the coastal areas of EA and the rift valley regions experience hot temperatures which encourage high evaporation rates leading to high humidity.

▪ **Water bodies** such as lakes and oceans are sources of water vapour through evaporation. Areas near water bodies therefore experience high amounts of water vapour and hence high humidity e.g. around the Lake Victoria basin and the coastal areas compared to areas far away from water bodies e.g. North eastern Uganda (Karamoja region) and North western Kenya (Turkana land)

▪ **Vegetation cover**

Areas with thick vegetation cover such as forests experience high rates of evapo-transpiration resulting in high humidity than areas with scanty vegetation such as scrub, thickets and steppe savannah which experience minimum evapotranspiration and therefore low humidity.

▪ **Inter Tropical Convergence Zone (I.T.C.Z)**

The apparent movement of the sun leads to variations in humidity between the northern and southern hemisphere. When the sun is overhead in the north, hot temperatures are experienced leading to high humidity in the north and low humidity over the south while the south experiences high humidity than the north when the sun is overhead in the south. The equatorial region however experiences uniformly hot temperatures throughout the year thereby leading to high humidity throughout the year.

▪ **Continentality or Distance from the sea**

Areas near the coast experience high humidity because of the effect of the land and sea breezes while the areas far away from the coast experience low humidity due to the absence of land and sea breezes. Coastal areas also experience low humidity due to the effect of warm ocean currents which transfer warm temperatures towards the land masses leading to high evaporation.

▪ **Influence of ocean currents**

Warm ocean currents raise the temperature of the winds blowing over them hence resulting into high humidity while cold ocean currents have a cooling effect on the winds blowing over them leading to low humidity. The high humidity experienced along the EA coast is therefore as a result of the influence of the warm Mozambique current.

▪ **Prevailing winds**

Winds have the ability to transport moisture from place to place thus influencing the amount of water vapor in a given place. Moist winds such as the South east trade winds cause high humidity in the areas over which they blow e.g. the EA coastal areas and the Lake Victoria basin. However, dry winds with less moisture cause low humidity in the areas over which they blow e.g. the North east trade winds are responsible for the low humidity in Karamoja in North eastern Uganda and in the Turkana land in north western Kenya.

▪ **Relief**

Highland areas tend to have high humidity on the windward side because of the ascending moist winds e.g. on the windward slopes of Mt Rwenzori, there's high humidity than on the leeward side.

▪ **Human activities** such afforestation, re-afforestation and agroforestry encourage high rates of evapotranspiration resulting into high amounts of water vapour in the atmosphere hence high humidity while activities like bush burning, overgrazing, deforestation and swamp reclamation lead to reduced evapotranspiration and hence low humidity.

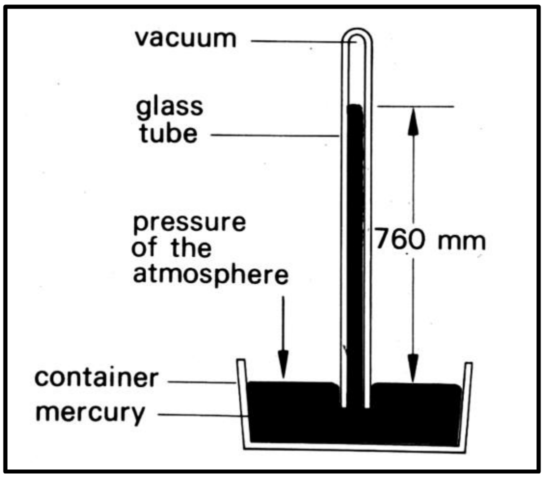
Revision Questions:
1(a) Distinguish between absolute humidity and relative humidity.
(b) Account for the variations in the humidity experienced in EA.
2(a) Explain what is meant by relative humidity.
(b) Discuss the factors that influence the humidity of a place.

ATMOSPHERIC PRESSURE

This is the ***weight (force) of the air exerted per unit area on the earth's surface***. Air is made up of a number of mixed gases and has weight and therefore exerts pressure on the earth surface which varies from place to place and from time to time. Atmospheric pressure is important because variation in pressure within the Earth–atmosphere system creates our atmospheric circulation and thus plays a major role in determining our weather and climate.

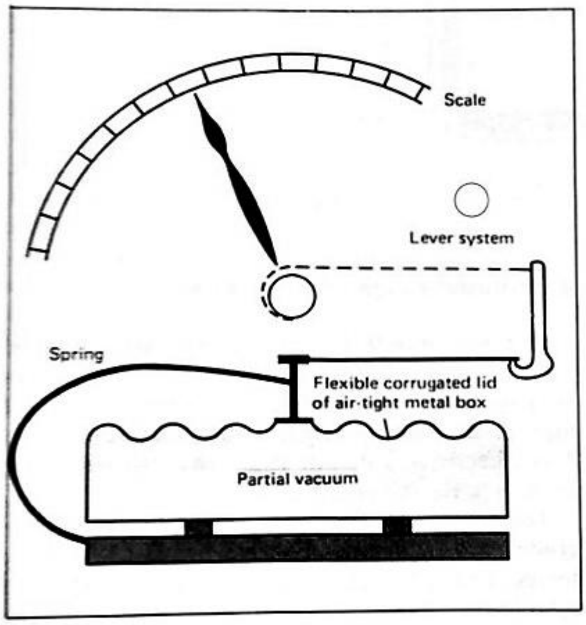
Measuring Atmospheric Pressure

Pressure is measured and recorded in units known as ***millibars (mb)*** using a ***mercury barometer*** or an ***aneroid barometer***. A mercury barometer consists of a long glass tube which is inverted in a bowl of mercury, whose surface is exposed to the air. Variations in the atmospheric pressure on the mercury surface are balanced by the column of mercury in the glass tube. This gives the pressure of air and can be read off quickly from the scale on the glass tube. The glass tube is marked in mm as illustrated below:

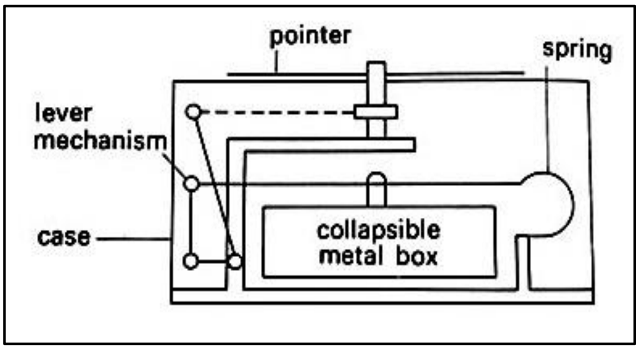


Air has weight and therefore exerts pressure on the earth's surface. A rise in atmospheric pressure caused by air pressure over the surface forces the mercury to rise in a glass tube. When atmospheric pressure falls, mercury is forced to flow out of the glass tube and the mercury column in the glass tube falls. Atmospheric pressure is measured by looking at the column of mercury supported in the glass tube. The pressure of the air on the mercury in the container supports a column of mercury about 760 mm high. When air pressure decreases, as less air presses on the surface, the mercury column in the glass tube drops and when air pressure increases, the mercury column in the glass tube rises. The recorded mean pressure values are used in tables, maps and charts. On maps places of equal pressure are joined by lines called ***isobars***.

An aneroid barometer comprises of a small metal container with most of the air driven out to form almost a vacuum. As there's practically no pressure at all inside the box, any increase in pressure on the outside of the box will cause the top of the box to bend in hence registering high pressure by the indicator on the revolving dial or a graduated scale. When there's a decrease in pressure, the lid springs outwards registering or recording (indicating) low pressure by the indicator on the revolving dial.



Aneroid barometer which measures air pressure



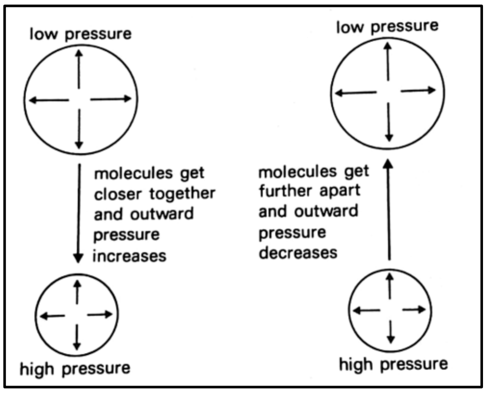
Section through aneroid barometer

NOTE:
For continuous record of pressure changes, as is sometimes required, the self-recording ***barogram*** is used.

Factors Influencing Atmospheric Pressure

(a) **Temperature**
There's an inverse relationship between the temperature and atmospheric pressure of a place. Hot temperatures lead to low pressure while cold temperatures lead to high atmospheric pressure. When air is heated, the air molecules expand and become less dense then air rises, hence there is less air near the surface resulting in low pressure. When temperatures are cool or cold air molecules contract and condense, i.e. decrease in volume and increase in density, causing air to sink and pressure to increase. For that matter, Polar Regions are high pressure zones while equatorial areas are low pressure belts.
NOTE:
Warm air = lighter and rises = less density = lower pressure.
Cold air = weighs more and sinks = higher density = higher pressure.

(b) **Altitude**
Atmospheric pressure decreases with an increase in altitude. As one moves upward from sea level leaving behind the heavy gases at lower layers of atmosphere, air pressure decreases because the upper air is light and its density is low. Thus in highland areas pressure tends to be generally low because there is less air at a high altitude, and the air is rarefied (has less impurities) and is less dense so pressure is less or low. Low altitude areas such as foot hills and sea level on the other hand experience high pressure because the air near the ground supports a greater weight of air above it, hence the air molecules at sea level push outwards with a force equal to that exerted by the air above it. Also its due to the high concentration of air impurities like dust particles and carbon dioxide at the low altitudes making air dense thus exerting a high pressure.



NOTE:
Higher altitude = less impurities = less air pressing down = lower pressure.
Lower altitude = more impurities = more air pressing down = higher pressure.

(c) **Rotation of the earth**
As the earth rotates, air at the poles (North and South poles) is blown/thrown away towards the equator. It crosses parallels which are getting longer. The cold dense air at the poles crosses from the high latitudes towards the equator spreading over a wide area leading to low pressure as it expands thus pressure falls. This accounts for the low pressure at the equator. On the other hand, air rising at the equator spreads out as it moves towards the poles. It crosses parallels which are getting shorter and it has to occupy less space thus it contracts and its pressure rises. This accounts for the high pressure at the horse latitudes.

(d) **Latitudinal location**
Air pressure tends to increase away from the Equator towards the Polar Regions. The equatorial region experiences low air pressure because of the intense or high insolation (heat) from the overhead sun and hot temperatures causing air to expand hence low pressure (doldrums) develops while Polar Regions which experience a low intensity of insolation and low temperatures which cause the air to contract thus high pressure.

(e) **Nature of the earth's surface**
Land and water surfaces experience varying air pressure because of differences in the rate of heating and cooling. This however affects atmospheric pressure at a local scale. During the day, land surfaces absorb heat faster than water surfaces leading to low pressure over the land and high pressure over the sea. Conversely at night, low pressure develops over the sea and high pressure over the land because the land surface cools faster than the water surface.

(f) **Amount of water vapour in the atmosphere (Humidity)**
Moist air is cold and dense hence it exerts high pressure on the earth's surface while dry air with little or no moisture is warm and light (less dense) hence exerting low pressure on the earth's surface.

Water vapors are light in weight therefore they rise up and pressure of humid air decreases as compared to dry air.
Moist air = reduced air density = lower barometric pressure.
Dry air = increased air density = higher barometric pressure.

(g) **Apparent movement of the sun (Influence of the I.T.C.Z)**
Low pressure belts shift with the apparent movement of the overhead sun. When the sun is overhead the northern hemisphere (Tropic of Cancer) in June – July, hot temperatures are experienced in the north leading to low pressure and high pressure over the southern hemisphere. In December – January when the sun is overhead in the southern hemisphere (Tropic of Capricorn), temperatures rise and low pressure develops over the south while the north develops high pressure.

Revision Questions:
1(a) Describe how atmospheric pressure is measured and recorded at a weather station.
(b) Explain the factors that influence the atmospheric pressure of a place.

ATMOSPHERIC STABILITY AND INSTABILITY

Stability in the atmosphere refers to a state of equilibrium reached in the atmosphere when a mass of ascending dry air has a lapse rate that is greater than that of the surrounding air i.e. the dry adiabatic lapse rate of the ascending air mass is higher than the environmental lapse rate. The rising air mass becomes colder than the surrounding air at a certain height then it becomes denser and descends/sinks thus causing atmospheric stability.

Instability is a state of unstable equilibrium of the atmosphere where the environmental lapse rate of an air mass is greater than the dry adiabatic lapse rate. A surface pocket of unsaturated air when heated, will rise and cool at the dry adiabatic lapse rate and because it is warmer than the surrounding air mass, it will continue to rise and expand. Due to the fact that the surrounding air is denser than the rising air mass, it will force it up to greater heights where it cools from. In other words, atmospheric instability is caused when the rate of cooling of rising air (dry adiabatic lapse rate) is lower than the normal lapse rate.

- High instability leads to the formation of cumulo-nimbus clouds, stratus and cirrus clouds. The strato-cumulus and cumulo-nimbus clouds are associated with intense rainfall and thunderstorms.
- The cirrus and stratus clouds give rise to clear skies/sunny weather conditions
- The alto-cumulus and alto-stratus clouds give rise to light drizzles and unstable windy conditions.
- High humidity is formed with in the atmosphere

Revision Questions:
1(a) Distinguish between stability and instability in the atmosphere.
(b) Explain the effects of atmospheric instability on the weather conditions of a place.

AIR MASSES

An air mass is a ***large body/volume of air in a horizontal direction with fairly uniform temperature and humidity, covering an extensive surface area***. Air masses can extend thousands of kilometers across the surface of the Earth, and can reach from ground level to the stratosphere—16 kilometers (10 miles) into the atmosphere. They play a crucial role in the formation of the weather and climate patterns that we attribute to different regions and countries throughout the year.

An air mass develops over an area which is extensive and uniform in build and shape, e.g. a desert surface such as the Sahara, or an ocean surface, with uniform temperatures and humidity, called ***source regions***. Thus, ***an air mass develops due to stagnation of air over a relatively uniform and extensive area thus taking on features of the source region, such as heat or cold***.

They also develop due to continued motion of the same air (air moving slowly) over the source region. This air is modified by the surface over which it moves thus altering its humidity, temperature and stability. Thus the air mass must have sufficient time to acquire the characteristics of the source region. The similar characteristics within an air mass are derived from the region where it forms (**source region**), and generally these characteristics are retained and transferred by the air mass when it moves to another region.
Thus for an air mass to develop the following conditions should prevail;
- There should be a large uniform surface, e.g. an ocean or desert
- There should be no change in weather conditions
- There should be relative constant temperatures

Types of Air Masses

Air masses are classified according to the latitude they originate and this determines their temperature and humidity characteristics. There are four main types of air masses namely polar (P), tropical (T), equatorial (E) and Arctic/Antarctica (A) air masses. Each of these types is sub-divided according to whether they form over the sea or land. Air masses that form over the sea are called ***maritime*** (m) while those that form over the land are called ***continental*** (c).

Polar air masses form near the sub-polar low pressure belts. These air masses are cool to cold, e.g. polar continental which is cold and dry, polar maritime which is cold and moist. Arctic and Antarctica air masses form over the ice sheets of Greenland and Antarctica respectively. They are very cold, dry and stable. Equatorial air masses form over equatorial oceans. They are hot, very moist and unstable. Tropical air masses form near the sub-tropical high pressure belts or tropics. They give rise to warm air masses like tropical maritime (SE trades) which are warm and moist, tropical continental (NE trades) which are hot and dry as well as the westerlies.

Characteristics of Air Masses
- They have uniform temperatures though out the air mass, e.g. warm tropical, cold polar, etc.
- They have uniform humidity throughout the entire air mass
- They have a definite source origin, e.g. the tropics, poles, etc.
- They blow from a high pressure to low pressure regions
- Air masses move at slow speed long enough to take on the features of the source region, such as heat or cold
- Air masses converge at fronts, namely cold and warm fronts
- Air masses modify the weather of the areas they blow either partially or completely
- Air masses can be maritime when they originate from oceans or continental when they blow over land surfaces.

Air masses which affect the climate of East Africa include:-
(a) Tropical maritime or south east trade winds. These originate from the Indian Ocean and blow on shore of the adjacent land masses. They lead to high humidity, modified (cool) temperature, cloudy conditions and heavy rainfall along the East African coast. They transverse mainland of Tanzania when they are hot and dry causing very hot temperatures less humidity, clear skies and dry conditions there. Over Lake Victoria they are recharged with moisture and deflected to the right at the equator thereby bringing conditions of high humidity, cloudy and wet conditions over the northern shores and north eastern shores of L. Victoria. However because of this deflection they blow off Ankole-Masaka dry conditions leading to low humidity, unreliable rainfall and clear skies.

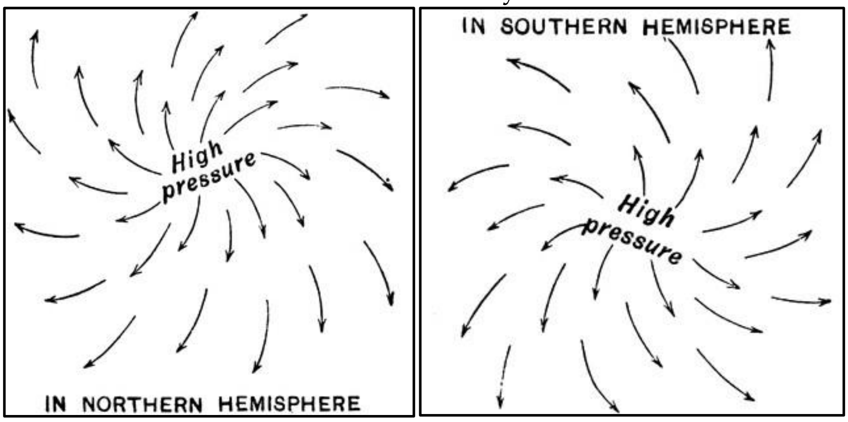
(b) North east trade winds
These originate from the Arabian Desert drop all their moisture on the leeward side of Ethiopian highland and on descending into northern Kenya, north western Kenya and north eastern Uganda they are dry and hot, causing conditions of very low humidity, clear skies and low/unreliable rainfall.
Often times, tropical maritime and the north east trade winds meet at the I.T.C.Z and in the process, the warm moist tropical air masses are forced to rise, thereby giving rise to cumulo nimbus clouds, light variable winds, frequent thunderstorms and cyclonic rainfall.

(c) Westerlies
These blow from Congo basin and they are warm and moist. During their east ward journey, they blow over western Uganda highlands bringing heavy rainfall, thick cloud cover, high humidity, modified temperatures. On descending the leeward side of, the western Uganda highlands the western are hot and dry which cause conditions of no clouds, no rainfall, very hot temperatures etc. in eastern Kasese and Ankole - Masaka dry corridor.

Revision Questions:
1(a) What is meant by an air mass?
(b) Describe the weather conditions associated with the meeting of air masses over the EA region.
2(a) Describe the characteristics of an air mass.
(b) Explain the formation of air masses.

ANTICYCLONE
This is an area of high pressure with a large-scale circulation of winds (air descends and converges). They develop when two air masses of great density meet at a front, causing a high pressure at the centre which later sets off diverging winds. When shown on a map, an anticyclone has an oval or circular shape of closed isobars. An anticyclone develops in a region where the air is

descending, and the winds associated with it blow outwards in a clockwise direction in the northern hemisphere, and an anti-clockwise direction in the southern hemisphere, i.e. it has diverging winds. The direction of the winds is caused by the rotation of the earth.



Characteristics of an Anticyclone
- They occur in areas of high pressure, i.e. pressure increases toward the centre due to cool environmental conditions
- They often remain stationary for long periods
- They tend to move very slowly
- They're associated with fine weather because of the light/gentle winds and clear skies due to divergence of cool dry winds
- They lead to dry conditions due to divergence of winds
- They bring about hot temperatures in summer and cold temperatures in winter
- Often they cover a large area, sometimes affecting a whole continent
- In the dry season they are associated with dry and dusty winds such as the harmattan winds that affect parts of West Africa
- Winds blow outwards away from the centre of high pressure
- In the northern hemisphere they blow outwards in a clockwise direction while they blow in an anti-clockwise direction in the southern hemisphere
- Anticyclonic conditions may last for days or weeks and then fade out quietly

CYCLONES/DEPRESSIONS ("AKAZIMU")

This is a large scale wind circulation around an area of low pressure. On a map they're shown with an oval or circular shape with closed isobars and lowest pressure at the centre. In a depression air circulates inwards or converge toward the center in an anti-clockwise direction in the northern hemisphere and a clockwise direction in the southern hemisphere, i.e. the winds blow towards the centre. Cyclones tend to form intense storms. Cyclones develop when two air masses meet, e.g. in temperate latitudes where humid tropical air meets cold polar air, i.e. in latitudes 60^0 N and 60^0 S. The zone where these two different air masses meet is called the polar front.

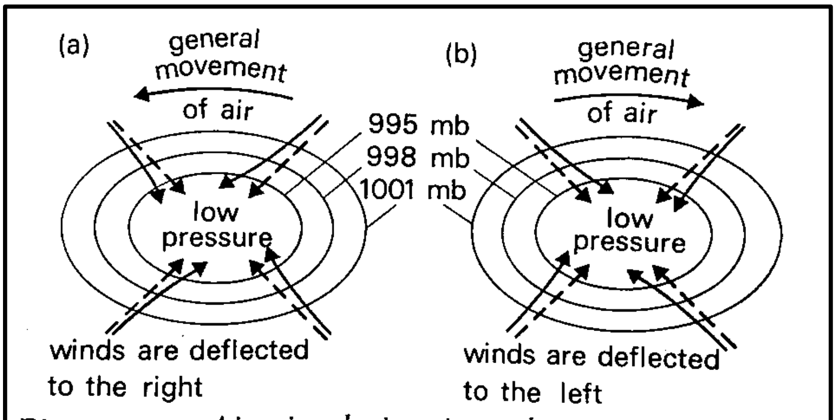
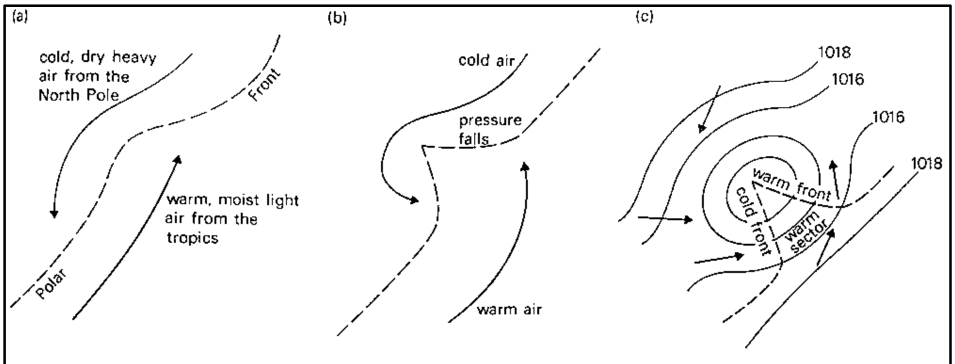


Fig. 15.22 Air circulation in a depression: (a) northern hemisphere; (b) southern hemisphere

Characteristics of Depressions or Cyclones
- They occur in areas of low pressure, i.e. pressure decreases toward the centre. This often due to warm environmental conditions
- Air circulation in a depression is anti-clockwise direction in the northern hemisphere and clockwise direction in the southern hemisphere
- Air circulates inwards or converges towards the centre in a depression due to low pressure at the centre
- They often develop in temperate latitudes 60^0 N and 60^0 S but sometimes also develop in the tropics/doldrums
- They're not stationary and move in a general easterly direction
- Some depressions are small while others are large
- Depressions are associated with severe weather usually with dense clouds or dark skies, strong winds and heavy rain. The rain is caused by uplifting of the warm, moist tropical air by the cold, drier polar air, i.e. they form cyclonic rainfall.
- Cold and warm fronts occur where the convergence of warm tropical air and cold polar air take place

How a depression/cyclone develops
Warm and cold air meet at a polar front. The frictional effects of the two contrasting air masses cause a wave-like kink or bend to develop in the front. At this bend warm air pushes poleward (a warm front) and cold air pushes equatorward (a cold front), with a centre of low pressure where the two fronts are joined. At the warm front, warm air rises up over the cold air at the front of the bulge/bend/kink and at the cold front, cold air forces its way under the warm air. As the depression advances warm temperatures and cloud cover develop as well as light to heavy rains. With the passage of the depression, the sky clears and cool temperatures prevail.



The development of a temperate depression.

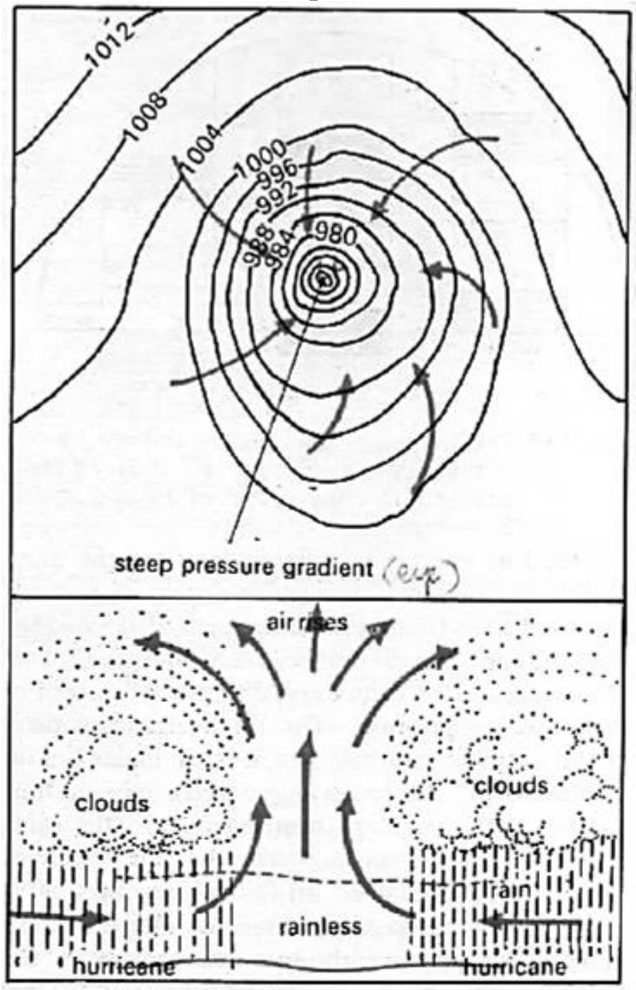
Types of cyclones
1. **Temperate (Mid-latitudes) cyclones**
These are low pressure cells which develop in the temperate regions as a result of polar winds from the Polar Regions meeting with the westerlies from the tropical high pressure latitude 30^0 N and S of the equator at the temperate low pressure latitude 60^0 which begin to swirl to create low pressure at the centre.

2. **Tropical cyclones/low latitude cyclones**
These are low pressure cells which form as a result of trade winds meeting at the doldrums or within the tropics swirling and creating low pressure at the centre.

TROPICAL CYCLONES
This is an intense, low pressure disturbance into which violent (strong and powerful) winds blow. Tropical cyclones occur in the tropics between latitude 5^0 and 20^0 north and south of the equator, particularly along the inter-tropical convergence zone (I.T.C.Z). They originate in tropical oceans, mainly on the eastern side of continents, between 50^0 and 20^0 north and south of the equator. Examples of tropical cyclones include typhoons that occur in Asia; hurricanes in the West Indies; tornadoes (***whirl-winds***) in the Guinea lands of West Africa and southern USA (***willy-willies*** in Australia). Tropical cyclones frequently occur in August and September in the northern hemisphere, and in February and march in the southern hemisphere.

Characteristics of tropical cyclones;
- They originate from within the tropical latitudes usually between 5^0 and 20^0 north and south of the equator
- They cover a diameter of between 80 and 400kms
- Are low pressure systems especially at the centre than the periphery
- Winds circulate towards the centre
- Circulation of winds is anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere
- Winds move at high speeds of about 200km/hr hence they tend to be destructive
- They're strong winds characterized by lightning and thunderstorms
- They develop over water especially large oceans and seas
- They have violent peripheries/vortices with strong winds, thunderstorms and cloudy conditions
- They originate from western sides of oceans and affect eastern sides of continents
- Cyclones tend to move in a western direction
- They usually occur between July and October within the northern hemisphere and January and April in the southern hemisphere
- They tend to be circular and mobile capable of moving from one area to another and later decay at landfall/coast
- The direction of movement is usually determined by wind direction

Conditions for the formation of Tropical Cyclones
The conditions which favour the formation and intensification of tropical cyclone storms are:
- Large sea surface with warm, moist air of temperature about 27° C
- There must be an outward flow of air in the upper level
- The air must be blowing inwards and rising rapidly to great heights to create clouds of great vertical extent with torrential/heavy rain
- Presence of the Coriolis force which deflects the path of the wind anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere

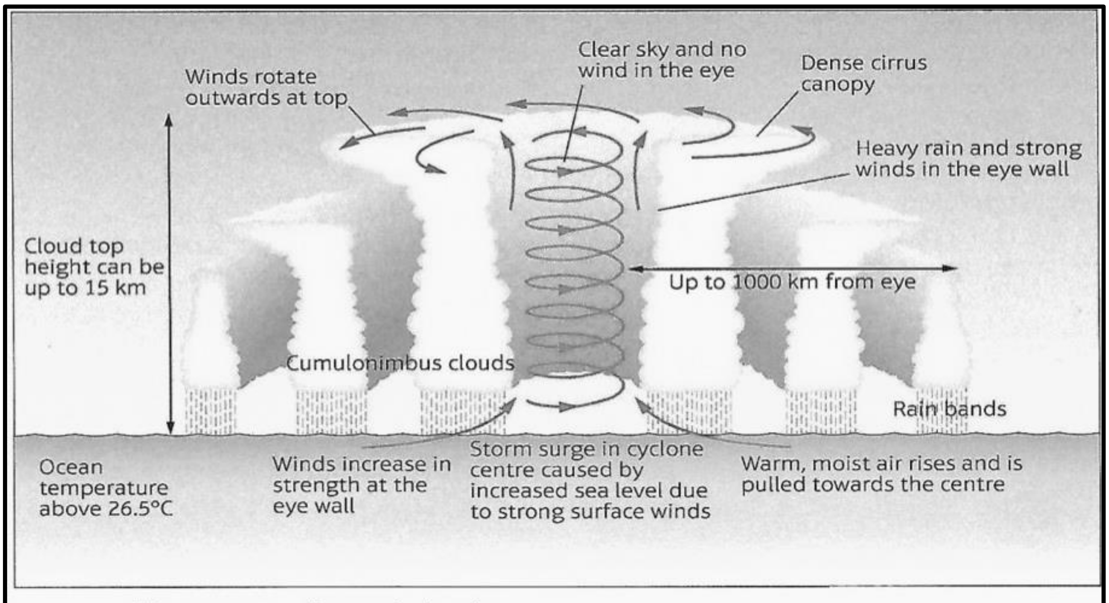


A tropical cyclone—a hurricane in the West Indies

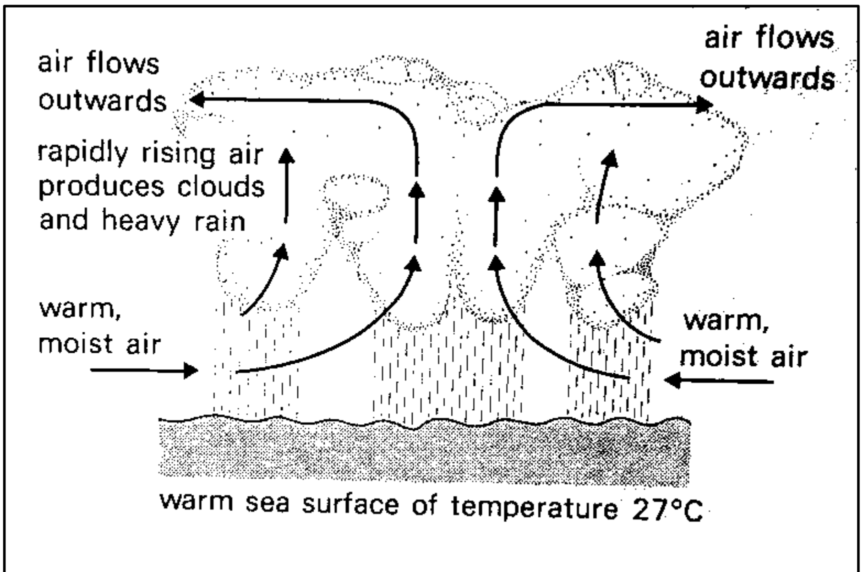
How tropical cyclones develop

Tropical cyclones develop where air masses brought by the northerly and southerly winds meet along the inter-tropical front (ITCZ). When the two air asses meet one is lifted up over the other. The rising air cools and its moisture condenses to produce heavy rainfall. Latent energy released through condensation of water vapor powers and strengthens the cyclone to rotate anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere. Tropical cyclones move in a generally westerly direction. On reaching land, they gradually die out because their supply of warm, moist air is cut off, and friction with the land surface reduces wind speeds.

In a tropical cyclone, strong winds spiral towards the centre, rushing upwards with great force in the area called the ***vortex*** which surrounds the centre or ***eye*** of the cyclone. The rapidly rising air gives rise to torrential rains and strong winds that cause extensive damage to buildings and vegetation.



The structure of a tropical cyclone



The structure of a tropical cyclone

The weather associated with a tropical cyclone

Tropical cyclones influence weather conditions such as pressure, humidity, rainfall and cloud cover. The weather conditions vary with vortices, i.e. those in the advance vortex may be similar to those in the rear vortex but in the eye of the storm they're different.

(a) Before the tropical cyclone arrives the air is calm and very still, temperature is hot, pressure and humidity are high.

(b) There are gusty winds and thick clouds as the front of the vortex of the arrives.

(c) There are violent winds, dense clouds and torrential rains as the vortex arrives.

(d) There is also reduced visibility.

Weather conditions in the advance vortex;
- There is decreasing pressure
- Increasing wind speeds averaging about 150 – 200km/hr
- Winds are also violent
- Dense clouds develop due to up-surging of humid winds that then condense into clouds
- There is heavy rainfall with lightning and thunderstorms
- Reduced visibility due to low dense cloud cover as well as stormy conditions
- Temperatures are hot hence the great evaporation and high humidity

Weather conditions in the eye of the storm;
- There are calm/light and still/stationary winds
- Temperatures are generally hot
- There are bright and dry conditions
- Skies are clear or cloudless

Weather conditions in the rear vortex;
- There is low but rising atmospheric pressure
- There are strong winds with high speeds between 120 – 200km/hr
- Winds are also marked by vertical instabilities, i.e. rising air currents
- There are thin dense clouds, i.e. it tends to be cloudy
- There is high humidity
- There is heavy rainfall with thunderstorms

Revision questions:
1(a) What is an anticyclone?
(b) Describe the weather characteristics associated with anticyclones.
2(a) What is a tropical cyclone?
(b) Describe the weather conditions associated with tropical cyclones.
3. Examine the causes and effects of tropical cyclones.
4(a) Distinguish between a cyclone and an anticyclone.
(b) With reference to specific examples, examine the effects of tropical cyclones on the areas where they occur.
5(a) Describe the characteristics of tropical cyclones
(b) Explain the weather conditions associated with tropical cyclones.
Approach
- Define tropical cyclones; identify location/areas where they occur; mention different names of tropical cyclones; describe characteristics of tropical cyclones
- Describe weather conditions associated with tropical cyclones in the different vortices, i.e. advance, rear & eye