CONTINENTAL DRIFTING

This refers to the large scale movement of land masses of the earth. The earth is made up of continents and ocean basins. It's is believed that continents have not always been fixed in one position but have moved (drifted) though time and are still moving (drifting).

Many theories have been put forward by different geographers to explain the origin of ocean basins and continents. These are collectively known as continental drift theories and they include:

1. Expanding earth theory
2. Taylor's theory of continental drifting
3. Wegner's theory of continental drift
4. The sea floor spreading theory
5. The plate tectonic theory.

1. THE EXPANDING EARTH THEORY

This theory is one of the earliest theories which suggest that the earth was much smaller and covered with a thin continent and crust at the surface. The earth's interior began to expand and the outer crust was forced to crack. It then separated crustal blocks (continents) and the widened gap in between becomes oceans. The reason why it expanded was that it grew older, it's gravitational force became weaker making its materials spread outward and expanded.

2. THE TAYLOR'S THEORY OF CONTINENTAL DRIFT

This was put forward by F. B Taylor in 1910. He described continental drift as huge landslides from the Polar Regions to the equator. According to Taylor, there were originally two land masses called Laurasia near the present day North Pole and the other was the Gondwanaland located near the South Pole. He said that the moon came closer to the earth and exerted a very powerful gravitational force which pulled these land masses from the Polar. Laurasia moved south wards and Gondwanaland moved north wards towards the equator. When the two collided, the sediments in between led to the formation of the Alps and the Atlas Mountain. These two i.e. the Laurasia and Gondwanaland dropped further to form the various present day continents.

Illustration

The theory was critised because of the following;

However, this is highly doubtable that the two super continents cannot move due to gravitational pull of the moon.

He also failed to explain the formation of the earliest fold mountains which were former before the collision of the two super continents.

The causes of continental drifting should have come from the interior of the earth and not like it did happen like Taylor's explanation.

3. WEGNER'S THEORY OF CONTINENTAL DRIFTING

In 1915, Alfred Wegner published a book entitled "the origin of continents and ocean basins". In his book, he argued that continents have changed from their original positions. According to his theory of continental drifting, the present day continents originated from one landmass known as a **Pangaea**.

The Pangaea is said to have been positioned to somewhere near the South Pole and it was surrounded by a large expanse of water known as Panthalassa.

The landmass was split into two super continents namely Laurasia and Gondwanaland. The two super continents were separated by a body of water known as the sea of Tethys. Wegner believed that the Laurasia crossed the equator while Gondwanaland remained near the South Pole.

According to him, during the late palaceozoic and early Mesozoic periods, numerous cracks started to develop on those two super continents which later led to their separation and subsequent drifting.

The Laurasia gave birth to North America, Europe, Asia, and other landmasses in the northern hemisphere like Greenland and UK.

Gondwanaland after its break up gave birth to the present continents of South America, Africa, Australia, and even Indian sub continents which later collided with Asian landmasses.

Wegner asserted that each piece drifted apart like solid vasts of land. The gaps which remained after the separation of the continental blocks were filled with water to promote to form ocean basins or water bodies.

Illustration

4. Hess' theory of sea floor spreading

This is one of the modern theories that explain the force behind the drifting of continents. It was put forward by an American geologist called Hess.

He asserted that the earth's mantle behaves like a giant convective current system. The materials which were heated by the radioactive elements in the interior slowly rise in the atmosphere (crust) lifting the plastic rock zone into the lithosphere.

The molten material (magma) reaches the earth's surface along the mid ocean ridge and flow away then cooling and hardening as new lava emerges out of the ridge and attaches its self on the solidified lava plates (continental blocks) and then force them to move alongside or sideways thus drifting or movement of the continental blocks. The gaps which remained behind formed the oceans after being filled with water. It can be illustrated as below.

5. The plate tectonic theory.

What is meant by the term plate tectonics?

How does the theory of plate tectonics explain the present day distribution of continents and ocean basins?

Plate tectonics is a theory that was pout forward to explain the present distribution of continents, oceans basins and resultant landforms.

The theory assumes that the crust is divided into a number of divisions called tectonic plates i.e. six major plates, 12 minor plates and other many smaller plates. These plates are rigid and mobile. The force that drives them is derived from the radioactivity that is generated by the heat within the core of the earth.

The plates may move away or sideways along adjacent blocks or plates creating plate boundaries forming different types of boundaries i.e. divergent, convergent and transform boundaries.

Plate tectonics and present day distribution of continents.

Plate tectonics theory came up as a result of I investigating about the Hess' theory of sea floor spreading. The sea floor spreading showed that parts of the crust were being destroyed for instance along the edges of the pacific plate.

The theory assumes that the crusts is divided into 6 major plates i.e. the African plate, Indian plate/ Indo-Australian plate, pacific plate, Eurasian plate Antarctica plate, 12 minor plates and other smaller plates.

The theory of plate tectonics describes the current distribution of continents and ocean basins with the greatest part of the continents in the northern hemisphere compared to the southern hemisphere.

The theory pre-supposes that plates generally move northwards, others like American plate move west wards while Africa Europe, Asia, Australia are moving north east wards

Geo-chemical, radioactivity and geo-physical reactions generate the heat that melts the rocks giving rise to convection currents which drive the plates.

As plates move, so do continents following the direction of the plate movement.

There are three types of movements caused by convectional currents that affect the distribution of continents.

a. **Divergent boundary**. This is said to exist when plates are moving away from each other. This means that in the process of movement, ocean basins characterized by mid ocean ridges and islands are formed for example the mid-Atlantic ridge was formed as the southern America plate moved away from the African plate.
   Illustration

b. **Convergent boundary.** The convergent boundary on the other hand occurs when the plates move and converge. When plates move close to each other, sediments are folded to form fold mountains or ranges e.g. when India moved towards Asia, they formed the Himalayas.

   Continents may also move towards each other causing subduction of the denser plates. This is assimilated to the mantle forming trenches e.g. south American plate moved against the Nazca plate forming the Nazca trench.

   In the process of converging, plates may move towards each other and in the process, trenches and arches are formed e.g. the pacific plate and the Eurasian plate have led to the formation of Mariana trench and the Japan arch.
   Illustration

c. **Transform boundary**. In the transform boundary, one plate moved passed the other and slowly descended in the interior where it slowly became heated and eventually assimilated into the surrounding.

Evidences to justify the movement of continents.

Alfred Wegener gathered a pile of evidences in trying to justify or prove the drifting or movement of continents. These evidences include the following.

Visual fit (jig saw fit). The first proof which shows that continents are constantly moving away from each other is the visual fit of continental coastlines with one another. The eastern coast of south America and west Africa are so related in shape that it seems obvious that the two continents once fitted together like a piece of jig saw but just separated.

Matching geology. The same geological rock structure exists on both sides of the continents for instance rocks between West Africa and South America have a got a convincing matching geology like along the parts of North Eastern Brazilian coast, South Eastern Nigeria and Cameroon and Accra in West Africa and Sao Luis in Brazil. This shows that they were part of the same landmass before breaking up.

illustration

similar geology. Oil beds of brazil are similar to those of Angola.

Matching organic belts. This is an alignment of belts of fold mountains. This is because the fold ranges of Falkland of Argentina are similar in age and structure to those of south west cape of south Africa. This clearly implies that the two continents were once together.

Lateritic evidence. Lateritic soils form under tropical climates (high rainfall and high temperatures). However, these lateritic soils are unbelievably found in the temperate regions of north America, Britain and parts of Russia. This is an evidence that by the time these laterites were formed, such areas were in the tropics and hence have since then drifted into the temperate regions.

Coral evidence. Like lateritic soils, coral reefs only grow in tropical waters. Coral polyps only survive in water whose temperatures are as high as 20^0C. It's amazing however to find these coral reefs in the temperate areas of Greenland, oxford England and other temperate areas. So this is a clear evidence that coral reefs formed in tropical areas with high temperatures but just drifted away from the tropics to the temperate regions.

Saul salt evaporates. Like lateritic soils and coral reefs, salt evaporates only form in hot climates. To the amusement of most geographers however, these salt evaporates are found in large quantities in areas like north America, Britain and on the foothills of Ural Mountains of Russia. These salt evaporates are believed to have been in the tropics and when drifting took place, salt evaporates went to such areas.

Similarity in flora and fauna. The Brazilian coast of south America and the coast of west Africa have animal and plant life which are similar particularly with forests in Congo and Gabon i.e. similar plant life and tree species and animal life.

Occurrence of similar fossils. Evidences from fossils are good indicators of continental drifting. Fossils' structures of the same land animals and plants have been found in all southern continents in rocks dating about 250 million years ago for example a fern like plant and animal resembling a crocodile, their remains have been found in India, south America, Australia and Africa. This indicates that before drifting, these continents were once together as one block.

The proximity or nearness of the continental blocks near the north pole than in the south pole is a clear evidence that continents are still moving northwards.

The extension of Sahara Desert southwards indicates that Africa as a plate is still moving northwards.

Effects of continental drift on relief and landforms.

The forces of continental drift together with convergent and divergent boundaries have resulted into formation of structures and features like the great east African rift valley, block mountains, volcanic mountains, basins which hold water e.g. Lake Victoria due to warping and others associated to volcanicity etc.

In that sense, continental drift is directly or indirectly related to various processes which have resulted into various landforms.

LANDFORM EVOLUTION OR DEVELOPMENT IN EAST AFRICA (EARTH MOVEMENTS)

The term earth movements refer to all crustal disturbances of endogenic origin. Therefore, earth movements include volcanicity, faulting, folding, crustal warping and earth quakes.

Other terms used under earth movements are; diastrophism, tectonism, plate tectonism, tectonic movements, endogenic processes, geo-chemical reactions, radioactive elements etc.

The origin of earth movements are the convectional currents in the earth's interior. Whenever convection currents are generated in the mantle, they rise upwards towards the crust. The rising causes epinogenic forces (uplifts) which results into slow but large scale uplifts within the crust. After reaching in contact with the colder earth crust, they move laterally in opposite direction thereby stretching the crust at the point of divergence. This stretching causes the crust to fracture and at times displaced due to generated tensional forces. This fracturing is called **faulting**.

At the point where convectional currents meet and sink back into the earth's interior, compression forces are generated which push continental plates together. This results into **folding** of the crust.

The faults (lines of weakness) created may lead to the escape of hot magma from the mantle and this process is called **volcanicity.**

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

Sometimes the earth's crust has got denser plates (simatic plates) and lighter plates (sialic plates). The simatic plates are forced to sink thus causing crustal warping.

Faulting

Faulting refers to the breaking of rocks within the earth's crust. It's also involves displacement of rocks on either side of the fracture or fault.

Therefore, faulting refers to the fracturing, breaking and displacement of rocks on either sides of the fracture.

Faulting may cause uplifts or subsidence or horizontal displacement of rocks on either sides of the fracture. Faulting results into several landforms in East Africa like the rift valley, block mountains, fault scarps, fault guided valleys, tilt blocks, grabens among others.

Types of faults.

Normal faults.

A normal fault is formed when crustal blocks are stretched by tensional forces. In other words, these are faults which develop at a divergent boundary where tensional forces are generated stretching the overlying earth's crust.

It can be illustrated as below.

Reverse faults

A reverse fault is formed due to the influence of compressional forces. These are produced by compressional forces. As the crust is being compressed, time will come when one block will override the other.

Illustration.

Tear fault

Tear faults are caused by forces operating parallel to each other in opposite direction.

Illustration.

Effects of faulting on landform evolution in east Africa.

A block mountain.

A block mountain refers to an upland bordered by faults on one or both sides. It has a level summit and stands above the general level of the surrounding land. Its formed as a result of uplifting forces along lines of weaknesses or faults.

Block mountains maybe formed with one scarp or more. For a horst mountain to form, the blocks of the earth's crust may have moved in the following ways;

a. **Differential uplift.**

In this way, three blocks were forced to rise but the middle block rose faster than the outer blocks. The faster moving blocks (middle block) then became the peak of the horst.

It can be illustrated as below.

b. **Differential subsidence.**

In differential subsidence, three blocks may subside but the outer two blocks subside faster than the middle block. The middle block remains behind at a higher elevation than the outer two blocks. The middle block then forms the peak of the horst. It can be illustrated as below.

Examples of block mountains include Rwenzori in Uganda, Usamabara, Urunguru, Ufipa in Tanzania among others.

A tilt block.

This is a steep block where land falls from a higher elevation to a lower elevation. Its formed when one side is uplifted higher than the other side. When tilting occurs, the slope top of the middle block will not be flat but inclined or tilted. The middle block then becomes the tilt block. Such landscapes are composed of angular ridges for example the Usamabara tilt blocks in Tanzania.

Illustration

The rift valley.

A rift valley is an elongated depression bordered by in-facing scarps or escarpments. A good example is the great East African rift valley which forms a series of rift valleys by different forces extending for about 7200 km. this rift valley is divided into four sections i.e.

I. The Ethiopian section which stops at lake Turkana.
II. The eastern rift valley which extends through Kenya
III. The Malawian section between Malawi and Zambia.
IV. Western rift valley covering western Uganda and Tanzania.

The width of the rift valley varies from place to place with some areas extending for about 60 km in width and its depth or height also varies from place to place.

The formation of a rift valley is mainly due to compressional forces, tensional forces, differential uplift or differential subsidence.

Tension force theory.

These develop with forces pulling in opposite directions, cracks or the lines of weakness then developing leading to the formation of the normal faults. The middle block is then separated from the outer two blocks. The loose heavy middle block sinks downwards displacing the underlying rocks further below in the interior. This leaves a depression behind on the earth's surface which is called a rift valley. It can be illustrated as below.

Compressional force theory.

This is the stress in the earth's surface which develops when forces are pushing towards each other. Compression sometimes forces the side block to override the central block. The fault scarps are then smoothened by erosion and a wide rift valley is formed. It can be illustrated as below.

Differential uplift theory.

Under this theory, three blocks were forced to rise but the outer two blocks rose faster than the middle block. As the outer blocks rise at a higher speed, they gradually form a high edge of a depression called a rift valley. It can be illustrated as below.

A fault scarp or an escarpment.

A fault scarp is an inward facing of a rift valley. It is a steep slope caused by vertical earth movements along a fault. Examples include Songwe fault scarp in Rukwa valley in Tanzania, Ufipa, Manyala, Buhati fault scarp near Nakuru Valley, Mau fault scarps, Nandi fault scarps, Butiaba around lake Albert, Bunyaruguru scarps among others. A fault scarp can be illustrated as below.

A fault line scarp.

By contrast, a fault line scarp is a steep slope whose original profile has been modified by denudation processes. It does not therefore look like the original fault scarp. It can be illustrated as below.

A graben or rift valley lake.

Further faulting within a rift valley may create a rift valley basin. This occurs when the land on the rift valley floor is further acted upon by secondary or further faulting i.e. the rift valley floor is faulted lower than the surrounding parts and there after it forms a depression known as a graben. A graben is a result of secondary faulting or further faulting within the rift valley floor. These depressions are usually deep, steep sided, elongated and narrow. In east Africa, these depressions have been filled with water to form rift valley lakes for example lake albert, Tanganyika, Malawi, among others. It can be illustrated as below.

Fault guided valleys.

In east Africa, faulting has led to the formation of fault guided valleys. As faulting takes place, rocks are displaced and shuttered and therefore relatively weakened than the adjacent ones which are not similarly affected. Weathering and erosion may take advantage of these lines of weaknesses. A river may flow along the line of weakness or along the fault curving out a valley. This valley normally flows following the nature of the fault line. An example is river Aswa in Acholi land in northern Uganda which evolved in this way, Kerio valley between Elegeyo escarpment and Kamasiya ridge in Kenya. It can be illustrated as below,

Influence of faulting on drainage.

Drainage refers to all surface water like lakes, rivers, swamps etc. in many parts of east Africa. Faulting has had a great significance on the flowing rivers and on the drainage systems as seen below.

Vertical faulting across a river valley may cause the occurrence of water falls, rapids and other related features such as plunge pools. A water fall is a sharp break in the channel gradient over which water flows. Examples in east Africa include the Murchision falls, kisizi falls etc. it can be illustrated as below.

Faulting has resulted into the formation of grabens or rift valley lakes. Grabens develop with in the rift valley floor after secondary or further faulting on the rift valley floor. When the resultant depression is filled with water, it then forms a rift valley lake. This has therefore accounted for water surfaces like lake Edward, albert, Tanganyika, Malawi, Turkana among others. These lakes are usually elongated, deep, narrow and steep sided. It can be illustrated as below.

Faulting has also led to the development of fault guided river valleys for example river Aswa in Acholi land in northern Uganda. During faulting, the faulted zones became more prone to weathering and erosion. A valley was curved out following the fault line in which a river passed leading to the formation of a fault guided river valley. It can be illustrated as below.

Horizontal or lateral displacement of tear faulting across a river may cause a river to be offset at the point it crosses a fault as shown below.

Faulting has also resulted into the formation of tilt block lakes. A tilt block is a steep slope where land falls from a higher elevation to a lower elevation. Its formed when one side of the fault is uplifted higher than the other. When tilting occurs, the top part of the block will not be flat but instead inclined or tilted. The middle block then becomes a tilt block. The depression may be filled with water to form a tilt block lake for example lake olbolsat.

Illustration

Faulting has also indirectly affected water surfaces through creation of block mountains. These mountains experience frequent orographic rainfall and are sources of rivers. Block mountains are characterized by radial drainage whose subsequent streams also develop dendritic patterns for example on mountain Rwenzori rivers like Mubuku, Mpanga, Sebwe, Nyamwamba among others are radiating from its top creating radial drainage system and as they flow downstream, their subsequent streams have resulted into dendritic drainage patterns or systems for example river Nyamwamba

Faulting in conjunction with warping, resulted into the formation of open enclosed basins e.g. Lake Victoria and Kyoga which were as a result of these processes. After the formation of the Victoria basin by down warping, the rivers that were flowing westwards into the Congo basin for example Kagera and Katonga all were reversed into the basin forming Lake Victoria.

The up thrust in western Uganda led to the formation to the formation of Rwenzori mountains and it was followed by a slight up thrust in the east making the rivers that were flowing east wards to also flow back into the basin. These included river Mara, Nzoia eventually leading to the formation of Lake Victoria and kyoga.

Today much of Lake Victoria is a vast shallow depression of papyrus swamps and its peculiar outline is due to river kafu being forced to flow back into its own valley and tributaries. Therefore, it's important to rule that crustal warping (up warping) across a river valley will gradually force a river to reverse its direction of flow and run back if its unable to maintain its original flow.

It can be illustrated as below.

Importance of faulting to man.

(research)

FOLDING

A fold is a geographical structure in which beds of rocks are bent. Folding is therefore a process through which rocks are forced to bend hence developing undulations or undulating structures. Rocks that fold are normally geologically young and compressible.

Folding principally produces two structures i.e. anticlines and synclines.

Illustration

Types of folds

Simple folds / symmetrical folds. These are folds produced by gentle compression that causes the rock strata to develop simple crests and synclines that are similar and uniform.

Asymmetrical folds. These are folds produced by an increase in the degree of compression and particularly when the pressure on one side is greater than the pressure on the other side. Hence one crest is steeper than the other. In other words, they are asymmetrical or not uniform.

Over folds. These are produced when the degree of compression is very high due to high pressure such that the land folds so much that the crest is pushed over the other syncline.

Over thrust fold. These are produced when the degree of compression is so intense that folding occurs in the overriding crests.

EARTH QUAKES

An earth quake is a rapid movement and adjustment of the land within the rocks of the earth's crust causing propagations of a series of elastic shock waves outside in all directions.

One can define earth quakes as strong vibrations of the earth or violent movement on the earth's surface. Earth quakes originate from plate tectonism. The collision of plates causes an impact that triggers off strong vibrations of plates causes an impact that triggers off vibrations within the earth's crust.

The plates are light and float on the upper mantle. They are therefore mobile and may move vertically or horizontally. This movement is caused by radioactive elements and convection currents that are generated within the earth's interior. When the plates converge, deformations occur on either sides of the edges within the mantle.

As the plates are dragged, the rocks become more plastic and elastic thus storing energy. Frictional resistance holding the rocks together is overcome by compression and eventually, the edges become slippery. The rapid release of energy makes the energy radiated in all directions from the focus to form explosive shock waves thereby causing vibrations which are known as earth quakes.

Eventually, rock elasticity returns to its original shape and this is referred to as elastic rebound. It should be noted major earth quakes produce small ones after few years or days. The waves travel from the center of disturbance as one shock wave.

The point in the earth's crust from which vibrations originate is called a focus while an epicenter is a point on the surface of the earth above the origin of the earthquake (a vertical point above the focus).

Shock waves are transmitted quickly through the earth's crust to the surface. When an earthquake occurs, these shock waves decrease in strength as they travel away from the focus.

Earthquakes usually occur in areas of china, japan, California, India, Mexico, Peru and in East Africa they are commonly experienced in Kabarole (Toro), Bundibugyo among others.

Effects of earth quakes

There is loss of lives especially in the 1966 earth quake where about 150 people died in Toro and in 1994 in Bundibugyo where many people perished.

Earth quakes trigger off landslides particularly in highland areas and are associated with many problems of communication blockage.

Earth quakes result into the destruction of socio-economic infrastructures like schools, roads, hospitals etc. like in 1994 when vilica hospital was destroyed.

Leave some people homeless or displaced for example in 1994 in Toro.

Increased government expenditure in areas prone to earthquakes in form of emergency funding for disaster preparedness. In addition to that, there are high costs of replacing destroyed property like roads, buildings among others.

Flooding in the coastal areas due to the tsunamis created or generated by earth quakes in the sea and this may also result into drowning.

Earth quakes can also be used for study purposes.

Question

Explain the cause of earth quakes in east Africa.

Examine the effects of earth quakes to the people of east Africa.

Vulcanicity.

This refers to the total process by which gases and molten rocks from the earth's interior are intruded into the earth's surface or extruded onto the earth's surface.

When the molten material (magma) is intruded into the earth's surface, it solidifies giving rise to intrusive features. When the materials reach on top of the earth's surface (lava), it solidifies to form extrusive features.

The molten material originates from the upper plastic layer of the earth's mantle. This material is kept in a semi molten or plastic state due to the high temperatures and additional heat sufficient enough to take the material to melting point.

Through the natural process of radioactivity, heat is generated and this makes the rocks to be plastic and fluid. Any additional increase in heat can trigger off upward movement of molten rock. The lighter elements of the material begin to rise upwards to the surface. The rising is made possible along lines of weakness like cracks or faulting.

The magma then forces its way out to the surface along fault lines and forms various landforms on reaching the surface.

It should be noted that when magma erupts on the surface and loses its gases, it is then known as lava.

It's the escaping gases and steam which expand rapidly and its due to high pressure that makes the eruptions to be explosive.

Lava varies considerably in its composition particularly in its silica content. The nature if lava partially affects the nature of landforms.

Basic lava is very fluid and mobile and therefore forms extensive lava plains. On the other hand, acidic lava is so viscous and largely immobile and consequently solidifies quickly to form steep sided landforms like volcanic plugs. Sometimes acid lava solidifies so quickly and blocks the fissures resulting intro explosive eruptions.

When an eruption takes place explosively, the magma is often ejected inform of ash, cinder, stones, blocks and gases and the finest is ash. The fragmental materials are referred to as pyroclasts.

Lava varies considerably in chemical composition particularly in its silica content. The silica content determines the degree of mobility.

Because of this, there are three types of lava and these include acidic lava, intermediate lava and basic lava.

Type of lava	**% of silica content**	**Degree of mobility**	**Example of rock type**
Acidic	Above 66 %	Extremely viscous and immobile and solidifies quickly.	rhyolite
Intermediate lava	Between 52-65%	Fairly viscous and able to flow for a far distance	Trachyte
Basic	Between 42-51%	Very fluid and mobile able to flow for long distance before solidifying.	Basic

The process results into formation of volcanic landforms namely;

Extrusive volcanic landforms

Intrusive volcanic landforms.

Extrusive volcanic landforms or features.

These are formed when magma is extruded onto the earth's surface. They take various forms depending on the type of lava which forms them. They include the following;

A volcano. A volcano is a hill or mountain formed by eruption of molten lava from the central opening known as a vent onto the earth's surface. The material erupted builds around the vent and generally forms a dome or cone with a funnel like structure or depression on top called a crater.

As long as there is continued supply of magma, the volcano will continue to grow to a height to which the difference in pressure can still force the erupted materials onto the earth's surface. If the pressure becomes insufficient for magma to reach the main crater, the mountain rock may then force its way on the earth's surface through other vents and may build up parasitic or secondary cones on the slopes of the main volcano.

Illustration.

Volcanoes vary in size from small ones to few meters high to large mountains like Kilimanjaro and Elgon among others.

They can also be classified according to the present state of activity i.e. active volcanoes, dormant volcanoes and distinct volcanoes.

Active volcanoes. An active volcano is one that has erupted its thought to have erupted within the last 500 years. Examples include Longnot, Meru, Oldoinyo-Lengai all in the eastern arm of the rift valley.

Dormant volcanoes. This is one which has not been known to have erupted and yet it is not extinct. Some dormant volcanoes show limited activity in form of fumaroles like Kilimanjaro.

Extinct volcanoes. These refer to the volcanoes which show no further signs of eruptions and much of their original structure may have been destroyed by denudation processes of erosion and weathering for example mountain Elgon.

Basalt dome or shield volcano. A basalt dome is a large flat topped or convective dome which is formed from basic lava with gently sloping sides. It's usually low in height relative to its large base. Its flat topped shape is caused by very fluid lava which is able to flow for some time before solidifying. Usually a shallow steep sided sunken crater is found located on the basalt top. A good example is found near Muhavura ranges in south western Uganda. In this case, lava flows through numerous fissures other than a single vent.

Illustration

Volcanic plug / neck. A volcanic neck is formed as a result of magma which is so viscos that is forced out as a rigid cylindrical plug. The base of the plug is surrounded by exploited debris. The eruption that leads to the formation of the plug is very explosive and the plus is extruded amidst clouds of hot ash and cinder for example Tororo rock in eastern Uganda.

Illustration.

Explosion crater. An explosion crater is a shallow flat floored depression which is surrounded by a low rim of pyroclasts and local rock. Craters are usually less than 50m in depth. Explosion craters may appear in singly or in groups. Their formation is based on two theories i.e.

The first theory states that a crater is formed as a result of explosive eruption which blows off the upper part of a volcano creating a small depression called a crater.

The second theory states that as magma is poured on the earth's surface from the earth's interior, a chasm (empty space) is created and with the weight of the material, the volcanic plug sinks in creating a depression called a crater. This process of sinking is called couldrone subsidence. Examples are found in western Uganda. Some of these craters are dry while others remain swampy and marshy. When these craters are filled with water, they now form the crater lakes like Katwe, nyamunuka, nyamusingwe among others.

Lake Katwe is the largest crater lake and it's a source of salt.

It should be noted that craters are as wide as 500m in diameter.

Illustration

A caldera. A caldera is another landform resulting from volcanicity. A caldera is a wide depression or big crater. It can be formed in two ways i.e.

The first theory states that a caldera is formed as a result of explosive eruption which blows off the upper part of a volcano leaving behind a big depression called a caldera.

It can also be formed through the process of couldrone subsidence. Major eruption may reduce magma supply and leaves a big space (chasm) beneath a volcano. Consequently, the weight of the overlying solidified magma becomes too great, faults develop and collapses into the chasm leaving behind a big depression known as a caldera.

Calderas can also develop from a combination of both explosion and subsidence. Prominent calderas in East Africa include menengai near the Nakuru valley in Kenya, Suswa in Kenya, Napak in south western Karamoja, Ngorongoro in Tanzania among others. When a caldera is filled with water, it forms a caldera lake for example lake Ngonzi in Tanzania.

It should be noted that a caldera extends for about 1km in diameter.

A cumulo-dome. A cumulo dome is a steep sided convex feature of acidic lava. It is formed from very viscous lava which doesn't flow for far but instead it piles around the vent where it hardens quickly. Where the extrusions are unable to reach the earth's surface, the overlying layers will be curved outwards. When a cumulo dome develops in a crater, it's called a theloid. An example can be seen at the Ntumbi cumulo dome in Tanzania. It can be illustrated as below.

Lava plateau or plain. A lava plateau is a highland with more or less a monotonous relief and is formed of successive layers of lava. It is formed by the eruption of very fluid or mobile or basic lava that upwells the surface through various fissures. The lava reaches the surface and then spreads out for long distances. Eventually, the depth of lava may be hundreds of meters thick completely covering the original hills and valleys. Vertical jointing may cause the plateau edges to be abrupt and where a plateau has been dissected by rivers, a valley tends to be steep sided and gorges are formed. Examples of lava plateaus include Laikipia lava plateau and Kisolo lava plateau in south western Uganda.

Illustration.

Ash and cinder cone. These are steep sided hills formed by volcanicity. Pyroclasts of all sizes are ejected and accumulate around the fissures to build up a volcanic hill or an ash and cinder cone. Such cones are steep sided and approximately 150m high above its base. Examples are in Kisoro district and Lakaiyu cinder cones in the south of lake Turkana. Illustration

Geysers and hot springs. A geyser refers to hot water accompanied by steam. A hot spring is natural hot water issuing out of the ground. It is also hot or warm. Both features owe their origin from the existence of hot rocks associated with volcanicity beneath the surface of the earth. They are formed when rain water sinks into the ground and comes into contact with rocks associated with volcanicity (hot rocks). The water is therefore heated and due to the pressure differences, the water upwells the earth's surface inform of geysers and hot springs.

They differ in a way that a hot spring is super-heated water which flows quickly whereas a geyser; water is thrown with a great force and accompanied by steam (geysers are ejected explosively / as jets). Examples include the Sempaya hot spring in Bundibugyo, Kitagata hot springs in Bushenyi and Kisiizi in Rukungiri.

Lava dammed lakes. They are formed when basic lava comes out from a volcanic mountain and may block a flowing river creating a lava dammed lake. Examples include lake Bunyonyi, Mutanda, Mulehe among others.

Intrusive volcanic landforms.

In general, intrusive volcanic landforms affect relief only after they have been exposed by denudation processes. Intrusions of various forms depend on the relative hardness or may depend on resistance of the surrounding rocks.

The various forms of intrusions can be seen as below;

A batholith (s). This is a very large intrusion formed at a great depth. They are usually bottomless and are usually from granitic rocks. Batholiths are the largest forms of intrusions and they result from large scale intrusion of magma which cools slowly beneath the surface of the earth. Examples include the Tanganyika batholith which out crops between mwanza and Iringa, batholiths are also found in Mubende district particularly the single batholiths. In Kenya, they are found in Maragoli.

When they are exposed by denudation forces, batholiths form uplands when their rocks are more resistant than the adjacent rocks. However, if the rocks making up the batholiths are softer than the surrounding rocks, they then are then eroded away forming depressions called arenas.

Illustrations.

A dyke. A dyke is a vertical or steeply inclined igneous intrusion. It's said to be discordant with the rock layers. Dykes are formed when molten magma up wells across the layers and solidifies within the earth's crust before reaching the earth's surface. Sometimes they occur in groups and they are referred to as ring dykes. Examples are found in south and west of lake Turkana in Kenya.

After denudation, if the dyke is more resistant than the surrounding rocks, it may form an upland with steep slopes. If on the other hand, its less resistant than the adjacent rocks, it may form a trench.

It can be illustrated as below.

A sill. Sills are horizontal intrusive features which lie between rock layers. They are therefore concordant with the rock layers. Magma rises from the earth's interior and spreads horizontally along the bedding planes. After denudation, a resistant sill may form escarpments of flat topped hills. In a river valley, resistant sills may form waterfalls and rapids for example the Thika falls in Kenya are as a result of this. Sills may appear singly or in groups and examples of sills are found in Thika district in Kenya.

It can be illustrated as below.

Laccolith. This is a dome shaped intrusion with more or less a flat base. Its formed when magma rises and solidifies within the crust before reaching the earth's surface. Its formed from viscous magma which is unable to move and spread for long distances. Magma accumulates in large mass forcing the over lying rocks to arch upwards. Laccoliths are found in Madagascar and Algerian coast. If the formed laccolith is more resistant than the adjacent rocks, it may form an upland.

Illustration

Lapolith. It's a very large saucer shaped intrusion formed when magma forces its way out of the earth's surface but cools very quickly before reaching the earth's surface. Its saucer shape is due to the increased weight of the crust which may cause sinking. If the lapolith is exposed by denudation processes, then then up turn edges may sometimes form out facing scarps. Examples are in Zimbabwe north of Harare. It can be illustrated as below.

Economic importance of volcanicity to man.

Volcanism leads to the formation of volcanic soils which are fertile and useful for agriculture for example in Mbale on the slopes of mountain Elgon.

Some water falls formed on the slopes of volcanic mountains provide and are suitable sites for construction of hydro Electric power plants for example the Siipi falls in Kapchwora.

Volcanic mountains moderate climate i.e. relief or orogenic rainfall.

Water from hot springs and geysers are used for medicinal values i.e. in Kitagata hot springs in Bushenyi.

The peculiar landforms promote tourism like volcanic plugs, the highest mountain in East Africa is Kilimanjaro with 5895 meters above sea level and snowcapped in the equatorial region. This attracts many tourists throughout the year. Others include hot springs and geysers.

Some volcanic mountains help in the demarcation of country boundaries in East Africa for example mountain Kilimanjaro which demarcates Kenya and Tanzania, Elgon which demarcates Uganda and Kenya.

Volcanic activity results into the formation of valuable minerals like salt in Katwe in Uganda, limestone in Tororo and Toro region.

Plutonic igneous rocks are potential and actual resources as far as quarrying is concerned. These rocks can be excavated and crushed to get materials which are used in building and construction purposes.

Volcanic mountains are associated with heavy rainfall and luxuriant vegetation on their slopes. The vegetation can be used for forestry and lumbering.

Negative.

Volcanic eruptions can be destructive to both life and property for example of the most destructive volcanic natural disaster was mountain Nyivagingo in Zaire which erupted in 1977 and 2002 which destroyed many coffee plantations, many people died and many people were left homeless.

Volcanic mountains create rainfall on the windward side but influence aridity on the lee ward side. The lee ward side is located is located in the rain shadow and therefore largely dry for example the water parts of Kenya are in the rain shadow of mountain Elgon.

The steep slopes of volcanic mountains have rendered volcanic highlands inaccessible. The regions have remained remote because of difficulty and high costs involved in construction of transport and communication infrastructures for example some of the highlands in kigezi are not well served with transport infrastructures.

Steep slopes of volcanic mountains are prone to soil erosion and land slide and rock falls. This is common in kigezi, Kenya and kipengere ranges in southern Tanzania.

Revision questions

1. Examine the influence of volcanicity on drainage.
2. Examine the relationship between the nature of material ejected and extrusive volcanic landforms in East Africa.
3. Examine the impact of volcanicity on landform evolution in East Africa.

ROCKS IN EAST AFRICA.

A rock is an aggregate or combination of minerals in a solid state. In other words, a rock is an aggregate of one or more elements existing in a solid state.

Rocks form the upper layer of the lithosphere. Minerals that make up the rocks include potassium, calcium, iron, aluminum, magnesium among others. Some minerals such as gold, diamond and silver have only one element while others like quartz, bauxite have more than one element in them.

In popular use, a rock is something hard, consolidated, compact and massive. Rocks can therefore be classified by their mineralogical composition but not necessarily their hardness. Rocks of the earth's surface are commonly classified according to their origin into three types and these are; igneous rocks, sedimentary rocks and metamorphic rocks.

Igneous rocks.

They are formed from crystallization and solidification of molten magma. They may be deposited onto the earth's surface or with in the earth's crust i.e. extrusive or intrusive rocks respectively. The main process for the formation of igneous rocks is volcanicity. This is due to the radioactivity and connectivity with in the earth's mantle. Lines of weakness or fault lines are created in the earth's crust through which magma is either extruded or intruded.

Igneous rocks are usually described as fire formed rocks, igneous rocks are characterized by being hard, don't contain fossils and they are crystalline in nature. As magma is pushed from deep in the earth's interior, it cools in different parts of the earth's crust thus forming different types of rocks. They include

Volcanic rocks or extrusive rocks

Hypabyssal or intermediate rocks

Plutonic or abyssal or deep seated rocks.

Volcanic or extrusive rocks.

These are igneous rocks formed on top of the earth's surface. They are formed from fast flowing surface cooling lava with much smaller crystals due to exposure to oxygen. Examples include basalt, rhyolite, trachyte and andesite etc. extrusive rocks are generally hard.

Hypabyssal or intermediate rocks.

These are igneous rocks formed between volcanic and plutonic rocks. They are firmed near the earth's surface and cool at a moderate rate or average rate with medium sized crystals. Like plutonic rocks, hypabyssal rocks are also intrusive. Examples include quartz and dolerite.

Plutonic rocks or deep seated rocks.

These are igneous rocks that are formed at a greater depth with in the earth's crust. They are also described as deep seated rocks. The magma which forms these rock type rises for a short distance and cools in the crust very far from the earth's surface. This magma cools extremely slowly at a greater depth due to lack of oxygen and results into formation of rocks with large crystals and examples include gabbro, granite, diorite among others.

Igneous rocks can be illustrated as below.

Summary of various types of igneous rocks.

Rock type	**Where it is found**	**Cooling rate**	**Size of crystals**	**Example**
Volcanic or extrusive rocks	On top of the earth's surface	A fast rate	Small crystals	Basalt, andesite etc.
Hypabyssal or intermediate rocks	Shallow depth or near the earth's surface	An average rate or medium rate	Medium sized crystals	Quartz, diorite etc.
Plutonic or deep seated rocks	At greater depth	Cools at a slow rate	Forms large crystals	Gabbro, granite etc.

Magma from the mantle which is ejected varies in chemical composition which has an effect on its viscosity or thickness. This in turn influences the cooling rate and the process of crystallization.

Acidic igneous rocks have a higher amount of silica content; intermediate igneous rocks have a mixed structure of minerals (average silica content) where as basic igneous rocks contain less content.

Igneous rocks in East Africa are found around volcanic mountains of mountain Kenya areas, Kilimanjaro areas, Muhavura areas and around the great east African rift valley.

It should be noted that formally intrusive rocks may later be exposed by denudation processes and when they are resistant, they form uplands for example the Mubende batholith, Tanganyika batholith and the inselbergs of Eastern Uganda.

Question

Account for the formation of igneous rocks in East Africa.

Sedimentary rocks.

These are rocks composed of deposited minerals and rock fragments or sediments produced by mechanical or physical or chemical weathering of former rock masses of igneous rocks. They are therefore derived from already existing igneous rocks and because of this, they are sometimes referred to as derived rocks or secondary or laid down rocks.

The weathered materials are then transported by erosion agents of water, ice, and wind and are later deposited in layers (strata) on either a dry land or in valleys or under water (in oceans and seas). The layers are separated by bedding plains which demarcate the end of one deposition cycle and the beginning of another. Layers can be horizontal, gently sloping or steeply dipping.

Generally speaking, sedimentary rocks have the following characteristics;

- They contain fossils of dead plants and animals.
- They have layers i.e. strata (they are stratified)
- They are non-crystalline in nature
- Stratas are either horizontal or gently sloping or steeply dipping.

Processes of formation of sedimentary rocks.

- Weathering of the already existing igneous rocks
- Erosion and transportation of weathered materials
- Deposition of sediments by ice, wind or running water or ocean waves.
- Stratification of deposited materials.
- Compression of stratified materials by overlying weight.
- Compaction of layers
- Consolidation of materials.
- Cementation of deposited layers.
- Transformation of sediments into sedimentary rocks

The formation of these sedimentary rocks can be classified into three types and these include;

- Mechanically formed rocks
- Organically formed rocks
- Chemically formed rocks.

Mechanically formed rocks.

Mechanically or physically formed sedimentary rocks result from the breakdown of the already existing rocks into valid textures then forming valid rock types depending on the agent of erosion. These agents cause erosion, transportation and deposition of the eroded materials. These deposited materials accumulate and become compact and as time goes on or elapses, the deposited materials are cemented and consolidated and then turn into a mass of rock called mechanically formed sedimentary rocks.

River deposition creates alluvial soils, ice or glacier, till or moraine, wind deposits loess and marine or wave action creates marine deposits.

Examples of resulting rocks include sandstone, mudstone, clay, shale, gravel among others.

Organically formed sedimentary rocks.

Organically formed are formed from remains of once living plants and animals for example coral reefs or coral rocks. Coral rocks are derived from coral polyps which are small marine organisms or animals which live in sediment free water of about 200C and above all rich in plankton which is their food. Their skeletons are made up of calcium carbonates so when they die they are deposited on the sea or ocean floor, accumulate and are cemented together with other marine organisms or features like algae.

They are then compressed by their own weight. With time, they turn into hard rocks known as coral rocks. Coral rock is therefore an organic limestone rock and is very common along the East African coast.

On the other hand, when plant die, their leaves and branches decompose and are compacted together to form rocks for example plant accumulation during the carboniferous period were compressed by sediments and formed coal of varying types for example pit coal, brown coal and lignite coal among others.

Chemically formed sedimentary rocks.

These are rocks which result from the chemical precipitation and evaporation of salt solution in hot tropical regions. When water evaporates, the beds of salt known as evaporates are left behind as a residue or deposit which dries up, get compact, cemented, consolidated and transformed into a hard rock ie chemically formed sedimentary rock. Examples include dolomite, rock salt among others.

Question

Account for the formation of sedimentary rocks in East Africa.

Metamorphic rocks

These are rocks whose original forms have been changed. They were originally sedimentary or igneous rocks but they have drastically changed by massive forces of heat (thermo-metamorphism), pressure (dynamic metamorphism) or both heat and pressure (thermos-dynamic metamorphism) working on them from either within the earth’s crust or outside the earth’s surface.

The metamorphic rocks are quite different from the original rock. The rocks are changed in structure, texture, chemical composition and the general appearance. Metamorphism is usually a cooking process i.e. it partly melts the rocks causing the mineral components to be changed. The chemical nature and character changes hence metamorphism.

Examples include

Original rock	**Changed rock after metamorphism**
clay	shale
shale	slate
limestone	marble
granite	gneiss
coal	Graphite
Sandstone	quartzite

DENUDATION

This refers to the exogenic (external forces) agents which wear away the land surface. Denudation involves a number of processes namely soil erosion, weathering, mass wasting, glaciation as well as the transportation of the broken down particles.

The term denudation is widely used to cover all the agencies / processes by which parts of the earth's surface undergo destruction, wastage and loss. This is the great work of weathering agents, mass wasting, erosion by running water i.e. rain wash, streams and rivers, by moving ice inform of glaciers and ice sheets, by wind and waves, tides and currents in the sea as well as the transportation of the broken up particles of the rocks.

WEATHERING.

Weathering refers to the disintegration or decomposition of rocks by either mechanical or chemical means resulting into the break up, decay and rotting of the rocks instu i.e. in one place. This definition suggests that under weathering, there is no transportation of the broken up particles of the rocks and if this happens, it will be regarded as erosion but not weathering.

The end product of weathering is the formation of layers of weathered rocks known as debris. The action of weathering in the destruction of rocks is dependent upon the removal of weathered layers notably by wind, water or ice.

If the weathered rock is not removed, it may act as a protective layer to the underlying rock. So weathering itself doesn't involve the removal of materials but as a process, it depends upon the removal of weathered materials by outside agents. Weathering is an extremely important process in shaping the landscape on the earth's surface.

Types of weathering.

These include;

Chemical weathering

This refers to the decomposition or rotting of rocks using water involving a change in the chemical composition of the rock to form new compounds or minerals.

Chemical weathering is most common in the humid tropical areas that receive heavy rainfall although it can also take place in deserts since they also receive occasional showers.

Chemical weathering involves a chemical reaction between the minerals of the rock as well as the atmospheric gases like carbon-dioxide, oxygen and acids from rotten plants and animals.

In chemical weathering, water acts as a medium of chemical reaction and the hot temperatures accelerate the rate of chemical reactions. Chemical weathering involves a number of processes or types and these include;

a. **Carbonation**

This takes place when rain water mixes with carbonates in the atmosphere to form weak carbonic acids. These carbonic acids react with minerals in the rocks like limestone rocks which contain calcium to form calcium carbonate which can easily be dissolved in water and hence carried away. This leads to creation of holes (solution hollows) on the surface and caves beneath. When the calcium carbonate is removed in solution by ground water, karst landforms are formed like stalactites and stalagmites, underground caves etc. at Nyakasura in fort portal, Bamburi and kilifi in kenya.

$Ca(s) + H_2CO_{3(aq)} \longrightarrow CaCO_{3(s)} + H_{2(g)}$

Calcium carbonate + H_2O + CO_2 $\longrightarrow$ calcium hydrogen carbonate.

Limestone + weak carbonic acids $\longrightarrow$ calcium hydrogen carbonate.

b. **Hydration.**

This is a process of chemical weathering by which rocks absorb water and expand in size. This expansion reduces the cohesiveness of the rock particles hence internal stress is created within the rock and therefore crumbling and fracturing of the rock and changing their chemical compounds. Some rocks like hematite absorb water changing to limonite. Others are calcium sulphate, after absorbing water changes to gypsum and feldspar mineral in granite absorbs water and disintegrates to form mud.

c. **Hydrolysis.**

This is the reaction between water and mineral elements i.e. the hydrogen ions of water and ions of the minerals (in the rocks). This water and mineral ions react chemically which gives rise to the formation of new compounds e.g. feldspar is broken down to produce potassium hydroxide and aluminosilic acid.

The aluminosilic acid is further decomposed into clay minerals while potassium hydroxide reacts with water CO_2 to produce potassium carbonate. The potassium carbonate is removed in solution leaving silica and residual clay minerals as the end product for example in the broad valleys of Buganda like at Kajjansi.

$$2KAlSO_3O_8 + 2H_2O + CO_2 \longrightarrow Al_2Sl_2O_5(OH)_4 + K_2CO_3 + 4SIO_2$$

Feldspar water carbon-dioxide clay minerals potassium carbonate silica

d. Oxidation

This is the reaction that occurs when additional oxygen is taken up by mineral compounds within the rocks. The oxidation of minerals nearly always occurs in association with water in which atmospheric oxygen has been dissolved. It is most active in the zone above the water table and particularly in sedimentary rocks such as clay which contain ion compounds. In this zone, water oxidizes the ferrous compounds into red or brown ferric compounds. In the zone below the water table, the ferrous compounds in clay are oxidized to give a grey or blue color.

This form of chemical weathering is common in rocks which contain mineral elements like ion, calcium and magnesium which can easily be oxidized to form oxides. The laterite soils / marrum soils on many hill tops in Buganda where we get murram for road construction were formed through this process. Mineral oxides can be formed as below.

$Fe + O_2 \longrightarrow FeO$ (iron oxide)

$2Ca(s) + O_2 \longrightarrow 2CaO(s)$

$2Mg(s) + O_2 \longrightarrow 2MgO(s)$

e. Chelation.

In this process of chemical weathering, organic acids and humic acids from decayed materials/ leaf litter and other remains of plants react with certain minerals. The exchange of organic acids with mineral elements or rock minerals causes the decomposition and change in the chemical composition in the rock particles hence chemical weathering (fracturing and decomposition).

f. Solution.

Under this process of chemical weathering, some soluble rock particles are dissolved and weathered in solution form e.g. water may mix with rock salts and form a solution. This means that rock salts have been weathered in that way.

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-bi-carbonate 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^{o}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.

Revision question

Examine the chemical weathering processes that take place in the humid areas of East Africa.

Approach

- Define weathering
- Define chemical weathering
- Identify the humid areas in E.A or areas prone to chemical weathering
- Give the processes of chemical weathering explaining them with relevant examples.

PHYSICAL / MECHANICAL WEATHERING

This is the breaking down of rocks into successively smaller fragments or particles. It doesn't involve mineralogical change or change in the chemical bond of the rocks. Its common in arid and semi-arid areas of Ankole-Masaka dry corridor, Karamoja area, northern Kenya and on the lee ward side of mountains like mountain Kilimanjaro, Kenya, Rwenzori and mountain tops which involve temperature changes and have a wide diurnal range and also on the mountains with very cold temperatures where rocks are broken down by frost action. The physical weathering processes include;

a. **Thermal expansion / exfoliation**

In this process, daily temperature ranges result into expansion and contraction of certain minerals that cause stress and strain into the rocks. Eventually, this stress and strain leads to fracturing of the rocks. Since the rocks are bad conductors of heat, no heat from the outer part of the rock is transferred to the inner part. The outer part then expands more than the inner part hence leading to expansion and peeling off of the outer rocks. This process of peeling off is called exfoliation and results into the formation of exfoliation domes. This is dominant in the arid and semi-arid areas of Nakasongola, Kumi, Soroti, Serengeti etc. which receive high temperatures during the day and abrupt cooling at night.

b. **Freeze thaw action or frost action / shuttering**

In areas subjected to alternating freezing and thawing, water sips into the cracks. When it freezes, the frozen water expands and widens the cracks. The jointed cracks are very prone to this process that leads to total disintegration of the rocks. Its common in Rwenzori areas, mountain Kilimanjaro areas and the mountain Kenya areas.

NB. Water expands by 10% of its liquid when it freezes.

c. **Block disintegration**.

In this process, the rocks are disintegrated, breaking down into blocks. It's is common in granitic rocks. As these rocks develop cracks, they cool down after exposure to thermal heating and cooling. The rocks expand and cool along the developed cracks and as they widen, the rock will fall apart in blocks (bigger particles). This block disintegration is very common in Kachumbara areas in Kumi district and the Mubende Batholiths along Mubende-Kyenjojo road.

d. Granular disintegration.

This takes place almost in the same way as block disintegration except that in this process, rocks break down or disintegrate into smaller particles called granules. This occurs when the rocks have different types of minerals of different heating and expansion co-efficient. So the various minerals heat and expand at different rates causing the rock to break into angular blocks.

e. Pressure release or unloading

Some rocks like plutonic rocks and metamorphic rocks are formed under great heat and pressure. The pressure comes from the weight of the overlying rocks. In case denudation removes the overlying rocks and exposes them, they will expand in the process of shedding off. This pressure release causes cracks to develop on the rock surface and particles start to peel off in a manner similar to exfoliation. It is common in Mubende.

f. Crystallization

This is one of the physical weathering processes in which some rocks absorb salty water. This salty water will collect into the rock joints or cracks. This water later evaporates and hence crystals begin to form or are left behind. As these crystals grow bigger and expand in size due accumulation, they exert pressure on the surrounding rocks hence leading to fall off of rocks (physical disintegration). Its common in Katwe areas.

g. Aridity shrinkage

This type of weathering occurs in areas experiencing extremes of weather i.e. wet and dry seasons. It occurs when drought succeeds a rainy season such that the rock loses the water that was previously taken up during the rainy season. As a result, the rock crumbles into smaller elongated fragments. For example, when a sample of clay dries out, it shrinks and its surface becomes filled with cracks hence facilitating its break up and its subsequent removal especially on a slope.

Question

Examine the weathering processes that take place in arid and semi-arid areas of East Africa.

Approach

- Define weathering
- Define physical weathering
- Point out areas in East Africa prone to physical weathering
- Give the processes of physical weathering explaining them with relevant examples.

BIOLOGICAL WEATHERING

This refers to the breakdown of rocks with the help of living organisms. Plants and animals help in rock weathering by both chemical and mechanical means i.e. bio-physical and bio-chemical weathering.

Plants like algae, mosses, lichens and other hydrophytes retain water on rock surfaces which result into chemical decomposition.

The roots of plants in the process of sucking water from the rocks release some acids (humic acids) that may react with rocks and disintegrate them.

Animals and plants can also disintegrate the rock or break the rocks. The roots of plants which are growing in the rocks may enlarge the cracks or joints which are already existing in the rocks thus making them to breakdown physically. The animals also physically break down the rocks as they move on the rock surfaces due to the pressure exerted on them.

Barrowing animals like rabbits, rats, termites and other animals drill holes into the rocks and therefore directly disintegrate the rocks.

Man through his activities of cultivation, mining, quarrying, rock blasting, road construction, etc. directly breaks down rocks and then disintegrates them physically.

Living organisms whether living or dead play a positive role. Urine of animals once exposed on rocks, reacts with rocks making them to breakdown.

The chemicals man uses in agriculture like herbicides, insecticides, pesticides and fertilizers also weaken the rocks and lead to their break up.

Decomposing organic matter release organic acids which are absorbed by the rocks hence making them to decay and decompose thus weathering.

However, a layer of decaying organic matter may prevent disintegrating since it mulches the soil and underlying rocks hence preventing them from exposure to agents of weathering.

NOTE: All the three types of weathering are interdependent because physical weathering may open up some areas through disintegration and chemical weathering act deeper in the rock. While physical weathering is at its maximum in arid and semi-arid areas because of high temperatures onto which the rocks are exposed to during day time and low temperatures at night which leads to a lot of stress and strain, chemical weathering is at its maximum in humid areas because of the presence of water.

However, it's important to remember that in general, all types of weathering operate hand in hand and are usually complimentary although in a given area, one maybe more important than the other.

DIFFERENCES BETWEEN PHYSICAL WEATHERING AND CHEMICAL WEATHERING

Physical weathering is the disintegration or breakdown of rocks into smaller particles or fragments instu while chemical weathering is the decomposition or decay or rotting of rocks instu at or near the earth's surface.

Physical weathering occurs due to temperature fluctuations (temperature changes) like alternate heating and cooling while chemical weathering occurs as a result of heavy or adequate rainfall and high humidity that provide water to act as a medium of chemical reactions and the hot temperatures to accelerate the rate of chemical reactions.

In physical weathering, there is no change in the chemical composition of the rock but instead the rock is broken down into smaller particles while in chemical weathering there is a change in the chemical composition of the rock i.e. new compounds are formed.

Physical weathering occurs inform of block disintegration, thermal expansion, granular disintegration, frost action etc. while chemical weathering occurs inform of carbonation, solution, hydrolysis, hydration etc.

FACTORS THAT INFLUENCE THE RATE AND NATURE (TYPE AND CHARACTER) OF WEATHERING.

THE NATURE OF THE PARENT ROCK.

Mineralogical composition of the rock: the mineral composition of the rock is very important in determining the rate and character of weathering from rock to rock e.g. igneous rocks are more prone to chemical weathering because they are formed under conditions very different from those operating on the earth's surface and they are therefore not chemically stable on the earth's surface. So when rocks come into contact with water, chemical weathering sets in at a very fast rate when exposed onto the earth's surface. Examples of such rocks which can easily be weather are basic igneous rocks with low silica content.

On the other hand, rocks with high silica content like granitic rocks are more stable and react to chemical weathering at a slow rate.

Rock jointing: rock jointing also influences the rate and nature of weathering. This is because joints are weak lines which are exposed by agents of weathering to cause rock break down. Water can easily penetrate thus enhancing chemical weathering processes of hydration to take place at a faster rate.

Physical weathering processes of freeze thaw action and thermo-expansion are very fast in rocks which are poorly jointed.

Similarly, biological weathering will also take place at a fast rate with the penetration of plant roots and animals which will only take place when cracks only exist on the rock. On the other hand, rocks which are well jointed, chemical, physical and biological weathering processes take place at a slow rate.

Rock color: rocks which are dull and dark colored absorb heat and therefore expand more quickly and with continuous expansion and contraction, cracks are then created and eventually lead to the fracturing of the rocks at a very fast rate by thermal expansion and block disintegration.

On the other hand, rocks which are light and shiny are less affected by weathering processes of thermo-expansion because they reflect heat. Therefore, dark colored rocks are weathered much faster than shiny rocks.

Rock hardness: hard rocks like quartzite are more resistant to weathering processes of carbonation and hydration. On the other hand, rocks which are soft like clay are weathered at a faster rate by chemical weathering processes of oxidation.

Rock permeability: rocks which are permeable like sandstone allow water to penetrate though them. Such rocks that allow water to penetrate though them are weathered at a faster rate by chemical weathering through the process of carbonation. On the other hand, rocks which are impermeable are weathered by chemical weathering processes at a slow rate.

Rock solubility: rocks which are soluble in water like rock salts dissolve in water at a fast rate. So rocks which are soluble in water are easily weathered by chemical weathering processes of solution.

Rock texture: rocks with rough texture can easily allow water to collect on such rocks on giving way for chemical weathering processes of hydration to take place at a faster rate. On the other hand, rocks which are smooth are weathered at a slow rate by physical and chemical weathering processes.

Influence of climate

Climate also determines the rate and nature of weathering. Rainfall and temperature are also the major elements that affect the rate and nature of weathering.

Areas with equatorial climate are characterized by high rainfall totals of about 1500mm. this rainfall is high throughout the year with double maxima (two rainfall peaks/seasons). These rainfall amounts facilitate chemical weathering processes since they require water as a medium of chemical reaction.

Chemical weathering is common in areas which receive high rainfall totals like Northern shores of Lake Victoria, slopes of mountain Elgon and Kilimanjaro (humid areas) among others and very slow in areas with little or no rainfall. The humid areas are also characterized by high temperatures which acts as a catalyst to chemical weathering processes. Therefore, chemical weathering is more dominant in humid areas i.e. areas with high rainfall and temperatures.

In savannah regions (transition zones), the alternating wet and dry seasons within these areas give way to both chemical and physical weathering to take place. Chemical weathering is more active during the wet season and physical weathering is more dominant in the dry season.

On the hand, arid and semi- arid areas that receive low amounts of low rainfall of less than 500mm per annum and a prolonged dry season characterized by very high temperatures of above 30^0C provide suitable conditions for physical weathering processes of thermal expansion, block disintegration and granular disintegration. This therefore means that physical weathering is more dominant in such areas like in the Ankole-Masaka dry corridor, north Eastern Uganda, Eastern Kenya in the Turkana and Masai land among others.

For mountainous areas where the temperatures are low like in areas of mountain Rwenzori, Mountain Kenya and Kilimanjaro, physical weathering processes of frost action / freeze and thaw is dominant. In this case, water freezes in the cracks and since ice is bigger in volume, cracks are widened and deepened leading to eventual breakdown of rocks therefore physical weathering is very fast in areas with low temperatures.

Effect of plants and animals (living organisms)

Living organisms like plants act as agents of weathering by the action of their roots in the process of sapping water underground where they dig dip and create cracks and keep on expanding the joints within the rocks in that way. In this process they therefore facilitate physical, chemical and biological weathering. However, thick vegetation may act as a protective layer against physical weathering and it may slow down the removal of the weathered layers.

Animals such as rats, termites etc. loosen the compactiveness of the rocks thus causing physical fracturing of the rocks. Water easily penetrates through the rocks giving room for chemical weathering processes of hydration. Therefore, where animals exist, physical, biological and chemical weathering take place at a faster rate than where animals are absent.

When living organisms (plants and animals) die, they decompose into humus and organic matter. With the addition of water, the humus turns into humic acid which decomposes the rocks plus organic acids. Therefore, in such areas, chemical weathering processes of chelation take place at a faster rate.

Man himself does his activities of rock blasting with explosives, mining, road construction among others facilitate physical break down of rocks (physical weathering/ fracturing). He also aids chemical weathering processes through his activities of application of irrigation, fertilizers, spraying with pesticides, insecticides, herbicides etc. since they involve the element of water. Therefore, there is chemical weathering in such areas.

Relief

Relief also determines the rate and type of weathering. The rate at which weathering takes place is related to the speed at which weathered rocks are removed. On steep slopes, the weathered rocks are quickly removed and the parent rock is exposed to further physical weathering. In other words, steep slopes encourage faster rates of physical weathering because of high rates of erosion that exposes the underlying rocks to further physical weathering.

However, gentle slopes and low lying areas promote the occurrence of chemical weathering due to the high retention capacity of water. In other words, this results into the occurrence of chemical weathering processes of hydration, oxidation, chelation among others at a faster rate because water accumulates on gentle slopes and low lying areas than on the steep slopes.

Time: It takes time for rocks to be broken down by physical and chemical weathering processes. The longer the time the rock has been exposed to the weathering, the more easily such a rock will be weathered and the shorter the time, the more resistant the rock will be to weathering agents.

Natural catastrophes: Natural catastrophes like earth quakes, lightning and thunder, volcanic eruptions etc. result into mechanical or physical breakdown of rocks. These catastrophes can further expose the underlying rocks to both physical chemical weathering.

Sample questions.

1. **To what extent does the parent rock influence the rate and nature of weathering.**
   Define weathering
   Talk about the types of weathering briefly
   Explain the influence of the parent rock on the rate and nature of weathering
   Then say, however it's not only the parent rock which influences the rate and nature of weathering in east Africa but there are other factors which include climate, living organism, relief, time etc.
   NOTE
   All factors identified should be explained with relevant examples.
   Give your personal stand or evaluation

2. **''Physical weathering is the most dominant weathering process in arid and semi-arid areas of East Africa''. Discuss**
   Approach
   Define weathering
   Define physical weathering
   Give the areas prone to physical weathering in east Africa
   Give the semi-arid areas in east Africa
   Talk about the physical weathering processes excluding free thaw action
   However, when it rains, chemical weathering may also occur.

3. **Examine the weathering processes that take place in the mountainous areas of East Africa.**
   Approach
   Define weathering
   Identify the mountainous areas in east Africa
   Give the types of weathering occurring on the different sides of the mountains i.e. on top where we have physical weathering e.g. freeze thaw action, and other processes of physical weathering on the lee ward side.
   On the wind ward side, we have chemical weathering

LANDFORMS RESULTING FROM WEATHERING IN EAST AFRICA. (EFFECT OF WEATHERING ON LANDFORM EVOLUTION IN EAST AFRICA)

Although weathering is all about wear and tear of the earth's surface, in the process it leads to formation of landforms especially within the karst regions. These landforms include;

Karst regions are regions made up of limestone rocks.

Glikes and clints:

These are formed during the process of carbonation where by rainfall dissolves CO_2 in the atmosphere to form weak carbonic acids. These carbonic acids act on limestone rocks to form calcium carbonates or converted to a more readily dissolvable form of calcium bi carbonates. In areas where limestone rocks alternate with rocks with different minerals, the weak $CaCO_3$ are removed in solution to form ditch like depressions called grikes while the hard resistant rocks remaining behind form round topped ridges called clints e.g. at Kajjansi near Kampala.

Stalactites.

These are features found mostly in karst regions (areas with limestone rocks). They are protrusions found on the roof of a chemically weathered limestone cave. Stalactites are therefore formed when rain water mixes with carbon dioxide in the atmosphere to form weak carbonic acids. These carbonic acids dissolve the limestone rock on the roof of the cave and the solution starts dripping on the floor. When water evaporates, dripping stops and finger like projection are left on the cave and are called the stalactites. Best examples are found at Nyakasura in Fort-Portal in kabarole district in Uganda and Tanga in Tanzania.

Illustration

Stalagmites

These are formed together with stalactites in the karst regions. A stalagmite is a landform that arises from the floor of the cave due to the accumulation of materials deposited on the floor from ceiling drippings. These are therefore formed on the floor of the cave by dripping water from the roof of the cave. When water evaporates from the dissolved calcium carbonate, it leaves behind a dry and compact mass of limestone protruding upwards and this forms a stalagmite and are also found at Nyakasura.

Illustration

Pillars.

A pillar is an upright shaft or structure of stone or any other mineral relatively slender in proportion to its height and can be of any shape in section. Pillars are formed hen stalagmites and stalactites meet in a limestone cave. They appear as vertical stands of calcium carbonates.

Illustration

Underground caves.

These are natural hollows formed under ground by rivers. They are formed when a river flowing into a karst region disappears underground hence removing the limestone rocks in solution. They are formed due to solution. Solution is the removal of rock in solution by acidic rain. Some rocks are chemically weathered by being dissolved in water for example limestone and after weathering off such rocks, it forms impressive features like widened hollows for example the caves at Nyakasura.

Illustration

Sinkholes.

A sinkhole is a depression or hole in the ground caused by some form collapse of the surface area. Sinkholes occur due to erosion or underground water. They start developing longtime due before it actually appears. Most of the sinkholes occur due to karst processes of chemical dissolution of carbonate rocks. The formation of sinkholes involves the process of erosion or gradual removal of slightly soluble bedrock such as limestone by percolating water, the collapse of cave roof, or a lowering of water table. Sinkholes often from through the process of suffusion for example ground water may dissolve the carbonate cement holding the sandstone particles together and then carry away the lax particles gradually forming a void or sinkhole.

Exfoliation domes

An exfoliation dome is a large dome-shaped form, developed in massive homogenous coarse-grained rocks especially granite by exfoliation. Exfoliation is a term used to describe the peeling away of sheets of rock millimeters to meters in thickness from a rock's surface due to a range of physical and chemical processes during exhumation and weathering. Therefore, if a form of mechanical weathering in which curved plates of rocks are stripped from the rock below.

Exfoliation domes therefore a result of physical weathering by exfoliation. The rapid heating and cooling especially in the areas of high temperatures cause expansion and contraction of rocks. The outer most layer of the rock is eventually detached from the original and it peels off. This leaves behind a round topped rock called an exfoliation dome. Best examples are seen at Mubende along Mubende- kyenjojo road.

Arenas: these are lager circular depressions on the earth's surface. They are formed in areas of alternating bands of hard and soft rocks. So the soft rocks are weathered away leaving behind the hard and resistant rocks. The soft rocks are removed leaving behind circular depressions which may or may not be filled with water to form arenas. Examples can be seen on the slopes of mountain Rwenzori in the areas of Ntoroko.

Tors: these are remnants of weathered rocks rooted in the bed rocks. These appear onto the earth's surface as basaltic remnants. They are common in jointed rocks which are weathered deep and when denudation forces remove these debris, tors remain as resistant rocks bedded in as un-weathered. Best examples can be seen in Kenya at Kitmikaye near Seme, Bismark rock in Lake Victoria near Mwanza.

Illustration

MASS WASTING

Mass wasting refers to the movement of materials downhill or down slope under the influence of gravity. Its therefore the falling, creeping, sliding or falling of rocks and weathered materials downhill under the influence of gravity. The major factor that helps to overcome any resistance is water. Therefore, water acts as a lubricant for material to move down easily. A water saturated mass moves more easily than a dry one because water both increases the weight of the mass and also decreases the cohesive power of the material.

In other words, mass wasting is a largescale movement of materials downhill in which the stability of the slope has failed. As a result, the materials move downhill under the influence of gravity with water acting as a lubricant. It is alternatively referred to as slope failure or slope collapse.

Mass wasting is a general terminology which includes all forms of movement along a slope ranging from the slowest to the fastest. Therefore, mass wasting refers to the creeping, flowing, sliding or falling of rocks and weathered materials downslope under the influence of gravity using water as a lubricant.

It's different from erosion in a sense that in erosion, water physically transports away the soil particles but in mass wasting, water doesn't physically wash away the materials but assists the rock to slide under the influence of gravitational pull.

Mass wasting occurs in highland and mountainous areas of East Africa like along the slopes of mountain Elgon, Rwenzori, Kilimanjaro, Kenya, kigezi highlamds, Kisoro, Rwampara hills, Kipengere ranges of southern Tanzania, Bulecheke areas in Mbale, Sirinko areas among others.

TYPES OF MASS WASTING

The types of mass wasting include soil creep, talus creep, mud flow, rock slump, rock slide, solifluction, rock falls, avalanches and they can be classified as slow and fast or rapid movements.

Slow movements. Sometimes loose soil particles can flow extremely slowly down slope sometimes as slow as 1 cm per year. Slow movements involve the following types;

a. **Soil creep:**

this refers to a very slow movement of the soil and fine materials downslope on a very gentle slope. Soil creep can be detected by bending of trees, electric poles, fencing poles etc. in the direction of the slope. It can be illustrated as below.

b. **Solifluction:**

this is limited to glaciated regions of cold climatic zones or areas. Solifluction refers to the slow movement of saturated solid gravel materials underlying a frozen ground on a moderate slope. It can be illustrated as below.

c. **Talus creep:**

this refers to the slow movement of angular wastes or particles of all sizes on a moderate slope.

Illustration.

<u>Fast or rapid movements.</u>

Mud flow: this refers to the fast downhill movement of semi liquid material saturated by heavy rains on a moderate slope.

Illustration

Rock falls: this refers to a very fast movement of individual rocks falling freely from a very steep slope under the influence of gravity.

Illustration

Rock slump: this refers to a very fast movement of rocks on an over steepened slope like scraps, creeps and road cuttings. In slumping, a rock doesn't break up into different particles in the process of slope failure but the materials just slide as a whole mass. It moves in a back ward rotation such that the slump strata which was originally horizontal is tilted backwards. Slumping is mainly caused by massive rocks overlying weak rocks.

Rock slide: this refers to a fast movement of large masses of rocks and debris over a steepened slope and road cutting. Here, the rocks slide from faces of slope or jointed steep slope downwards.

Illustration

Avalanches: this refers to a large scale movement of materials embedded in ice. It's also a fast movement.

NOTE: the rapid movements of materials down the slopes usually involving large boulders and rock particles is sometimes called ***Landslides.***

CAUSES OR FACTORS THAT INFLUENCE THE RATE AND NATURE OF MASS WASTING

Climate: some areas in east Africa experience heavy rainfall sometimes exceeding 2000mm per year which leads to the absorption of water by the soils or rocks. This leads to the increase in weight of the soils and rocks and also reduces the cohesion of the material in the mass of the rock. Therefore, the loose rock materials can easily slide downhill under the influence of gravity.

Secondly the pounding effect of direct rainfall destabilizes the rock surfaces resulting into mass wasting.

Temperature fluctuations results into expansion and contraction of rocks which results into weathering of these rocks. The loosen particles can the easily fall down under the influence of gravity.

Relief / nature of the slope. Steep slopes usually encourage fast or rapid movements of materials downhill e.g. rock slides, rock falls, rock slumps etc. due to the steep gradient. Gentle slopes on the other hand lead to limited mass wasting and also encourage slow movements e.g. soil creep, solifluction etc.

Nature of the rock. The structure, permeability or porosity of the rock and its jointing determine whether mass wasting will occur or not. Highly jointed rocks are prone to rock falls. This is because jointed rocks are easily affected by physical weathering involving block disintegration. The loose blocks of rocks can easily slide down wards or downhill in form of rock falls.

Where a permeable layer of rocks over lie an impermeable layer, the saturated permeable layer can easily slide downhill under the influence of gravity.

Nature of soils. Clay soils become slippery after absorbing water. The absorbed water increases the weight of the soil and also lubricates it and the ground where it's seated i.e. between the soil and ground hence facilitating downhill movement.

Loose sandy soils are affected by increasing temperatures. The temperatures turn the sandy dust which can easily creep downhill.

Earth movements (crustal instability). Areas in east Africa which are affected by increasing landslides are the ones that are prone to the occurrence of the earth's movement is greatest for example earth quakes and earth tremors, volcanicity etc... these destabilize loose particles of rocks and weathered rock materials resulting into mass wasting.

Over steepening of the slope by either river or lake erosion. Lakes may lead to the creation of cliffs due to wave erosion. This over steepened cliff can facilitate mass movement of weathered materials.

Over loading of the slopes by weathered materials where the excess load can easily be destabilized hence fall off by the influence of gravity.

Heavy moving objects like lorries, heavy machinery like trains cayuse vibration of the earth's surface that trigger off mass movements.

Human activates like mining, quarrying, road construction, grazing of animals on steep slopes, lumbering in mountainous areas etc. result into destabilization of loose rocks on steep slopes resulting into landslides and rock falls.

Effects of living organisms e.g. barrowing animals like rats which loosen the rocks and the soils resulting into weathering which eventually makes the rocks prone to mass wasting. Wild animals grazing in mountainous areas trample on the surface and cause vibrations hence disturbing unconsolidated rock materials and finally results into landslides.

EFFECTS OF MASS WASTING

Loss of lives. Severe landslides especially those associated with heavy rains and earth quakes result into rock falls and rock slides that destroy settlements and kill people living in s uch settlements like on the lower slopes of mountains like the Bulecheke landslides in 1996 killed about 100 people, in Buhweju many people were killed by the landslide s that occurred in May 2002, 2010 and 2018 on the slopes of mountain Elgon.

Loss of property by the falling and sliding of rocks of various sizes. Many houses and settlements are normally destroyed for example in 1996 in Bundibugyo, a land slide occurred and destroyed several homes and properties for example roads, and electric poles connecting Bundibugyo to Fort Portal were destroyed and that from Kabale to Kisoro. Many crops and the would be agricultural land are often destroyed as they are buried by the debris from the upper slopes.

Destruction of forest resources. When a slope with forests fails, chances are that those forests are rolled down and totally buried and therefore destroyed for example the landslide that occurred in 1985 in Bundibugyo destroyed some good forested area in the Semiliki National Park.

It results into displacement and resettlement of people to other areas e.g. the recent transfer of people from mountainous areas of Elgon to Bunyoro. This resulted into loss of cultural identity as well as heavy government expenditure to resettle these people.

Mass wasting results into damming of rivers which may result into back ponding to form temporary water reservoirs or permanent lakes eh lake Bujuku on mountain Rwenzori, Lake Mbaka in southern Tanzania.

Results into exposure of fresh rocks to weathering.

Creation of landforms e.g. terracets, scars, etc. and this has promoted both local and foreign tourists who earn the government income.

Mass wasting results into the provision of fertile soils on lower slopes of hills, mountains by soil creep, exfoliation, etc. which has promoted agriculture in valleys e.g. vegetables growing in the valleys of kigezi.

MEASURES TO REDUCE LANDSLIDES OCCURRENCE

Among the measures taken to combat the problems of landslides' occurrence include the following;

Re- afforestation and afforestation. Planting of tress on the slopes where the trees were cut should be done in order to increase the cohesiveness of rocks. This has been on the slopes of the Kigezi highlands where eucalyptus trees have been planted. The government should establish forest reserves on the slopes and protect them against people's encroachment. This helps to increase the firmness on the slopes and reduces the chances of landslides to occur.

Hillslope drainage. A lot of water on the slopes increases the lubrication, saturation and weight levels of the rock particles on the slope which accelerates the chances of slope failure and landslides. This therefore means that excess water should be drained away through the drilling of pine lines on the slopes or construction of deep channels or trenches. This has been done on the Kenyan and kigezi highlands.

This can also be done through the planting of eucalyptus trees so that they can drain away the excess water on the slopes of highland areas.

The government should come in to stoop people form cultivating on the slopes of mountains and highland areas like on the slopes of mountain Elgin, the kigezi highlands among others whose stability is doubtable. This will help to reduce the chances of landslide occurrence and their associated impacts on the environment and people.

(research for other measures)

Revision questions

1. **With reference to specific examples from East Africa, examine the causes of mass wasting**

Approach

Define mass wasting and site the areas prone to mass wasting in East Africa.

Identify, explain and illustrate the various forms of mass wasting (both the slow and fast movements)

Give and explain the causes of mass wasting linking them to various types of mass wasting

2. **To what extent are the various forms or processes of mass wasting influenced by climate in East Africa.**

Approach

Define mass wasting and site areas prone to mass wasting in East Africa.

Identify, explain and illustrate the various forms of mass wasting (both the slow and fast movements)

Thoroughly explain the influence of climate on mass wasting

However, …………. give other factors

Give an evaluation or conclusion

LAKES IN EAST AFRICA

A lake is a large body of water that occupies a basin or hollow on the earth's surface. Some lakes are big and others are small. Some are permanent and others are seasonal. For a permanent lake to form, the following conditions must prevail;

- The hollow or basin must be deep enough so that it can store a sizeable amount of water.
- For it to remain permanent, there must be a fill or supply of water permanently inform of rainfall or inform of inlets like streams and rivers.
- The nature of the hollow is also important in that if the hollow is made of permeable rocks, the lake will not remain permanent but instead water will sip through the beds of rocks and eventually the lake will dry up. Therefore, the depression or lake should have impermeable lakes.

Although the above factors may exist in a particular hollow, the volume of water may fluctuate because of other factors like evaporation rates, number of outlets inform of rivers or streams and rainfall seasonality thus the occurrence of seasonal lakes for example lake Chad whose waters decrease drastically during the dry season.

CLASSIFICATION OF LAKES

Lakes can be classified according to the make or origin of formation of the hollow or depression which is alter filed by water to form a lake. The origin might be due the earth movements both endogenic processes like faulting, volcanicity, warping etc. and exogenic processes like erosion, deposition, glaciation among others.

The various types of lakes include

1. **Lakes formed as a result of faulting**
   a. **Rift valley or Graben lakes**

These are lakes that are formed from the earth movements associated with faulting across a rift valley. After the formation of a rift valley, **secondary or further faulting** occurs or takes place on some parts of the rift valley floor making them to be faulted further and therefore are lowered compared to other parts of the rift valley. After these depressions are filled with water and a rift valley lake is formed. Rift valley lakes are steep sided, elongated, deep and narrow for example lake Albert, Tanganyika, Malawi, Turkana, Magadi, Naivasha.

It can be illustrated as below

   b. **Tilt block lakes**

These are formed during block tilting. Some blocks are raised to form angular ridges while others are lowered to form depressions. Water is then collected within these depressions to form tilt block lakes for example lake Ol-bolassat on the western Abadere ranges in Kenya.

2. **Lakes formed due to crustal warping**

These lakes are generally large in size and are shallow. They were formed by uplifting of the western and eastern arm. This was followed by down warping of the central part due to convective currents which caused a depression in the middle of the two lifts. The up lifts caused the reversal of rivers like Kagera, Katonga and Kafu and flowed back into the crustal depression thereby filling it with water. On the eastern side, rivers like Nzoia were reversed and flowed backwards into the depression hence leading to the formation of crustal warped lakes. Examples include Lake Victoria and lake Kyoga.

Illustration

3. **Lakes formed due to volcanicity**
   a. **Crater lakes. A** crater lake is a steep sided depression with roughly a circular appearance. It is formed as a result of an explosive eruption that blows off the top part of a volcano creating an opening called a crater. When it’s filled with water, it then forms a crater lake. A crater lake stretches to about 500m in diameter.

   b. **Explosion crater lakes**
   An explosion crater is a shallow flat floored depression which is surrounded by a low ream of pyrocrasts and local rock. Craters are usually less than 50m deep. Explosion craters may appear singly or in groups. There formation cab be described basing on two theories;

The first theory states that a crater may be formed as a result of explosive eruption which blows off the upper part of the earth's surface creating a small depression called a crater.

The second theory states that as magma is poured onto the earth's surface from the earth's interior, a chasm (empty space) is created and with the weight of the material, the volcanic plug sinks in creating a depression called a crater. This process of sinking is called cool drone subsidence. Examples include Lake Kigere and Nyabikere in fort portal, lake Nyamunuka, Rutoto in Rubirizi and lake katwe in kasese

c. **Caldera lakes**
A caldera is a wide depression or a big crater which is formed by either explosiveness of an eruption which causes the top part of the volcano to be blown off or the subsidence of the top part of a volcano into a chasm that has been left behind by magma erupting on top of the earth's surface. When it's filled with water, a caldera lake is formed for example lake Ngonzi in southern Tanzania, Suswa in Kenya, Ngorongoro in Tanzania. It should be noted that calderas extent to almost 1 km in diameter.

d. **Lava dammed lakes**
These are formed when basic lava from a volcano flows down the foot hills and finally blocks a river and reduces into back ponding or damming. As a result, water accumulates and a lake forms. Examples include lake Mutanda, Bunyonyi among others in south western and lake Saka at Nyakasura in kabarole district Uganda.

4. **Lakes formed due to glacial activity**

a. **Cirques lakes/ corrie lakes/ cwm lakes/ tarn lakes**
These are semi-circular steep sided rock basins which have been cut into the sides of a glaciated mountain. It is formed when water enters the rocks and freezes breaking them down. The joints become enlarged. Abrasion drags the debris over the rock floor deepening the depression, back wall cutting or recession also enlarged the depression as well as steepening the sides. Plucking also steepens the cirque, when filled with water, it forms a tarn (lake) such as teleki and mawenzi on mountain Kenya and Kilimanjaro respectively. Others are Lac du Noah, Lac du Catherin and Lac du vent on mountain Rwenzori.

b. **Rock basin lakes**

c. **Moraine dammed lakes**
These are formed by deposition of terminal moraine across a river valley. Terminal moraine may dam a river making water to accumulate back and forms a lake for example lac Gris on mountain Rwenzori

d. **Kettle lakes**
Kettle lakes are formed when the mass of ice enclosed in a terminal melts creating a depression on top of a terminal moraine.

5. **Lagoon lakes**
Lagoons are described as lakes. They tend to be shallow and originate from the growth of a barrier or spit across a bay. The spit cuts off the water in the bay from the main water body thus enclosing some parts of the water forming a lake. Examples include Lake Nabugabo which was

cut from Lake Victoria. These lakes are normally by swamps like lake Nabugabo is surrounded by Lwamunda swamp.

6. **Lakes due to river action**
   a. **Ox bow lakes**

   b. **Delta lakes**

7. **Lakes due to wind deflation**

8. **Lakes due to solution**

9. **Lakes due to landslides/ mass wasting**

10. **Man-made lakes**
    Numerous lakes in East Africa have come into existence through man's activities for example man has dammed rivers to create water reservoirs for irrigation. Man has dug valley dams to store water for irrigation, animals and for fishing activities such as Lake Kibimba, others are traced on river pangani in Tanzania.
    Man has dug lakes for cultural purposes like Kabaka's lake in Mengo, Kampala. Others are depressions that have been left behind by the mining process and have been filled with water to form lakes for example in the areas of Kajjansi along Kampala-Entebbe road. Others are dug for religious purpose for example the martyrs' lake at Namugongo

GLACIATION

This is the process by which glaciers shape the earth's surface. Or it can be defined as the work accomplished by moving snow and ice. Glaciation is an important process which has affected the landscape in the mountainous areas with snow and ice. In East Africa, glaciation is taking place on mountains like Kilimanjaro, Kenya and Rwenzori.

Snow and ice can permanently occupy areas where;

- Temperatures drop to below freezing point such that snow and rain freezes to form ice.
- Areas which are highlands or mountains which rise above the snow line. In east Africa, the snow line starts at 5000m while in the temperate areas snow and ice can even form at sea level.
- It also exists in areas where snow falls (snow accumulation during winter) exceeds snow wasting during summer.

Glaciation is one of the denudation forces which takes place on top of the earth's surface. Glaciers pound the rocks as it passes over them or the materials being carried by the glaciers. This creates both glacial erosion and deposition features.

In east Africa, glaciation can only take place on very high mountains that rise above the snow line at 5000m namely mountain Rwenzori, Kenya and Kilimanjaro. On mountain Rwenzori, there are 37 glaciers e.g. stanely, speke, Bujjuku, Mubuku, Edward, Backer, Moore etc.

Mountain kenya has the second largest coverage of glaciers and best examples here include lewis, Gregory, krapf, dawin, tyndal, ford, diamond, heim etc.

On mountain Kilimanjaro glaciers include kibo, great penk, furt wangler etc.

A GLACIER

A glacier is a mass of moving ice which moves down slope along a pre-existing river valley under the influence of gravity. Glaciers move continuously from higher to lower ground and is enclosed within valley walls.

Formation of glaciers.

When the temperatures in an area fall below 0^0, water vapor in the atmosphere condenses to form snow. The snow accumulates in pre glacial hollows. Under pressure, the air in it escapes melting and freezing occurs. Further compaction expels all the air and the bottom layers are compacted into ice. With time under the influence of gravity, the ice moves out of the hollow and is now known as a glacier.

Illustration.

Glaciers can retreat or advance depending on the balance between winter accumulation and summer wastage.

Types of glaciers.

a) **Valley glaciers**; these are formed on highland or mountain peaks and upper valleys of mountain ranges. Valley glaciers move by sliding over the rock surfaces. Friction with the ground produces heat that in turn melts ice and helps to lubricate the sliding process.
b) **Lowland glacier**; this is a glacier found in colder and higher latitude mainly between 60° latitudes and the poles. They are mostly found in Greenland, Arctic and Antarctica

Moraine

Is the material that is transported and deposited by the moving ice or glacier. Its composed of rocks, gravel, sand and huge boulders. Moraine carried at sides is called lateral moraine, moraine called in the middle is called medial moraine and the moraine at the top is debris called as terminal moraine.

Illustration.

Snowline

Is the height above which is always permanent snow or above which snow doesn't melt. In east Africa it is found at 4700m above the sea level, Greenland it's at 650m and at the poles it's at any height above sea level.

REASONS FOR LIMITED COVERAGE OF GLACIERS IN EAST AFRICA.

Latitudinal location of east Africa. Latitude refers to the distance from the equator. East Africa lies along or astride the equator at approximately 5 degrees north and south of the equator. For this reason, whether the apparent overhead sun shifts north or south, the angle of incidence of the solar rays is still small. So the sun rays strike the earth's surface at a wide angle and at a short distance hence ensuring maximum solar heating throughout the year. This implies that the temperatures in east Africa are high throughout the year. Therefore, its only in highland areas which rise above the snowline where temperatures drop to below freezing point that enables glaciers to form. However, these are very few areas where temperatures can drop below zero degrees hence limited coverage.

Altitude. East Africa lies on a raised plateau rarely rises above 3000m above sea-level. So very few areas in East Africa rise to the current snowline of 4800m above sea level hence the limited coverage of glaciers in East Africa.

Precipitation. East Africa generally receives moderate rainfall of between 1000 to 1500m per annum. This is just sufficient to sustain life. However, glaciers form in areas where temperatures drop below freezing point and with torrential rainfall.

Mountain Rwenzori has the highest number of glaciers although it's the shortest among the three glaciated mountains in east Africa. However, it receives cool moist winds from Congo basin and the Atlantic Ocean which are forced to rise, cool and condense to form clouds hence giving torrential rainfall and very low temperatures hence glacier formation.

The highest is mountain Kilimanjaro but with the smallest coverage of glaciers due to the influence of the warm dry winds which brings about a warming effect and low rainfall.

Global warming. The world temperatures have been rising with time and this is attributed to human activities like burning fuels e.g. coal, oil and natural gas which increases carbon-dioxide concentration in the atmosphere and other greenhouse gases. These gases absorb a lot of heat from the sun during day and prevent heat loss at night (they act as a blanket). This accounts for the increase in the global temperatures by 2.5°C. this increase in temperature has led to the melting away of glaciers to the point of extinction of some glaciers e.g. the sempaya glaciers on mountain Rwenzori.

Aspect. This refers to the angle at which the slope receives the sun's insolation. East Africa lies between the tropics and therefore experiences direct over sun throughout the year. This implies that all slopes of the mountain are subjected to at least 10 hours of great sunshine a day without any sheltered slope or obstructed slope to enable glacier formation.

All the precipitation received in east Africa is in form of rainfall but not snow. This also explains the little coverage. In the few areas where temperatures drop to below freezing point, rain water has to be first frozen to ice which is a long process.

Impact of volcanism. Some of the high mountains where glaciation would have taken are volcanic in nature. The temperatures in these mountains are high due to the hot interior which brings about the warming effect on the surroundings. This is therefore preventing glacier formation.

LANDFORMS RESULTING FROM GLACIAL EROSION.

Glacial erosion occurs through the following processes;

Plucking or exaration.

It is the tearing away of the blocks of rocks which have become frozen into the sides and bottom of a glacier (glacial depressions).

Abrasion.

It's the wearing a way of rocks underneath a glacier by the swirling of rocks embedded in glaciers. In this process, the glaciers use the materials being carried or transported as the grinding tool which is used to break up rocks along the floor and sides of the glacier trough. The flow is swapped and polished creating deep grooves deepening the valleys on the relative hardened rocks and that of the rock floor.

Sapping.

This involves the breakup of rocks by alternate freezing and thawing of water at the bottom of cracks between a mass of ice on the sides and floor of a valley or the side of a mountain.

GLACIAL EROSION FEATURES / GLACIAL UPLAND FEATURES

CIRQUES/CORRIE/TARNS/CWMS.

These are semi-circular steep sided rock basins which have been cut into the sides of a glaciated mountain. It is formed when water enters the rocks and freezes breaking them down. The joints become enlarged. Abrasion drags the debris over the rock floor deepening the depression, back wall cutting or recession also enlarged the depression as well as steepening the sides. Plucking also steepens the cirque, when filled with water, it forms a tarn (lake) such as teleki and mawenzi on mountain Kenya and Kilimanjaro respectively. Others are Lac du Noah, Lac du Catherin and Lac du vent on mountain Rwenzori.

illustration.

Pyramidal peak /horn

this is a jagged peak formed by the steepening of the back walls of several cirques which lie on the sides of a glaciated mountain. Two or more cirques cut back into the original mountain sides leaving an isolated peak called a pyramidal peak. These peaks become shaped by frost action. Examples include kibo, mawenzi on mountain Kilimanjaro and margarita peak on mountain Rwenzori.

Illustration.

Arête.

This is a sharp knife like feature or narrow ridge in between two or more cirques on the mountain sides. It's formed when two or more cirques erode backwards (back to back) in the process of head Wall recession. The wall between the cirques collapses by sapping. Best examples can be seen on my Rwenzori from Mount Backer up-to bujuku Valley and point John and midget peaks on mountain Kenya.

U-shaped valleys or glacial troughs.

These are broad flat bottomed steep sided valleys with an open u shape in the cross profile. These were usually former river valleys which are filled by glaciers. Through the process of abrasion, plucking and sapping, the valley floor and sides were worn away hence deepening and widening the valley. So the valley is changed from a V-shape to an open U-shape hence its name. within this widened Valley or trough are a number of other landforms for example rock steps, moraine materials etc.

Examples of u shaped valleys include Mubuku valley, bubusu Valley and komusonso valleys on mountain Rwenzori, hobley and teleki valleys on mountain Kenya and the karanga through on mountain Kilimanjaro.

Illustration

Hanging valley

These are small narrow short and V-shaped valleys found in highland areas through which river glaciers from the cirque pass. Hanging valleys are tributary valleys of the U-shaped valleys joining the U-shaped valleys at vertical slopes forming water falls at that point. For example, nithi river is joined by the little nithi from a hanging valley on mountain Kenya.

Truncated spurs

Interlocking spurs of a former river valley are cut off by lateral erosion resulting from accumulated glaciers in the valley forming a U-shaped valley with Truncated spurs instead of interlocking spurs for example around Mubuku and bujuku Valleys on mountain Rwenzori.

Rock basins

These are depressions that are filled with water to form lakes along the glaciated Valley. They are formed by glaciers when they scoop out rock protrusions along its paths to form hollows which are filled by water to form rock basins.

similarly, the path of the glacier may have rocks of different types and resistance to weathering and erosion. Where a band of soft rocks Alternate with bands of hard rocks, the soft rocks will be worn out to form a depression which is filled by water to form a basin lake. Best examples include lac Michaelson on mountain Kenya, Lac nour and Lac vert in the kamusoso valley on mountain Rwenzori.

Illustration

Rock steps.

These are hard rock projections in the glacial valley forms as a result of differential erosion due to difference in rock resistance and variation in glacier thickness. The increased ice in the main valley makes it possible to cut deep in the valley creating step like features known as rock steps for example at Vivian falls on mountain Kenya
illustration.

Crag and tail.

This is an elongated rock mass with a steep slope on the upstream which protects the softer lee ward rock from being eroded or worn out by the glacier. Its formed when advancing ice meets a resistant rock protecting a weaker rock downstream from erosion leading to the formation of an elongated tail on the side of the weaker rocks while the resistant rock mass forms a crag with a steep slope.

Illustration.

Rock montane.

These are rock masses glacially molded with a smooth gently sloping up stream, smoothen by abrasion of ice. The downstream is steep and rough due to plucking of ice. Examples can be found at the mobuku valley along the slopes of mountain Rwenzori and along the George valley on mountain Kenya.

Question

1. Account for the formation of upland glacial landforms in east Africa.
   Approach
   Define glaciation
   Identify areas where glaciation is taking place in east Africa
   Factors or conditions for the formation of glaciers.
   Processes of glaciation
   Identify and describe the landforms

2. Describe the processes responsible for the formation of glacial erosion landforms in east Africa

Glacial deposition – landforms formed due to glacial deposition

Glaciers transport a variety of materials ranging from fine rock flour to large boulders. All these materials are deposited in the valleys just beyond the point of melting and can modify the landscape markedly. Glacial depositional landforms are mainly found in the lowlands in the lower slopes of the mountains I.e. the valleys. The moraine transported and deposited by the glaciers results into the formation of depositional landform and these include:

Moraine

This refers to the rock debris that is eroded by flowing ice from the sides and base of the valley and deposited in the low lying areas. Moraine are large and small fragments that are detouched, transported and deposited when ice losses it's capacity to transport the materials.

Terminal moraine

It's a ridge like feature formed by accumulation of unsorted fragments of all sizes extending across the country rocks as a belt of low hills for many kilometers. It's formed by extensive deposition along the snout of an ice sheet and may cover a reasonable distance and height of 50 meters. It builds up when the glacier is static. At this point there is a balance between the amount of ice coming and the ice melting away. Melting ice Carries away materials which are finally laid beyond the terminal moraine as out wash plain. Examples can be seen in the low lying areas of Rwenzori i.e. bujuku, Mubuku valley kimberly plains of South Africa etc.

Lateral moraine

This is an elongated ridge or moraine formed along the valley glacier sides. The deposition is as a result of friction between the moraine and the valley sides.

Medial moraine

When two glaciers meet, the lateral moraine of the inner sides of both glaciers are joined to form medial moraine. Medial moraine forms at the center of the glacier when a glacier retreats and drops it's moraine.

Ground or basal moraine.

This is formed when moraine is deposited at the bed of the glacier. It's composed of mainly fine glacial moraine dropped by retreating ice. Ground moraine almost covers the whole width of the valley.

Illustration

Borders or erratics

These are rock fragments of varying sizes which are eroded, transported and deposited in areas where they are far different from the surrounding rocks where it's deposited. They are useful in determining the direction and source of ice movement. However subsequent erosion has pasted these rocks together to an almost level ground and they are known as perched blocks. Best examples can seen at kamusoso and bujuku Valleys on mountain Rwenzori in western Uganda.

Till plains.

These are extensive areas of monotonous relief or landscape formed when moving Ice transports boulders and clay hence burying former and hills e.g. teleki valley on mountain Kenya and Mubuku valley on mt Rwenzori.

Illustration

Eskers

These are long winding steep sided ridges of sand and gravel lying parallel to the direction of ice movement. They are more than 30 meters high and several kilometers long. Sometimes they are formed by rivers flowing beneath or within ice. they develop on areas of stagnant ice where rivers maintain sub glacier tunnels.

It's process of formation is attributed to stagnant ice sheets under hydrostatic pressure hence the ice develops melt water streams flowing with in the ice following permanent sub glacial tunnels thereby deposition takes place within the tunnels. When the ice finally melts, it leaves behind long and steep sided ridges known as Eskers.

Drumlins

These are low, rounded and elongated hills composed of bolder and clays lying parallel to the direction of ice movement. They are usually about 30m high and cover an area of up-to 1km. Drumlins occur till plains in large groups or swarms aligned to the direction of the former ice advance. They are mostly formed when fragments or ground moraine are compressed by ice movements. Best examples are to be found in the teleki valley on mountain Kenya.

Illustration.

Out wash plains

These are wide gently sloping plains of gravel, fine sand and silt. They are formed due to enormous volumes of melt water spreading volumes of sorted materials in great ferns beyond the ice front. Braided strolls drop coarse gravel first and then fine sand, clay and silt are deposited last. Best examples can be seen at kibo and mawenzi on mt. Kilimanjaro, Mubuku and bujuku Valleys on mt. Rwenzori.

Kettle holes

these are circular holes in glaciated drift. Kettles are depressions formed when an ice block is detached from the main glacier as it retreats. Such a block is then buried within the till by fluvial glacial deposits. The subsequent melting of Ice blocks leaves behind depressions to form kettles. when water collects in these depressions, they form kettle lakes.

Kame moraine

These are irregular mounts of bedded sand and gravel deposited randomly. They are arranged in a chaotic and complicated or un uniform manner. The process of development is attributed to melt water from long stagnant and slowly decaying ice sheet.

ECONOMIC IMPORTANCE OF GLACIATION OR GLACIATED REGIONS TO THE PEOPLE OF EAST AFRICA.

Melt waters from glaciers form important sources of rivers used for various uses e.g. the chagga on the slopes of mountain Kilimanjaro use it for irrigation.

The water falls formed at the hanging valleys are potential sites for hydroelectric Power generation e.g. at Corinne falls on mountain Kenya.

The beautiful scenery provided by glaciated landforms such as arêtes, pyramidal peaks etc. attract tourists who bring in foreign exchange.

The moraine deposited contains sand and gravel which can be extracted for building and construction purposes e.g. in kasese.

The boulder clay plains in the glaciated low lands are sometimes very fertile and suitable for agriculture especially arable farming e.g. in the mobuku valley on the lower lands of mountain Rwenzori.

Glaciated areas may act as recreation and Sports centers for example mountain climbing

The U-shaped valleys form natural routes or ways for mountain climbers on the mountainous lands.

Negative

Glaciers which move downhill lead to extensive loss of property e.g. on the low lands of Rwenzori

Extensive areas are turned into myriads of lakes by moraine deposits. Such landscapes offer little scope for development by man.

Upland glaciation has removed most of the fertile top soil making the region unstable for agriculture.

RIVERS AND DRAINAGE PATTERNS

A river is a body of flowing water which transports dissolved substances and particles along a well-defined channel. Rivers are important aspects of the earths structure leading to the development of landforms.

River sources.

These are the origins of the rivers and are mostly found in highland areas of high rainfall or some rivers have their origins from underground springs, a marsh, spring, at the end of a glacier, lakes or as a collected surface run off of rain water.

River mouth

This is where the river ends its course of flow. These are normally lakes, seas or oceans. A river enters its mouth via a delta, estuary or otherwise.

River profile.

This is the outline or shape of the river valley and there are two types of profiles namely

a) **A cross profile**

This is the shape of the river valley from one bank or side to another. It can be v-shaped or u-shaped or open shaped.

Illustration

b) **The long profile.**
This refers to the shape of a river from the source to the mouth. It is a concave shaped and its divided or sub divided into youthful, mature and the old stage.
Illustration.

Stages of river development or development of a river valley.
a river develops its long profile by head ward erosion while its cross profile is developed by lateral and vertical erosion.
A river valley develops in three stages namely;

- The youthful stage (young / upper course)
- The mature stage or middle stage
- The old stage / lower course

The youthful stage

This normally takes place in the upper section of the long profile of a river valley. It displays the following characteristics;

- The river has a narrow v-shaped valley. In this case, the river covers the whole floor of the valley. The valley is made deep by vertical erosion.
- The river has a steep gradient.
- It flows at a very fast due to the steep gradient.
- The river forms waterfalls and rapids
- It has a small channel and many short tributaries.
- Its characterized by landforms such as inter locking spurs, waterfalls, rapids, plunge pools, v-shaped valleys, etc. e.g. at river Nyamwamba on the slopes of mt. Rwenzori.

Illustration

The middle stage

In the middle stage, a river develops mature features and the valley becomes due to lateral erosion. The middle or mature stage has the following characteristics;

- The river occupies a more open valley (U-shaped valley)
- The gradient of the river is lesser steeper and becomes more gentle.
- The speed of the river reduces due to the reduced river gradient.
- Meanders and river bends begin to develop.
- The load consists of rounded boulders and small stones.

Generally, the mature stage is characterized by lateral erosion, transportation and deposition which makes the river to develop a gentle slope.

Illustration

The old stage / senile stage of a river.

In the old stage. The river develops the following characteristics;

- The river valley is very wide and flat forming a flood plain.
- The river flows very slowly.
- The main work of the river is that of deposition since it has very little energy.
- The meanders are very pronounced.
- Most of the load is composed of sand and small particles.
- The landforms in this stage include flood plains, ox-bows, braided channels, deltas etc.

FEATURES / LANDFORMS FORMED ALONG A RIVER PROFILE OR RIVER VALLEY.

There are both erosional and depositional landforms

River erosion

A river erodes its bed and banks to form landforms through the following processes using its load it is carrying.

Processes of river erosion.

- **Hydraulic action;** in this process, the force of moving water sweeps out loose materials along the sides and floor of a river channel and water can surg into cracks of rocks hence helping in the break up in the breakup of solid rocks.
- **Corrasion or abrasion;** this is where the load eroded and carried by the river acts as a grinding material tool. Large rock debris carried by the river pound the sides and the floor of the river channel hence cutting potholes along the river floor. So the load itself being carried by the rivers becomes the corrosive or grinding agent.
- **Attrition;** this involves the wearing down or breaking of the load itself due to the collision of the load fragments against each other and with the river bed. This leads to the reduction in the size of the load or materials as its being carried downstream.
- **Solution/corrosion/chemical erosion;** this occurs in areas where the rocks are soluble eg limestone rocks are eroded or removed by the water in solution form and no fragments remain. This is also common in areas with salt rocks.

Features resulting from river erosion.

- ✓ V-shaped valleys
- ✓ Waterfalls
- ✓ Rapids
- ✓ Interlocking spurs
- ✓ Plunge pools
- ✓ Potholes
- ✓ Gorges

V-shaped valleys

These are valleys in the upper course of the river that have been undercut by vertical erosion. The rocks in the bed are always softer than the side rocks hence promoting more vertical erosion than lateral erosion. This results into the formation of a narrow V-shaped valley. Best examples can be found on river mubuku, Nyamugasani all on mountain Rwenzori.

Illustration

Waterfalls

A waterfall is a sharp break in the river channel's bed over which the river flows. It's found in the youthful stage of the river. It can be formed where vertical or horizontal bands of hard and soft rocks lie across the river bed. The soft rocks upstream are protected by the vertical band of the hard rocks across the river bed. The soft rock downstream is in low in height therefore forming a waterfall eg sezibwa falls near lugazi and sipi falls on river sipi in kapchorwa.

Illustration

A rapid

If the band of a hard rock is steep or slanted across the river bed but not vertical, then a rapid will develop eg at bujagali

Illustration.

Plunge pool.

This a broad depression formed at the base of a waterfall or an enlarged pot hole formed due to progressive drilling and grinding of the valley floor. Its formed on rivers with valleys in the youthful stage pf a river. The conditions necessary for the formation of a plunge pool include;

- A large volume of water
- Great erosive power of the river due to the steep gradient.
- The availability of the load being carried by rivers which act as a grinding tool of the surrounding rocks (abrasive media)

In its formation, falling water from a cliff cuts pot holes at the base of the waterfall. Then strong eddy currents swirling and erosion collectively enlarge potholes to produce plunge pools.

Best examples are at murchission falls, sezibwa falls, sipi falls in kapchwora and kisizi falls in Rukungiri.

Illustration.

Interlocking spurs. (for the diagram refer to the youthful stage of the river)

Interlocking spurs are termed as river twists and twins around obstacles of hard rocks along the channel. This results into the river taking a winding course. In the bends, there is more erosion on the concave banks which eventually causes projections of highlands called spurs. They alternate on either sides of the river to interlock hence they are called interlocking spurs.

Gorges and canyons.

A gorge is a steep sided hollow in depth as compared to its width. A river gorge is found where fluvial erosion cuts more rapidly than the forces of weathering can wear back and opens up the sides. Gorges can also occur where a river follows lines of weaknesses eg a fault line hence the river cuts vertically deeper into the rock than the sides hence creating a deep steep sided valley into which a river flows.

A gorge can also be formed in resistant rocks where there is vertical erosion in the center of the river valley so that the sides stand up steeply. Best examples can be seen at kyambura gorge in Queen Elizabeth national park, at Murchison falls on the Victoria Nile as it enters lake albert and the great Rucha gorge in Tanzania.

Illustration.

FEATURES FORMED BY RIVER DEPOSITION

CAUSES OF RIVER DEPOSITION

A river will deposit its load when the following occurs along its course;

- Drop or fall in gradient; when the gradient drops, the speed of the river reduces. It therefore has no energy to prevent its load and deposition occurs.
- Increase in channel width; when a narrow river valley becomes very wide, the energy of the water in the river reduces and deposition occurs.
- Excessive evaporation in an area due to high temperatures eg in an arid area will reduce on the volume of water therefore reduces the energy to carry the load hence deposition.
- Friction; when the river bed and channel become rough due to rock out crops and potholes, there is an increase in friction and the load is trapped and laid down or deposited.

LANDFORMS CAUSED BY RIVER DEPOSITION

- ✓ Leeves
- ✓ Differed tributaries
- ✓ Braided channels
- ✓ Flood plains
- ✓ Ox bows
- ✓ Alluvial funs
- ✓ Deltas

Leeves

Leeves are exercised banks built by a river on the sides of the channel. They are usually only about one-meter high. When a river floods, the water level rises and it over flows its channel. Friction between the water and the banks causes the river to deposit its load to form a raised bank known as a leeve. They usually encourage the formation of swamps in the flood plain since not all the water is able to return to the main channel when the floods subside eg leeves are found along river Malaba in eastern Uganda.

Illustration.

Differed tributaries.

When leeves are formed on the banks of a river, they make it difficult for the tributaries to join the river they therefore flow by the sides of a river for several kilometers. They are therefore known as deferred tributaries and where they join the river is known as deferred confluence.

Illustration.

Braided channel

This refers to a wide, shallow river channel in which the river divides and subdivides itself into a number of interconnecting channels separated by sand banks and islands of alluvium. The sand bars and main channels may disappear during floods since they sub merge.

River braiding occurs after the deposition of large quantities of course materials eg sand and gravel on the river bed. These gradually increase and form islands which the river dodges by subdividing into small channels hence forming braided river streams.

Illustration.

Meanders

These are curved bends of a river's channel which continuously swing from side to side in wide loops. They form in both the mature and the old stage of a river. Meanders are largely due to the river's load its carrying and the low gradient which leads to deposition of the load. They are formed by alternate under cutting and deposition leading to formation of concave and convex river bends. The constant erosion of the concave banks which produce a river cliff and the deposition on the concave banks forms a slip off slope.

Best examples can be seen on river Rwizi in Mbarara, R. Mpanga in fortportal, river semiliki etc

Illustration (leeve approximately 1 page for the illustration)

FACTORS / THEORIES / CONDITIONS FOR THE FORMATION OF RIVER MEANDERS.

I. **The obstacle theory;** this theory suggests that the presence of resistant rock outcrops along the river's channel may lead to a meandering river. Rivers tend to avoid resistant rocks and follow the soft rock regions there by forming meanders. This theory explains why river meanders may occur in the youthful stage of a river's long profile.

II. **Effect of river deposition**; when a river deposits its load on its bed, it will meander in order to dodge or avoid the materials it has deposited along its course. Therefore, rivers may meander in order to avoid obstacles of their own creation.

III. **Decreased gradient;** when the angle of slope reduces, the water in the channel decreases its speed due to flatness of the channel. This causes the river to meander in its plains trying to look for slopping areas.

Flood plains

This a wide flat plain of slope of alluvium on the floor of a river valley across which a river flows in a meandering / braided channel. In the old stage of a river, the gradient becomes flat or low, the river is carrying a lot of load which forces this river to deposit this excessive load along its channel over which it flows or sometimes dodges. Most flood plains are marshy with several swamps and small lakes.

A flood plain develops through the meandering of a river. As the river swings across the valley, it widens the valley floor. The valley sides and spurs are slowly worn back and with time a line of low bluffs or river cliffs is formed on the either side of the river plain. With time, the valley will become so wide, the alluvium deposited on the meander slip off slopes also called point bar deposits gradually joined up to cover the eroded valley floor with a layer of alluvium hence forming an alluvium plain / flood plain.

Illustration

Ox- bow

An ox-bow is a horse shoe shaped final section of a formerly pronounced meander which has been finally separated from the main river. If it contains water, it forms an ox-bow lake.

Ox – bows are formed along parts of the flood plain where meanders are sharp that only a narrow neck of land remains between the meander loops. During periods of floods, the neck may be broken through and the river may by pass the meander. Its eventually cut off by deposition at the old meander neck. If the ox bow lake is filled with alluvium, it will dry out hence leaving behind a meander scar. Best examples can be found at river Nzoi and Tana in kenya, River semiliki and Rwizi in western Uganda and R. Rufigi in Tanzania.

Illustrations

Alluvial fans

Its sometimes referred to as debris fun. Its defined as a fun shaped deposit left by a river as it emerges from a narrow valley onto a wide gentle plain. As the river flows down there is a sudden decrease in a gradient and an increase in the channel width which causes the river to deposit its load. An alluvial fun is therefore formed and their size ranges from a few meters to several meters. They are similar to deltas except that they are formed on land, examples are found in the Kilombero river valley.

Illustration

Deltas

A delta is a large flat low lying swampy plain characterized by presence of deposited materials, distributaries, small lakes and lagoons and vegetation and triangular I shape.

Illustration.

Conditions for the formation of deltas.

a. The river must have a large load
b. It must flow at a slow speed and allow deposition to occur in the river mouth.
c. The load must be deposited faster than it can be removed by the currents and tides in the sea.
d. It must not flow through a lake causing pre-mature deposition.

Process of formation.

As the gradient becomes low, the speed reduces and deposition begins to occur in the river mouth. The sediments collect on the continental shelf in layers and eventually a low plat form develops. When they appear above the water, the river splits up into several distributaries, spits and lagoons begin to form. The lagoons become filled with the sediments and swamps develop. As vegetation continues to grow in the swamps, they may disappear to form dry land.

Types of deltas

Arcuate deltas. This is the type of delta built by rivers with many distributaries carrying both fine and coarse materials. They are mostly composed of segments of gravel and sand. This type of deltas are in a triangular shape and rounded towards the sea. They have a number of tributaries for example rufigi delta in Tanzania, tana and yala in kenya, and semiliki delta at the southern tip of lake albert.

Illustration.

Estuarine delta.

This is a delta formed by rivers depositing materials in a submerged river mouth forming sand banks and islands around which wide several distributaries are formed.

Illustration.

Bird's foot delta.

This is formed by rivers carrying large loads of mainly fine materials into water where wave energy is low. A few very long distributaries boarded by leeves shoot out from the shore. It resembles a foot of a bird. Examples can be found at the mississippi delta, at river Nyando and miriu in kenya.

Illustration

Lacustrine delta.

Is an island delta formed on the bank of a lake eg; the albert Nile delta.

Illustration.

Importance of deltas

Deltas have fertile soils used for agriculture.

Deltas are also used for settlement e.g. Nile delta.

Deltas are also used for navigation e.g. Niger delta.

Deltas are used for fishing purposes e.g. Nile delta.

There is oil mining in the Nile delta.

Mangrove swamps in the Rufiji delta are used for building poles.

The papyrus swamps in them can be used for making hand crafts for example at albert Nile delta.

Deltas hinder the construction communication lines.

Swamps in delta also hinder settlement.

Delta areas are usually prone at flooding and can destroy people's property.

They harbor disease causing vectors such as snails and mosquitoes.

RIVER REJUVENATION.

This refers to the renewed erosive activity in a river valley. It is simply the revival of erosive power or activity especially by a river because of a fall in the base level or local movement of land uplift.

River rejuvenation may however occur without a change in the base level but when there is river capture or increase in the precipitation which increase the discharge and therefore greater eroding power to the drainage system. However, a positive movement of the base level ie a rise in sea level may produce the positive effect ie reduced erosive power, slow river movement and deposition of material along the river's course before reaching its mouth.

Rivers in east Africa that have experienced river rejuvenation include R. Nyando, Ngaila and Yala in kenya. River Rwizi, Birira, Mpanga and Kafu in western Uganda and this was due to uplift of the western rift valley shoulders of albert rift valley.

Causes of river rejuvenation

1. River capture; this refers to a situation where one powerful stream or river takes over the headwaters of another weak stream. This increases the volume of water in the river hence increasing its erosive activity.
2. Increase in the melting of ice on mountain tops (deglaciation) which leads to increase in the erosive power of the river because of the volume of water.
3. A general uplift in the land adjacent to the sea or in the middle course of the river caused by up warping. This leads to an increase in the gradient of the river channel due to tilting of the land leading to the formation of waterfalls at the mouth. Uplift of the land increases the speed, energy and the erosive ability of the river resulting into river rejuvenation.
4. A general fall in the sea level (ie a negative change in base level) which may be due to several factors like;
    - Sinking of the sea floor
    - Increase in the evaporation of water in oceans due to high rates of deforestation leading to global warming
    - Decreased cosmotic reactions ie reaction between oxygen and hydrogen over the oceans. When the level of the sea or lake falls, the river renews its down cutting until it adjusts to the new base level.

5. River damming which may be natural or caused by landslides which desilts the river and after this barrier of the dam, it will automatically have to renew its erosive activity.
6. Human activities like the digging of a big canal which pours into the neighboring stream which increases its stream volume of water hence renewed erosive activity.
7. Climatic factor. Increased rainfall in an area results into increase in the amount of water in a river resulting into undercutting of the stream.

Landforms formed by river rejuvenation.

These include paired terrace's, Knick points, incised meanders and valleys within valleys.

Such landforms have been formed through four main processes namely; hydraulic action, corrasion, solution and attrition as a river's erosive ability is increased.

Corrosion involves wearing away the river bed and banks by a river using its load like boulders, sand and stones as grinding tools. This happens when the load or boulders are swirling and grind the river bed to remove the rock fragments.

Solution involves the water washing away/dissolving away the permeable rocks like rock salts, limestone along its banks or bed. Such rocks are dissolved in the water and then washed away in solution form.

Hydraulic action is a process when a river erodes its channel and bed due to the force exerted on it by the weight of the water. Hydraulic action is most active on rocks which have been affected by weathering.

Attrition involves a double action of the load to erode the channel and also reduction in size they bump inti each other thus becoming easy for the river to transport.

Landforms.

Terraces. This is a steep like stretch cut along the side of a river valley in a flood plain. They are formed when a river increases its erosive ability as a result of a fall in the base level. Some parts of the flood plain are laterally eroded away while others may resist forming terraces. When the same process is repeated, again the river increases its channel deeper and again forms pairs of terraces. Examples are found on rivers like semiliki, Rwizi, Mpanga, kafu, Nyando, and Nyika.

Knick points.

A Knick point refers to the break pf slope in the long profile of a river valley. It marks the point where the rejuvenation started. If the base level falls, a break will appear in the slope of the long profile which will gradually work its way upstream. The position of the Knick point is characterized by a waterfall or rapids. The river's long profile may have several Knick points and some may persist for a long time.

Illustration.

Incised meanders;

This refers to the curved bend of a river that has been cut into the land's surface so that the river now swings between steep valley walls. Most of the incised meanders result from rejuvenation of an already meandering stream. There are two types of incised meanders namely;

- **Ingrown incised meanders.**

This is a curved river valley due to river rejuvenation such that it attains an asymmetrical valley cross profile. It has alternate steep sides with undercut slopes facing alternate gentle slopes. Ingrown incised meanders develop on resistant rocks and where the base level falls gradually. Best examples of ingrown meanders are on river rwizi in Mbarara and on R. Mwachi northwest of Mombasa.

Illustration.

- **Intrenched incised meanders.**

This is an undercut meander with steep sided symmetrical profile. This type develops on weak rocks and where the base level falls quickly causing rapid vertical undercutting. Examples are on river Mara and Kuja in western Kenya.

Gorge

Waterfalls

River drainage patterns.

A drainage pattern refers to the structural arrangement or layout of a river and its tributaries on the landscape over which they flow.

Drainage patterns are influenced by the rock structure over which rivers flow, the nature or type of the rock, amount of precipitation received in the catchment areas (sources). Drainage patterns can be divided into two;

- Accordant drainage pattern
- Discordant drainage pattern

Accordant drainage patterns.

This is where the river and its tributaries flow according to the slope of the land the dendritic drainage pattern, annular, radial etc. on the other hand**, discordant drainage pattern** refers to a situation where there is no systematic relationship between the river and the underlying rock type and structure.

Accordant drainage pattern

I. **Dendritic drainage pattern;** dendritic comes from a Greek word Dendron which means tree like. This is a tree-like pattern of drainage in which tributaries' coverage on the main stream from many direction and usually join the main river at acute angles i.e. less than 90 degrees. It develops in gently dipping areas which influence the speed of river flow.
   Illustration
   Conditions under which it develops
   - It usually develops in areas of homogenous rocks with the same resistance to erosion e.g. granite
   - It also develops in areas of gently sloping land
   - It develops in areas of heavy precipitation or rainfall.
   - All rivers and tributaries flow in valleys that are proportioned to their size.
   - The tributaries flow and join the main stream through head ward erosion eg R. Nzoia in kenya, river Athi, Nyendo in kenya, opethi and moroto in Uganda.

II. **Rectangular or trellis drainage pattern;** this is the drainage pattern where the tributaries join the main river at roughly right angles. Its formation is attributed to the following conditions;
   - Nature of the rocks. Trellis drainage pattern occurs in areas with alternating belts of hard rocks which lie at right angles to the general slope. So the river and its tributaries flow only on the soft rocks and if at all tributaries are to join the main river, its only possible at right angles.
   - Tectonic movements; trellis drainage patterns can also occur in faulted regions where the river will take the shuttered rocks of the fault line as soft rocks hence it will flow along fault lines thus joining at right angles.

- Climate; trellis drainage patterns take place in areas with heavy and reliable rainfall in order to maintain constant volume of water in river and streams.

Examples of trellis drainage patterns include or can be found on rivers Mayanja, kato, wasswa etc in Uganda

Illustration.

III. **Radial drainage pattern**

It's a drainage pattern where the rivers flow outwards in all directions from a central point which is usually a dome or cone shaped volcano.

Illustration.

Conditions for the formation of a radial drainage pattern.

- Develops in areas with a dome shaped volcano
- The river flows in accordance with the slope of the land downwards in all directions.
- Develops in areas with homogenous rocks
- Develops in areas with heavy precipitation or rainfall eg mt. elgon, Rwenzori in Uganda, Kilimanjaro and Kenya.

IV. **Centripetal drainage pattern**

It's a drainage pattern where the rivers flow inwards towards a depression which is usually a lake.

Conditions.

- Develops in areas of depression and the rivers flow down into it from all directions.
- Develops in areas with heavy rainfall.
- The rivers follow the slope of the land
- They flow in areas with homogenous rocks eg rivers flowing into Lake Victoria and Baringo in Kenya; they include Loboi and Olmukutan.

V. **Parallel pattern**

It's a pattern where the river flow parallel to each other from the same watershed which can be an escarpment.

Illustration.

Conditions

- It develops in areas with steep elongated slopes such as escarpments.
- Develops in areas of homogenous rocks
- Develops in areas with heavy rainfall
- The rivers follow the slope of the land downwards eg rivers flowing down the western edge of the Butiaba escarpment.

VI. **Hooked or barbed pattern**

In this pattern, the tributaries appear to flow in the opposite direction to the main river and look like a hook or a barb. They enter the main river at an acute angle.

Illustration.

- Usually develop in areas of river capture where drainage reversal occurs.
- Develop in areas of heavy rainfall eg river kafu, katonga and kagera in Uganda and the Rwizi river.

This pattern resembles a feather. In this case, tributaries join the main river at acute angles to make the pattern look like a feather

Illustration.

VII. **Annular pattern**

It's a circular pattern than develops within a volcanic crater. The streams join at sharp angles and are arranged in series of curves in the crater. It's not a common pattern and examples can be seen at lake Basumtwi in Ghana.

Illustration

DISCORDANT PATTERNS

A discordant pattern refers to where there is no close relation between the rocks and the drainage pattern exhibited by rivers. The major discordant drainage patterns include;

1. **Antecedent drainage pattern**.
   It involves a river which developed and established a pattern on landscape which was later uplifted by earth movements. The river conditions to flow in its original direction by eroding a gorge in the landscape.
   Illustration
   The uplift must be slow enough for the river to maintain its course in the path of the rising ground or land. The river must also be powerful enough to erode vertically downwards as fast as the rising land and therefore develops a gorge. Antecedent river patterns are therefore older than the landscape over which they flow eg R. Malagarasi on Tanzania.
2. **Super imposed drainage pattern**.
   This is the pattern that develops on a landscape which is afterwards is removed or changed. It's now super imposed or on top of a previously buried and completely different rock structure eg if sedimentary rocks are covering a folded rock structure as shown below.
   Illustration.
   When the sedimentary rocks are removed by erosion, the folded rocks below are exposed. The river is normally expected to flow through the synclines or valleys. However, it may manage to maintain its course and cut across the anticlines by developing gorges. Super imposed drainage is therefore younger than the landscape over which it flows.

COASTAL GEOMORPHOLOGY

A coast is a zone where the land and sea over lap and interact. A coast can either be gentle or steep, sandy or rocky. In east Africa, coasts are along the lakes and along the Indian Ocean.

Waves

These are defined as Undulations on the surface of the water caused by winds blowing across it. When the wind blows over the water, 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.

Waves can also be generated by tectonics movements such earth quakes that move under the sea, large whales, submarines, volcanic eruptions etc. Waves are the chief agents of marine erosion, transportation and deposition along the coast.

Each wave has a swash and back wash effect.

Illustration

The forward movement of a wave is known as the swash and it is usually more powerful when the wave breaks and retreats and then the back wash is formed.

Waves can be constructive or destructive. Waves which are constructive lead to deposition and its associated Landforms. Waves can also be destructive leading to erosion and its associated landforms or features.

Landforms resulting from wave erosion or formed by wave erosion.

Waves are very effective agents of erosion and wave erosion occurs through the following processes;

Hydraulic action, Abrasion, Attrition, Solution

- **Hydraulic action.** When a wave hits for cliff at the coast with great force, it compresses the air in the joints and cracks in the Cliff. When the wave retreats, this pressure is released explosively. When this pressure release action is repeated, the rock is stressed, cracks are then enlarged and pieces begin to fall off the cliff.
- **Abrasion**. It occurs when the rock particles that have been broken off by hydraulic action are thrown by the waves at the cliff. They erode it at the base leading to undercutting of the cliff.
- **Attrition.**

It occurs when the rock fragments and pebbles are knocked against each other in the water and become smaller and more easily removed.

- **Solution.**

it occurs in soluble rocks such as limestone is dissolved and washed away. However, no visible rock fragments are left. All these processes together produce landforms which include cliffs, caves, good etc. as explained below.

1. **A Cliff**

It's a steep slope or rock face along the sea or coast. It might be 400m in height or quite below. Cliffs may either be vertical or slanting. The formation of cliffs depends on the nature of rocks, their stratification and jointedness, their resistance to erosion and their homogeneity or heterogeneity. Cliffs are formed by waves that attack a gently sloping land towards the sea or lake resulting into the formation of notches.

These notches or cuts are created by waves through the processes of wave erosion like hydraulic action or abrasion. These notches are very common on rocks which have well developed gorges. continuous wave erosion, weathering and mass wasting results into the collapse and retreat of gently sloping rock leaving behind a steep rock surface along the sea or lake. Best examples of cliffs in east Africa include fort Jesus near Mombasa, port Garaza near Tiwa and at kasenyi on the shores of Lake Victoria.

Illustration

2. **Wave cut platforms.**

This refers to a gently sloping bend like rock sloping seaward below the Cliff. They form between low and high water tides. It's formed as a result of water attack on the cliff. These waves force the cliff to collapse and slowly retreat. This results unit the creation of wave cut benches through the grinding action of materials swept back and forth by the breaking waves. These benches are finally enlarged into wave cut platforms e.g. at Tiwi beech in Kenya and the oceanic hotel at Mombasa was built on wave cut platforms.

Illustration

3. Bays and headlands.

Bays and Headlands are indented coasts where water either projects into the adjacent land or land projects towards the sea. They are formed where there are alternating hard and soft rocks which lie at right angles to the coast.

Bays are wide indentions where the sea or lake projects towards the land. They are as a result of differential erosion of the soft rocks where the eroded soft rocks are forced to curve in into which the sea or lake water flows or follows. Best examples can be found at Sango bay, Murchison bay, the Napoleon Gluff, Barckley Gluff and Speke gluff on Lake Victoria and Watamu and Malindi bays in Kenya.

Headlands on the other hand are projection of land and resistant rocks protruding towards the sea. When the soft rocks are eroded to form bays and resistant rocks remain and stand out as headlands.

Illustration

4. **Caves**

Caves are holes or tunnels that are dug into the cliff. They develop from waves that enlarge an initial line of weakness in the rock especially along joints, faults and bedding plains. The breaking waves through the processes of abrasion and hydraulic action compress the air the crevices, joints and holes within the cliff face. When the water retreats, the air expands rapidly. This expansion and compression loosens the rocks and enlarges the cracks which later results into the formation of cylindrical tunnels called caves.

In some cases, the force of waves spurting into the air may weaken the roof of the cave so much that the roof collapses. The resulting landform is a vertical shaft or tunnel connecting the cave to the cliff top. This landform is called a blow hole or gloup.

When the entire roof of the cave collapses due to wave erosion along the major joints or faults, the resultant landform is called a geo.

5. Arch, stack and stump.

An arch is a bridge like feature found above the cave. It's formed when a cave is curved into the side of the headlands or where the caves develop on either side if a headland and they alternately join.

With continued wave erosion on the headland, the arch may collapse leaving behind an isolated rock mass separated from the main land called a stack. Best examples can be found at the rock pillar Stack near Entebbe airport at Kasenyi fish landing site. An arch is found at Vasco da Gama pillar in Malindi.

Illustration

Continued wave erosion of the stack may lower it below water level or maybe submerged at high tide to form a stump.

Landforms formed from wave deposition

For wave deposition to take place, the materials have to be moved along the shores by longshore drift i.e. a mechanism in which waves transport eroded materials before they are deposited to form various landforms.

The major wave deposition features include beaches, spits, bars, mudflats etc.

1. **Beach**

A beach is an accumulation of materials deposited by waves mostly consisting of sand, shingle or both along the coast. They are gently sloping coastlines of sane and shingle which are transported and deposited along the coast by longshore drift. It's formed when constructive waves remove materials from the bottom of the sea and deposit them at the shores where they accumulate. Beaches maybe submerged at high tide or may be exposed at low tide e.g. Nyaki beach in Kenya near Mombasa. Others include Nabugabo, Butembe, Gaba, Lido etc. along the shores of Lake Victoria.

Illustration

Types of beaches

1.1. Barrier beach

These are long Sandy ridges of islands lying parallel to the coast and separated by a lagoon. They are formed on gently sloping coastlines by longshore drift and waves breaking off shore materials are deposited under water as off shore sand bars and appear above high tides. Wave action gradually moves the deposits on the main land as barrier beaches. They are referred to as barrier islands when they are not joining the Coast.

Illustration

1.2. Beach cusps

These are projections of Sand and shingle that are cone shaped with an apex facing sea wards formed by eddies or head currents of a powerful swash.

or these are series of small horn shaped projections separated by shallow indentations that face sea wards giving the beach a pointed appearance. Cusps are formed mostly where waves break parallel to the shore and most cusps develop on exposed beaches where large waves are frequent.

1.3. Bay head beach.

It is a crescent of sand and shingle lying between headlands. Examples include Lutembe beach, lido beach, and Bugonza on the shores of Lake Victoria.

1.4. Spits

A spit is along narrow accumulation of shingle and sand in a linear form with one end attached to the land and the other projecting into the sea or across the estuary. A spit may link two headlands to form a bay bar. Spits develop from the movement of materials by longshore drift.

When the long shore drift operates across a river mouth, a zone of slack water develops between the long shore drift and river and any material carried by longshore drift is deposited.

The deposited material forms a spit. The main condition for the formation of spits is the presence of an ample longshore drift materials together with an irregular coastline. Examples include Kaiso and Tonya spits along the shores of Lake Albert.

Illustration

2. Tombolo

This refers to a spit that grows out from the coast and links an island to the mainland. The ideal condition for the formation of a Tombolo is an ample supply of debris for wave deposition to form connecting ridges and a low tidal range such that the deposited materials are not carried away. Best examples are found at Lambu Island which is joined to the mainland at Masaka

Illustration

3. Sand bar

This refers to a ridge of sand, mud, gravel and shingle deposited off shore and parallel to the coast. It's formed on gently sloping coasts and shorelines with an irregular shape. Its formation is attributed to waves that move or drift the materials along the shore or as a result of backwash combining the materials directly behind the beach.

Similarly, long breaking waves cause the sand grains to move seaward resulting into accumulation of materials on the submerged line known as break point bar. The repeated process leads to the formation of a bar behind which develops a lagoon, mud floods and mashed.

4. Bay bars

Bay bars form where spits continue to grow in length and link the two headlands which later enclose a lagoon and mashed. Examples are on lake Nabugabo in Masaka which is enclosed by Rwamunda swamp and lake Nabugabo was cut from Lake Victoria as a bay bar.

Illustration

5. Coastal dunes

these develop on coasts where winds are predominantly onshore and are sufficiently strong enough to move a large supply of sand inland from a wide beach area. They are Common along arid and semi-arid coasts.

6. Mud flats

Mud flats form when tides and waves deposit fine materials such as silt along gently sloping and sheltered coasts. The deposition of large quantities of Alluvium results into the building of a plat form of mud mixed with water called a mud flat e.g. the mud flats along the east African coast which are occupied by mangrove swamps and forests.

SEA LEVEL CHANGES

sea level changes refer to relative movements in the level of water in the sea, Ocean, lakes relative to the adjacent land. When the sea level changes on a worldwide, it's known as eustatism or an eustatic change. water in the sea is never constant.

Sometimes the level or water in the sea or ocean can rise relative to the land and this is referred to as submergence or positive change.

At times, the level of water in the sea or ocean Lowers or reduces relative to the land and this is known as emergence or negative sea level changes.

Therefore, sea level changes or base level changes involve two processes i.e.

- ✓ submergence or positive base level changes
- ✓ Emergence or negative base level changes

Sometimes the change in sea level is Worldwide and uniform which indicates an actual movement of the sea itself. This is known as eustatic sea level changes.

EMERGENCE

Emergence refers to where the land has risen relative to the sea or where the sea level has fallen relative to the adjacent land. This results into exposure of features that are formally under water and can be seen.

Causes of emergence

- ✓ Rise in the level of the adjacent land due to isostatic uplift.
- ✓ Fall in the level of the sea level due to drought, glaciation, global warming, widening of the sea floor etc.

SUBMERGENCE

Submergence refers to a situation where coastlines fall relative to the adjacent land or where the sea has risen relative to the adjacent land or Coast.

This therefore leads to formally exposed land / features being covered by water (indulated)

CAUSES OF SUBMERGENCE

- ✓ fall in the level of the adjacent land due to relative sinking (Down warping)
- ✓ Rise in the level of the sea because of illuviation, deglaciation, narrowing of the ocean floor etc.

CAUSES OF SEA LEVEL CHANGES

1. **climactic factors**

Temperature changes can also lead to sea level changes. High temperatures result into prolonged droughts hence high rates or excessive evaporation leading to a fall in the sea level relative to the land adjacent.

Temperature changes leads to expansion and contraction of the sea water. A rise in temperatures of the water will cause its expansion which later brings about submergence while a fall in temperatures results into contraction of sea water which later brings about emergence.

Pluviation i.e. increased precipitation or rainfall leads to a rise in sea level relative to the adjacent land while desiccation i.e. decrease in rainfall totals leads to a fall in sea level relative to the land. E.g. in 1997 - 1998 Uganda experienced el-Mino rains which led to an increase in water in lakes causing submergence. In 2010, there was a prolonged drought period which resulted into emergence due to reduced water in lakes as a result of excessive evaporation.

2. **Glaciation and deglaciation**

Deglaciation involves the melting of Ice due to a rise in temperatures. The melt waters lead to the release of large quantities of water which flow into the Sea leading to a rise in the sea level.

On the other hand, during periods of major glaciation, there is a drop in global temperatures. Water is frozen off into large ice masses in the Polar regions and mountains which cause a universal fall in the sea level.

3. **Tectonic movements**

These are related to processes of warping, faulting, volcanicity and seismic activity. Up warping of coastal areas and down warping of ocean basins leads to a fall in the sea level resulting into emergence while down warping of coastal areas and down warping of the ocean basins results into the rise of the sea level (submergence).

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 it ocean basins due to plate convergence leads to a rise in sea level.

4. **Volcanism:**

volcanoes at constructive plate boundaries and subduction zones displace water causing rise of sea level relative to the land.

5. **Isostatic re-adjustments**

The word isostasy is a Greek word meaning equal standing. The structure of the earth is in such a way that lighter rocks (sial) are sitting on denser rocks (sima). Due to isostatic re-adjustments, large amounts of weight e.g. glaciers, buildings, deposited debris etc. may be loaded or unloaded onto a region which may cause the land to sink or to rise and consequently cause emergence or submergence.

The addition of materials on continental areas increases weight causing continents to sink slowly hence a rise in the sea level e.g. ice accumulation during the Ice Age. After the melting of the ice sheets, the isostatic uplift of land masses occurred leading to a fall in sea level.

6. **Sedimentation.**

Deposited sediments in the sea or ocean basins by in flowing rivers reduce the size and depth of the ocean basins leading to a rise in the sea level hence submergence.

7. **Human activities**

The pumping of water or oil for the ground can lead to the gradual sinking of the ground which results into emergence.

Man can also carryout dredging or desilting of coastlines which results into emergence. Sometimes sand mining at the coast can also bring about emergence. this is because the size of the lake basin is enlarged therefore bringing about lowering or drop or decrease in the water level.

Pouring of sewage and other sediments in the lake brings about submergence since the sediments try to fill the ocean basin and causes the rising of water.

in some countries, there is pouring of expired food, items like wheat, rice etc. in the ocean and this brings about submergence.

8. **Global warming**

The world's temperatures have been increasing over the years by at least 0.6 degrees Celsius or 1 degree

This increase in global temperatures has been due to man's misuse of the environment involving deforestation, burning of fossil fuels e.g. coal, oil and natural gas etc. which reduces gases that trap heat in the atmosphere e.g. carbon-dioxide and carbon-monoxide which makes the climate to become warmer. This has resulted into melting of snow and ice e.g. at the poles resulting into submergence.

In the tropics, global warming has led to the reduction of glaciers which are potential sources of water to rivers that flow into oceans. This has resulted into reduction in the volume of water flowing into the seas and oceans hence bringing about emergence.

FEATURES OR LANDFORMS RESULTING FROM SEA LEVEL CHANGES

LANDFORMS RESULTING FROM SUBMERGENCE (RISE IN SEA LEVEL)

when the water level in the sea or oceans rises, areas or features which were not formerly in water become submerged.

Submerged features fall into two categories i.e.

- ✓ Highland features

- ✓ Lowland features

Submerged highland features

1. **Rias**

It's defined as a long narrow water inlet at the coast. Before the sea level rises, a river flows into the ocean through a Valley. When sea level rises, the valley is flooded or submerged by the rising water levels to form a ria. It's formed with a shape of a funnel and decreases in width and depth inland. Examples can be found along the coast of east Africa at the mouth of the Mwachi river which forms the Kilindi harbor at Mombasa, the drowned river mouth of the Kombeni river which forms the Mombasa harbor.

Illustration

2. **Dalmation coastline / longitudinal coastline.**

These are submerged tops of hills or highlands. They are formed in areas where hills and valleys lie parallel to the coast before submergence.

When the sea level rises, the valleys become flooded with water and the hills remain as chains of islands within the ocean and run parallel to the coastline. The water within the drowned valleys that separates the chains of islands from the main land is known as a sound.

Examples include the Smith sound west of Mwanza on Lake Victoria, the Pemba and Zanzibar coasts etc.

Illustration

3. **Fiords**

These are submerged or drowned U-shaped glacial troughs or valleys formed along glaciated coasts. They have steep walls often rising straight from the sea. When the sea level rises, the coast is submerged and the lower parts of the U-shaped valleys or glacial troughs are and filled with water hence forming fiords. They are usually steep sided and very deep. There are no examples in east Africa but there are many at the coast of Norway, British Columbian coast, at the Coast of Chile etc.

llustration

SUBMERGED LOWLAND FEATURES

4. **Estuaries**

These are submerged or drowned river valleys with a V-shaped cross profile pointing landwards. It is formed when the sea level rises along a low lying Coast causing the sea to penetrate Inland along river valleys eg the rufigi and kibanga estuaries. They are similar to Rias only that Rias form in highland coasts while estuaries form in lowland coasts.

5. **Creeks**

These are narrow inlets formed by submergence of small streams. They are similar to estuaries only that they are smaller. Best examples of creeks are mfwapa, Tudor, reitz and kilifi all formed due to sinking of small rivers and streams along the East African coast.

6. **Mudflats and lagoons.**

Mudflats are deposits of fine silt and alluvium of rivers to form plat forms of mud. Sediments are deposited in shallow water either behind shingle, bars, sand spits, or sheltered parts of estuaries and bays. At the Coast, such deposits enclose water and separate it from the rest of the sea to form a lagoon.

LANDFORMS FORMED DUE TO EMERGENCE

GENERAL ILLUSTRATION SHOWING THE DIFFERENCE LANDFORMS.

1. **Raised cliff**

Initially a Cliff is formed where the sea is in contact with the land. Through the phases of hydraulic action and abrasion, a notch is created and it becomes deeper due to continued wave erosion. When the above land loses support it collapses and a cliff is formed. when the sea level falls, the cliff is left isolated and it's no longer in contact with the water and therefore it's left behind at high tide to form a landform known as a raised cliff.

2. **Raised terraces**

Initially a wave cut platform develops at the coast as a cliff retreats. When the sea level falls, the Former wave cut platform is no longer in contact with the water and is now known as a raised terrace. An example of a terrace is at Lutembe beach where it was formed when the water level of Lake Victoria fell at one time.

3. **Raised beach**

This is formed when sea level falls such that the former beach is now left above the new water level which is above the present zone of deposition. This beach which is left suspended above the present water level is referred to as a raised beach. Best examples are found at Bagamyoyo in Tanzania where three layers of raised beaches can be found and at the Mamangina in Mombasa-Kenya.

4. **Raised caves**

Initially a hole develops in the cliff face where there is a joint in the cliff. Through continued hydraulic action and abrasion, the hole becomes larger and finally the cave forms. When the sea level falls, the cave is left high above the high tide level and with no anymore contact with the sea which is now known as a raised cave. 8

5. **A raised geo**

It's formed where the entire roof of a cave collapses through erosion to form a narrow water inlet called a geo. When the sea level falls, it will not be in contact with the sea level and therefore it will have no water in it. It's now called a raised geo.

Economic importance of features resulting from sea level changes

- Rias and fiords are used in the construction of natural harbours e.g. kilindini and Dar-es-salaam harbors.
- The landforms formed due to rise and fall in sea level are important tourist attractions and this brings in both local and foreign income in the respective countries
- The landforms are important sites for education and research.
- Mudflats are reclaimed for agriculture purposes and this improves on the food security in the country.
- Rias form natural route ways inland
- The raised beaches are used for sand mining.

Negative

Settlement is difficult along the sides of a fiord because of lack of level land.

the mudflats, swamps and marshes are breeding places for disease causing vectors eg mosquitoes etc.

there is a problem of occasional flooding especially in areas covered by Mudflats and this leads to destruction of property.

CORAL REEFS

Coral reefs are rock Platforms formed from the continued deposition and accumulation of shells or skeletons of marine organisms known as coral polyps.

Coral is a limestone rock made up of the skeletons of the tiny marine organisms ie coral polyps. The polyps usually live in closely peached colonies of thousands and their skeletons are made up of calcium carbonate.

When the polyps die, their skeletons and shells accumulate at the bottom of the sea and they are eventually compressed together with time by their own weight, consolidated and cemented together to build a coral reef. other organisms such as echinoderms and calcareous algae help to cement the space between the skeletons.

After a long time, hard rocks known as coral reefs are formed. Example are found at the east African coast along Kenya and Tanzania

CONDITIONS NECESSARY FOR THE FORMATION OF CORAL REEFS

Requires hot temperatures if the tropical climate ranging between 20-30^0 C which are ideal for the growth of coral polyps. They are found manly in the tropical and in the near tropical seas and oceans within 30^{0}N and S of the equator. They are mostly found on the Eastern side of land masses where warm ocean currents increase the sea temperatures hence allowing the growth of corals.

On the western side of landmasses, there are cold ocean currents which lower the temperatures hence preventing coral growth.

It requires salty, oxygenated sea water of between 27-40 parts per 1000 for calcium carbonate to precipitate hence enabling the growth of coral polyps. Salinity encourages coral growth since coral polyps take up calcium carbonate from sea water to build their shells.

It requires a shallow continental shelf with a depth of between 20-60m to allow the penetration of sunlight which is ideal for the growth of coral polyps.

There should be presence of clear silt free water and calm or stable water. The clear water allows light to penetrate to lower levels while the calm water allows the accumulation of coral polyps to form coral reefs. Coral reefs grow away from River mouths where silt laden water pours into the sea and dilute the salt concentration and destabilize coral formation.

There is need for a solid rock bed along the coast upon which coral reefs form or accumulate.

Availability of planktons which act as food for the coral polyps. Food supplies are usually most plentiful on the sea ward of a growing reef so that corals tend to grow more rapidly outwards.

Sea level changes caused by submergence of the coast which encourage coral deposition. A fall in the sea level exposes the coral polyps and they eventually die.

Presence of Minute sea organisms (very tiny) called polyps which die and their skeletons pile and accumulate to form Coral reefs.

TYPES OF CORAL REEFS

There are three types of coral reefs namely

Fringing reefs

Barrier reefs

atoll reefs

FRINGING REEFS

This consists of a platform of coral which is joined to the coast and extending sea wards for about 1km. It's separated from the coast by shallow and narrow lagoon of about 500 -2000m. Best examples can be found at kilifi and Tiwi at the coast of the Indian Ocean.

Illustration

BARRIER REEFS

These are coral platforms which are separated from the coast by a wide and deep lagoon. Barrier reefs are found several kilometers off the coast.

Illustration

ATOLL REEF

This is a circular shaped coral platform enclosing a mass of water to form an atoll. It has a fairly deep lagoon but it's generally broken in places by a narrow channel. Eg the Gilbert and Ellie islands on the Pacific Ocean and chumbe Island South of Zanzibar.

Illustration

NOTE

The process of coral formation involves:

- Coral landforms or reefs form when coral polyps die
- Skeletons of dead polyps drop and accumulate on the continental shelf.
- With continued accumulation of skeletons of polyps over time, there follows compression, compaction, cementation and consolidation of fossils thus corals are transformed into coral reefs.
- Living organisms e.g. algae help in cementation to turn limestone rocks into Coral reefs.

THEORIES FOR THE FORMATION OF CORAL REEFS

The formation of barrier reefs and atolls have created a lot of controversy as they have been found at far greater depth, in some cases exceeding 1000m a level where polyps cannot survive. As a result, relevant theories have been formulated to account for the origin of coral reefs.

These theories include the following;

Darwin's theory

John Murray's antecedent theory

Daly's theory of deglaciation

DARWIN'S THEORY OF SUBSIDENCE / SUBSIDENCE THEORY.

Darwin proposed his subsidence theory in 1842 when he was trying to account for the formation of coral reefs. According to this theory, it's states that originally there was presence of a volcano or volcanic island on the sea floor. The coral polyps colonized the edges of the volcano and later formed a fringing reef.

The volcanic island together with its fringing reef that had formed subsided or sunk as a result of isostatic re-adjustments that followed subsequent eruptions. Such subsidence increased the water depth beyond the level at which coral polyps can survive. The coral polyps subsequently died while some tried to grow to keep pace with changes in water depth.

The fringing reefs on the flanks of volcanic islands grow upwards and eventually grow into barrier reefs and finally into atolls When the volcano has completely submerged or sunk.

Illustration

RELEVANCE OF DARWIN'S THEORY

The theory is relevant because there was actual submergence of the east African coastline evidenced by the presence of Rias and Mudflats in the submerged coastal areas.

There is presence of volcanic islands off the East African coast in the Indian Ocean.

However, critics of Darwin's theory down Play its relevance by arguing that some coral reefs have also been found in areas where there is no evidence at all of submergence and also that some coral reefs have also been found at a great depth denying the assumption that when sea level increases or rises, coral reefs grow to keep pace with increase in the water level.

JOHN MURRAY'S ANTECEDENT THEORY

This theory assumes that coral reefs developed on a platform of pelagic deposits. Murray assumed that there were uneven growth rates of coral reefs grew up on the banks of their own debris and there was more rapid growth on the sea ward than on the land ward sides.

The platform provided a base for atoll formation. Corals first grew as fringing reefs then into barrier reefs then finally as atolls.

As the reefs grew upwards and outwards, those on the inner or landward were deprived of food causing them to die. The skeletons of sea organisms dissolved into water such that a feel lagoon formed or developed inside the reefs. According to Murray, there was no subsidence in it.

Illustration

RELEVANCE OF MURRAY'S ANTECEDENT THEORY

The proposers of this theory identified the barrier and fringing reef at Maryote between Madagascar and Mozambique. Atoll were formed around Aldabara as evidence to support this theory.

More pronounced coral polyps grow on the sea ward side than the Land Ward Side.

fragments of coral do exist in lagoons between reefs proving the idea of dissolving dead corals to form lagoons.

The steepness of the coral reefs is greater on the seaward side than on the landward side.

DALY'S THEORY OF DEGLACIATION

According to this theory, there existed submarine platforms or hills from which peri-glacial coral reefs were eroded and planed to the sea level. Barrier reefs and atolls started formation on the flanks or foot hills of these hills as fringing reefs.

Deglaciation emptied vast quantities of melt waters into the sea such that there was a rise in sea level.

As sea level rose, the coral reefs which had started growing on the platforms or hills as fringing reefs gradually transformed into barrier reefs and finally into atolls when the hills were completely submerged. This took place because the upward and outward growth of corals was able to keep pace with the rate of rise in sea level and be maintained at the water surface.

Illustration

ECONOMIC IMPORTANCE OF CORAL REEFS

- Some corals are precious e.g. this with a hard core are used by craft men to curve out jewelry materials.

- The lagoons cut off from the ocean are good for water sporting and swimming since they are normally free from dangerous fish e.g. sharks and whales.

- Reefs especially the fringing type shelter the coast from strong waves. The water above the reef is shallow which helps to check the speed of the approaching waves leading to the development of sheltered harbors.

- Research shows that the existence of corals is an indication of the possible presence of petroleum at the east African coast. The polyps which die have fats which accumulate into oil wells in sedimentary rocks. Therefore, the east African coast has some deposits of oil which when exploitation begins, they may help in economic development.

- The variety of shapes in which they appear e.g. sea fan corals, dwarf corals, reef building corals, mushroom corals, soft corals are a tourist attraction. Tourists to the east African coast normally carry them as souvenirs.

- Corals are important sources of calcium carbonate which is limestone which when processed into cement is an important raw material in the building and construction industry of both Kenya and Tanzania e.g. Bamburi cement industry in Mombasa and Waze cement works in Tanga Tanzania both use coral limestone.

- Coral reefs are also used for research purposes by scholars and for education purposes.

- Some corals weather into good soils making the coastal soils rich in nutrients and can support agriculture e.g. cloves at the east African coast.

- The corals have also supported aquaculture (tilapia), a crocodile farm and Agro forestry where by Bananas, vegetables and trees are planted on the Tanzanian coast and also farms e.g. at Bamburi quarry in Kenya.

Negative

- Where the coral reefs are found, the water is shallow and so they can cause damage on large ships in the ocean.

- The sharp reefs also tear fishing nets and may interfere with the fishing**.**