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PHYSICAL GEOGRAPHY

It will consist of three sections A, B and C. You will be required to answer only four questions. Section A is compulsory and will have two compulsory questions, one on map work and another on photographic interpretation. You will also answer at least one question from section B and one from section C.

COURSE OUTLINE

SECTION A

- ✓ Map work
- ✓ Photograph interpretation

SECTION B:(Geomorphology)

- Introduction of physical geography
- The structure of the earth
- The origin of continents and ocean basins
- Rocks
- Weathering and slope development
- Mass wasting
- Tectonism
- Glaciation
- Lakes
- Rivers and lake systems
- Coastal geomorphology

SECTION C: (climatology, vegetation and soils)

- ❖ Vegetation
- ❖ Climatology and meteorology
- ❖ Soils

INTRODUCTION

The term geography is got from two words i.e. **Geo** and **Graphia**. Geo means earth and was got from a Greek word **GAIA** or **GE** that stood for the ancient Greek goddess of the earth. Graphia on the other hand is also a Greek word that means description.

From the above words, geography means simply the description of the earth. Geography can however, be defined as the subject that deals with the study of man, what surrounds him and how best he can live in harmony with his surroundings.

Geomorphology is defined as a branch of physical geography that deals with the study of land form and land form processes. Land form is any feature produced by geomorphic processes. Land forms are either **intrusive** if they are formed under earth surface or **extrusive** if they form on the earth surface.

Geomorphic processes are either **Endogenetic** or **Exogenetic.** Endogenetic processes are those which originate within the earth crust (below earth surface). They include faulting, folding, warping and vulcanicity. Endogenic processes are of two types i.e. **Epeirogenic** and **Diastrophic forces.**

Epeirogenic forces operate vertically upwards or down wards in the earth crust. E.g. vulcanicity and warping while Diastrophic forces operate horizontally E.g. folding, faulting.

Exogenetic forces operate on the earth surface. Exogenetic forces can be divided into two;

I. Denudational process
II. Aggrredational (depositional) processes.

They include; Erosion, mass wasting, weathering, wave action, glaciation and austatism. Geomorphology deals with all these processes, landforms they produce and how these land forms are useful problematic to man and the environment.

Climatology is a branch of physical geography that deals with the study of climate. Under this we shall be dealing with meteorology (study of weather) and various climatic types pf the world. A branch of physical geography that deals with the study of soil is called **pedology.** In this part emphasis is put on East Africa and some global cases are also tackled for illustration. **Oceanography** and **Astronomy** that deals with the study of oceans and stars and outer space respectively are not dealt with here.

The surroundings of man fall under four spheres:

1. **Atmosphere** which deals with the environment above the earths surface. Climatology and Astronomy fall here.

2. **Lithosphere** which deals with soils and rocks and anything below the earth surface. Pedology and geology are found here.
3. **Hydrosphere** which deals with water resources. Oceanography falls here.
4. **Biosphere** which deals with living things. Plants and animals and man.

Qn: Distinguish between endogenic and exogenic geomorphic processes.

Geomorphology is the scientific study of the origin and development of the earth's land forms. It studies both the form of the land forms and the geomorphic processes. Geomorphic processes are the processes which lead to the evolution of land forms on the surface of the earth.

Geomorphic processes fall in two broad categories namely; endogenic and exogenic (also termed endogenetic) are the building processes that usually lead to an increase in elevation and relief. The processes are faulting, folding, warping and vulcanicity Endogenic processes are therefore initiated and generated by events from within the interior of the earth.

Faulting is the breaking or fracturing of rocks involving the displacement of rocks om either side of the fracture or fault. Faulting results in the evolution of land forms such as block mountains, rift valleys, escarpments, tilt blocks, grabens and fault guided valleys.

Folding is the slow but steady bending of rocks the earth's crust. It is a very gradual process whose effects are realized only after along period of time usually hundreds of thousands of years. Folding is responsible for formation of the fold mountains of the world such as the Himalaya, Alps, Rockies, Andes and the cape Range.

Warping is the deformation of the earth's surface by uneven upward or downward movement. Like folding, it is an infinitely slow process where the movement is generally slight but likely to extend over a wide area. The Lake Victoria ang Kyoga basins are examples of down warped basins in Uganda. (**Note**: The three processes of faulting, folding and warping collectively constitute earth movements)

Vulcanicity or vulcanism is the movement of molten and igneous material from the earth's interior towards or onto the earth's surface. When material reaches the surface of the earth. It solidifies to give rise to distinctive features known as volcanic land forms. (**Note:** Earth move together with vulcanicity constitute tectonic processes. The term tectonic process of faulting, folding, warping and vulcanicity)

Exogenic (also termed as exogenetic) processes are activities which operate on the surface of the earth. These involve **denudation** (degradation) and (aggradation). Exogenic processes are there fore initiated and generated by events external rather than internal to the solid earth.

ELEMENTS OF PHYSICAL GEOGRAPHY

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

Weathering is the physical disintegration and chemical decomposition of rocks at the surface of the earth in situ. Weathering can be divided into those processes involving chemical reaction and formation of new minerals (**chemical weathering)**

Erosion is the removal and wearing away of the land by the natural agents of rivers, waves, wind, glaciers, ice sheets and tidal currents. The same agents act as means of transport for the removal of the eroded material.

Mass wasting is the downslope movement of slope material under the influence of the gravitational force of the material itself and without the assistance of moving water, ice, air, or any other agent. The term mass movement if often regarded as synonymous with mass wasting although the latter is also used in broader sense to encompass all processes involved in the lowering of landscape.

Deposition is the complement of denudation, while denudation destroys, deposition builds up landscape. It is the laying down of the transported material by rivers, waves, tidal currents, wind, glaciers and ice sheets.

The process that shape the landforms of the earth are powered

By two major sources of energy. Endogenic processes are influenced primarily by geothermal heat is the radioactive decay of elements such as uranium, Thorium and potassium. As these elements experience radioactive decay, heat is generated and this leads to tectonic processes namely faulting, warping, folding and vulcanicity.

Exogenic processes are influenced primarily by potential energy arising from the height of material above base level and solar radiation reaching the surface of the earth. Receipt of solar radiation varies over the surface of the earth and this in return affects variation in temperature, atmospheric circulation (wind) and precipitation and therefore climatic zonation of the earth.

The wide range of climatic conditions over the earth's surface influences the nature of rate of operation of geomorphic processes. Particular climatic conditions tend to have an effect on geomorphic processes and therefore, overtime, can generate a distinctive association of landforms of regional extent. This is underlying idea behind **climatic geomorphology** (which seems to establish the nature of landforms associated with distinctive climatic regimes)

(**Note:** Areas characterized by landforms associated with a particular climatic environment are called morphoclimatic zones or morphogenetic regions)

THE EARTH: IT'S STRUCTURE AND ORIGIN

The earth is one of the 8 planets of the universe and its part of the solar system. It is the only plant where life exists i.e. flora and fauna. The earth is wrapped in an envelope of air (Atmosphere) and its surface is 71% covered by water. (Hydrosphere). The energy the earth receives, come from the sun (the natural source of energy) and this sun is about 150 million kms away from the earth. Its energy takes about 9 minutes to reach the earth surface at a speed of 3000,000,000ms^{-1} (metres per second).

The shape of the earth is spherical not flat. The first man to prove this notion was probably **Pythagoras** in about 530BC. Before this time people especially the sailors believed that the earth was flat. Later, **Magellan's** voyage proved that the earth is actually round when he sailed from Spain in 1522AD in an effort to move around the world. This voyage ended where it begun.

The structure of the Earth

The earth has got 3 fundamental layers;

I. The crust
II. The mantle
III. The core

THE CRUST

The crust is the upper most layer of the solid earth. It is a region of interaction between surface processes brought about by heat of radioactive reactions deep in the earth. It is the most complex layer of the lithosphere. In the physical and chemical nature, it contains a wide variety of rock types ranging from sedimentary rocks dominated by single minerals such as **sandstone** mainly **silica, limestone** which is mainly calcite to chemical machines of igneous rocks e.g. basalt layer and basalt intrusions. The crust has got two layers i.e. the **continental crust** and the **oceanic crust.**

a) **The continental crust (sial):** This is about 25 miles (40kms) thick and is the uppermost layer of the earth of the earth, it is also called sial. It is composed of light rocks of an average density of 2.7gm/cc. it is mainly made up of silica (si) and aluminum (AL) hence the name **sial**
b) **The oceanic crust (sima):** this follows the continental crust and forms a thin continuous layer of about 5 miles (8kms) thick. This layer forms the bottom of the sea hence the name oceanic crust. Its materials are heavy of about 2.8-3.0gm/cc and are dominantly basic and ultrabasic rocks. It is mainly composed of silica (si) and magnesium (ma) hence the name **sima.** Both the sima and sial consist of rocks with a density of about 3000kg/m^3

THE MANTLE

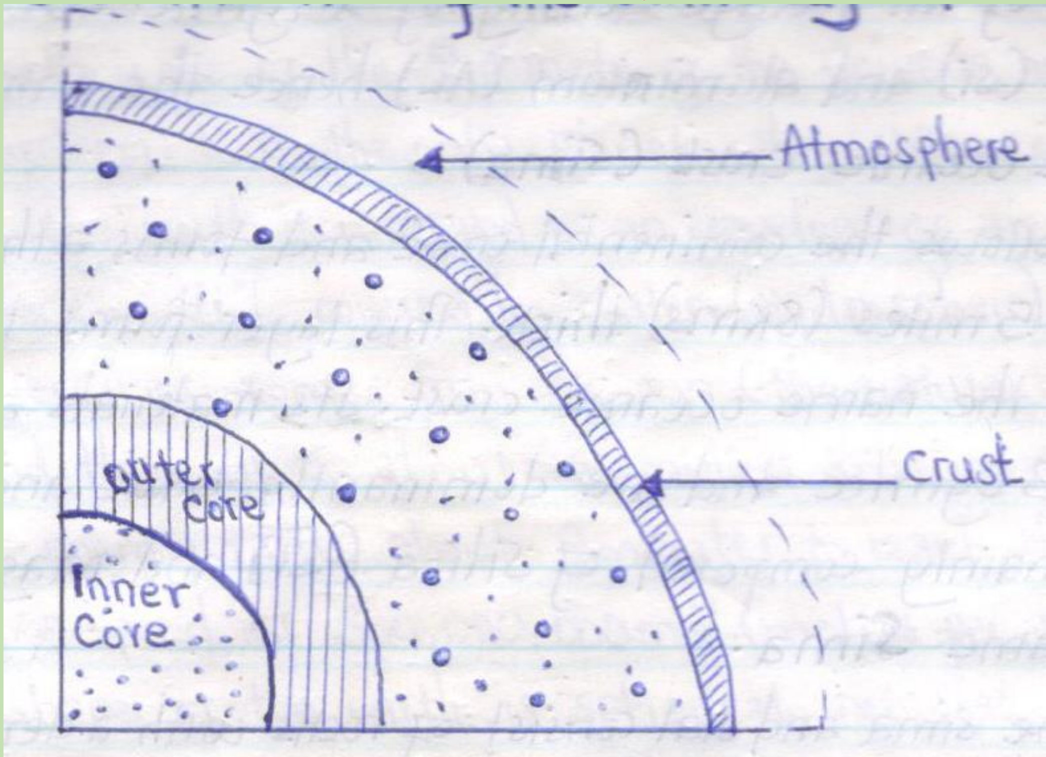
This layer is made up of denser rocks than the crust. It is the second layer from the crust and it extends to the boundary with the core at about 2,900km. The temperature in this region rises rapidly particularly between 60 and 125 miles (96-201km) below the surface where it reaches 1600^0F (871^0C), The boundary between the mantle and the crust is called **Mohorovicic seismic discontinuity** while the boundary between the mantle and the core is called **Gutenberg discontinuity.** This is a region responsible for seafloor spreading, earthquakes and volcanic eruption and hence the development of landform.

THE CORE

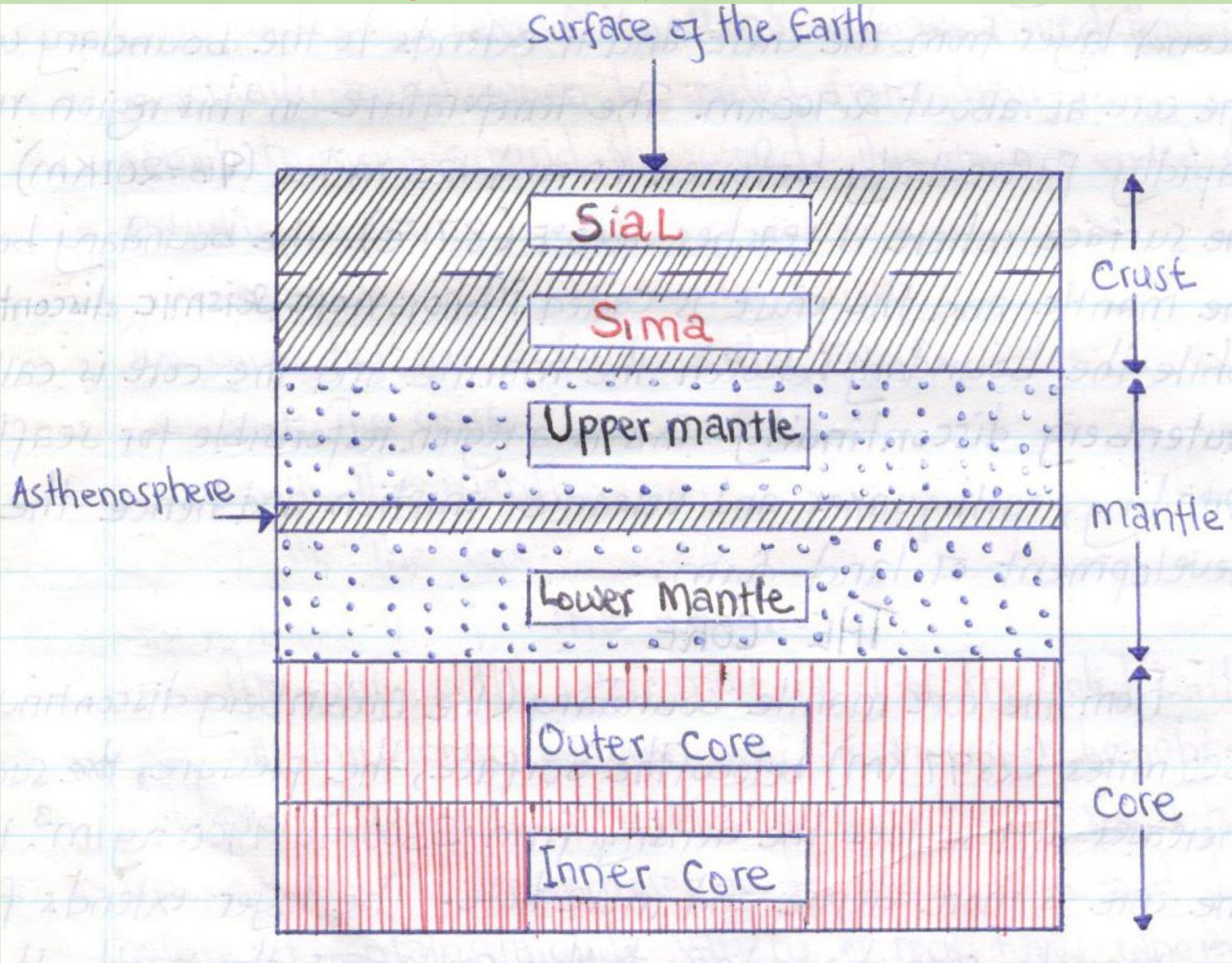
From the core mantle boundary (the Gutenberg discontinuity), 1800 miles (2897km) below the surface, the pressure suddenly increases and so does the density and more hotter. The layer extends from the mantle core boundary to the Centre of the earth. It has got two layers.

I. **Upper core;** this is totally semi fluid with an average density of 10gm/cc and mainly composed of iron and Nickel.
II. **Inner core;** this is a solid layer due to a great pressure and similarly composed of iron and Nickel. Its average density is 12gm/cc and has got very high temperatures of about 5500^0C

Cross-sectional view of the earth's Layered structure:



Vertical section through the Earth's Layered structure:



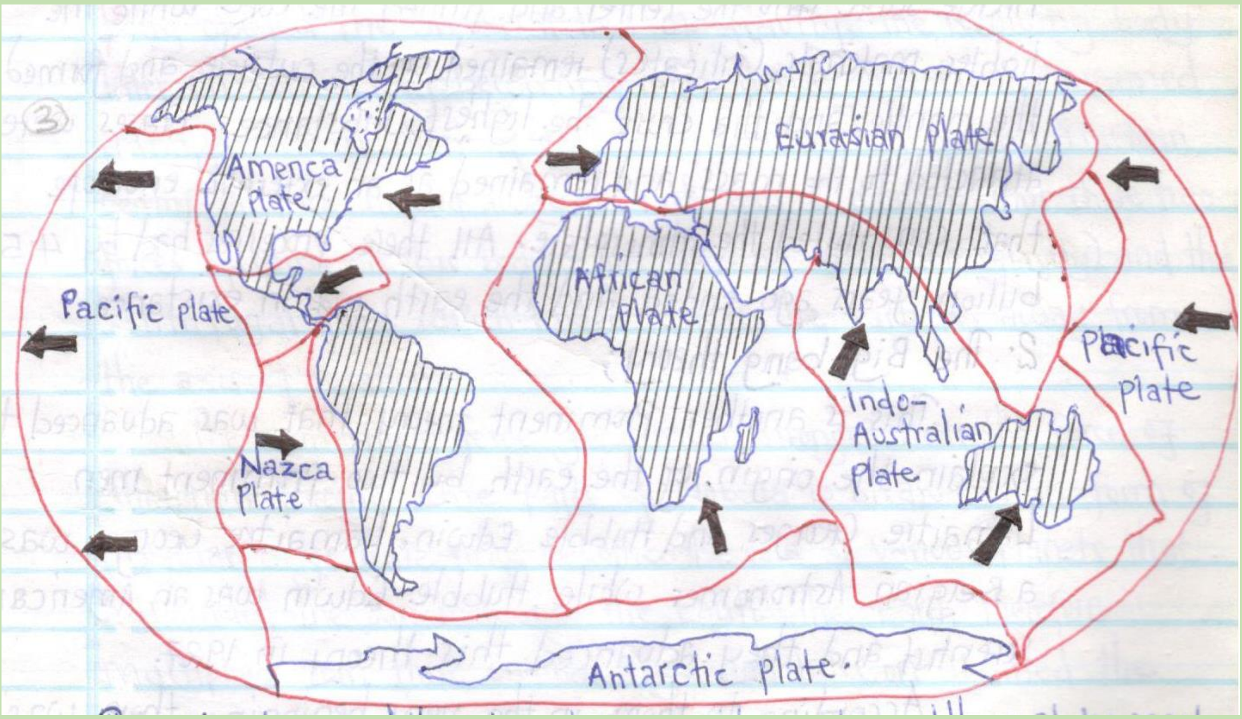
The structure of the Earth's interior has a vital link with the landforms that evolve on the surface of the earth. The interior of the Earth is a source of various endogenic forces that have led to the formation of a variety of landforms in many parts of the world.

The Earth and its plates:

A plate is a portion of the earth's outer layer consisting of crust and topmost mantle moves as a unit in response to convection in the mantle itself.

By mere physical observation, most of the earth seems inactive and unchanging. But in some places e. g California, Italy, Turkey and Japan, the earth crust is dynamic and therefore able to move producing earth processes and forces e.g. earth quakes. These regions and other mobile (active) areas lie on major earthquake. Zones most of which run along the middle of the ocean basins although some pass across continental land masses e.g. alpine Himalayan belt. Therefore, the earth crust consist of several large rigid plates and the movement of these plates produces the earths' major structural features e.g. mountain ranges, mid-ocean ridges, trenches and large faults.

Stable areas with few or no earthquakes or volcanic eruptions are positioned in the middle of a plate whereas active areas where rock structures are constantly being subducted or created are situated along the plate boundaries. Active zones of subduction (where the plates are being compressed and rocks destroyed) are off the coast of japan, California, S. America, the Caribbean and Newzealand. Active zones of expansion are in the middle of both the Indian and Atlantic oceans characterized by ocean ridges.



The main plates and their boundaries are shown above. Where plates meet, those are **destructive boundaries** while where they move in opposite directions, those are **constructive boundaries.**

The origins of the earth:

The way(s) the Earth came into existence has been and is still a matter of debate among scientists. A number of theories have been advanced to explain how the Earth came into existance.

A theory is a statement or group of statements established by reasoned arguments and intended to explain still needs proof but nevertheless it appears reasonable.

1**.the dust cloud theory:** Many scientists today believe that the earth formed from a vast spinning disk of dust and gas. This disk begun to condense into solid material about 5 million years ago. This time the gravitation force was generated and this force made matters at the Centre. The huge amounts of convergent pressure made temperatures to rise until a time when it was high enough to sustain numerous atomic reactions that begun to radiate heat. It is here that the sun was born.

On the other side of the disk, small concentrations of material begun to attract additional matter to themselves eventually growing into planets.

As the Earth begun to form, heavier materials e.g. iron and Nickle sunk into the center and formed the core while the lighter materials (silicates) remained on the outside and formed the mantle and the crust the lightest substances. Gases were attracted to the mass, and remained as an external envelope that constituted the atmosphere. All these processes had by 4.5 billion years ago ended and the earth was in existance.

2.The Big-bang theory; This is another prominent theory that was advanced to explain the origin of the earth by two prominent men Lamaitre Georges and Hubble Edwin. Lamaitre George was a Belgian Astronomer while Hubble Edwin was an American scientist and they advanced this theory in 1927.

According to them, in the very beginning, there was totally nothing. In about 15 million years ago however, an explosion (big bang) occurred and a speek of matter was produced. From its inception and formation this speek of matter has been expanding and therefore producing the Earth and all there is in it the atmosphere (air) and biosphere (living things). The wonder here is; how nothing could produce something.

3. The theory of Kent; Kent was another scientist who tried to trace how the Earth came into existance. According to him, matter that composed the universe was originally divided into elementary particles (rings) which filled the entire space of the universe.

These elementary particles Kent argues; later begun to acquire primary forces that gathered the towards the centers of attraction and simultaneously coming into rotary motion. These particles gradually condensed and formed planets the Earth inclusive. Kent wrote “Give me matter and I will build the world out of it”

4.The Laplace Hypothesis Theory; According to this theory, there originally existed an enormous body called the “**Nobula”.** This originally body had a dense center (core) that revolved about a common axis. All the particles of this body obeyed the universal law of gravity. The revolving body later on contracted; becoming denser and finally assumed a shape. The rotation of this body (nobula) generated a certain centrifugal force directed away from the axis of rotation. Thus, those two forces operated on this body-the force of attraction (gravity) and the centrifugal force which tended to tear the particles away from the axis of rotation.

The centrifugal force grew much stronger than the force of attraction forcing some parts of Nobula to break off in form of irregular rings. These rings became the core of various planets that surrounded the sun including the Earth. The Earth therefore multiplied from these original rings and later on attained the current shape.

6.The theory of chamberlain and moulton 1904: According to these two individuals, the planets are held to be biparental in origin and are therefore thought to have evolved from the interaction between the sun and another star of suitable mass. The star as it approached the sun generated enormous amounts of tidal disturbances' these disturbances coupled with eruptive forces inherent in the sun's layers was the ejection of small jets of sialic matter to greater distances which condensed to produce the Earth and other planets.

6.The Bible theory: This is the most commonly known and ordinarily accepted theory particular among Christians. This theory is generated from the Bible (Genesis ch.1) where there was totally nothing but the power of God created the Earth and everything in it. There was total darkness and God ordered light to appear and it appeared. Other things also followed God's command and the 7th day God) had finished his job of creating the Earth.

DISTRIBUTION OF CONTINENTS AND OCEAN BASINS:

The earth is made up of continents and oceans. These are 7 continents and 4 oceans. The nature of the earth and particularly the origin and distribution of these continents and oceans is physically mysterious and therefore for a longtime has been a subject of contention and controversy among geographers and geophysicists. The continents of the earth occupy only 29% of the total earth surface while 71% is occupied by water bodies.

The distribution of land in both hemispheres is not uniform. Much of the landmass is found in the Northern hemisphere (39.4% of the Northern hemisphere) while the land mass covers only 18.6% of the southern hemisphere. Hence the Northern is called the **Land** hemisphere while the southern is a **water** hemisphere. The land hemisphere is composed of North America, Africa Asia, Europe and more than ½ of south America. The remainder forms the water hemisphere with its pole near Newzealand. Land covers about 47% of the land hemisphere and 11% of water hemisphere.

Its important to note that almost all continents are in pairs expect Antarctica. Africa is paired with Europe. North America with South America and Asia with Austria. Also, all continents have got an antipodal relationship with oceans in a sense that whenever land occupies one part of the earth, directly

Explanation (theories) that try to justify why continents and ocean basins are the way they are;

Various attempts to justify why the earth, its continents and ocean basins appear the way they are have been made. They however, fall under two categories:

I. Those that were advanced by scientists earlier before the continental drift theory was accepted.
II. Those that were advanced in justification of continental drift theory.

Theories before continental drift:

1.The tetrahedral Hypothesis; the tetrahedral hypothesis state that the distribution of the continents and ocean basins is in resemblance of a tetrahedron. A tetrahedron is a 3-dimensuional figure with 4 equilateral triangles. This is a theory that attempts to explain the massive concentration of land in the North hemisphere and water in southern hemisphere it was believed that the contracting globe would tend to shrink in a tetrahedron from. Thus, regarding the earth as a collapse of crust in a shrinking interior.

The pacific Indian, Atlantic and Arctic oceans correspond to the 4 faces of the tetrahedron while the continents were left as elevated regions containing edges and corners. Its true that the present distribution of sea and land globally is similar to a tetrahedron structure though critics say that the earth has got a uniform crust which could go contrary to the theory of isostasy which tends to keep the earth in state of equilibrium.

They also argue that if the depressions of the oceans were a product of contraction, their floors would be made of sialic rocks which is not the case (are made up of simatic rocks). they also argue that the tetrahedron contraction is possible with a small globe but not an enormous, globe like the earth.

2. The moon Hypothesis; This theory is based on the formation of the moon. According to this theory, the moon is made up of sialic materials(rocks) which are the very rocks that make up the earth crust. Hence to justify the absence of sialic materials on some parts of the earth-particularly in some ocean's basins, some scientists e.g. **Esmond Fisher** (1881) argued that the missing sialic rocks were scooped from the earth when the great rapture occurred. Fisher suggests that the huge Pacific Ocean depression is a scar left 1/3 of the earth while the Pacific Ocean-depression is about 1/3 of the earth surface too.

Though impression, the moon theory has been criticized along the fact that if the moon is composed of material from the Pacific Ocean alone then how were other depressions of the other oceans formed? Also, it has been reasoned that for the moon to separate from the earth, it required strong and immense solar tides which mechanically has been proved impossible.

3.The Expanding Earth Theory; Supporters of this theory argue that the earth originally was small with a thin and uniform layer of sial around it. Since its inception however, the earth has been expanding and therefore the sialic layer collapsed and yielded continental rafts. As more expansion took place the rafts moved out radially and continued to be separate. Simalic materials escaped from deeper layers of the crust and occupied the gaps between these rafts to form ocean floors.

The cause of expansion according to this theory was the age of the earth. As the earth grows older; its gravitation force reduces and weakens making it expand due to enormous pressure from within it.

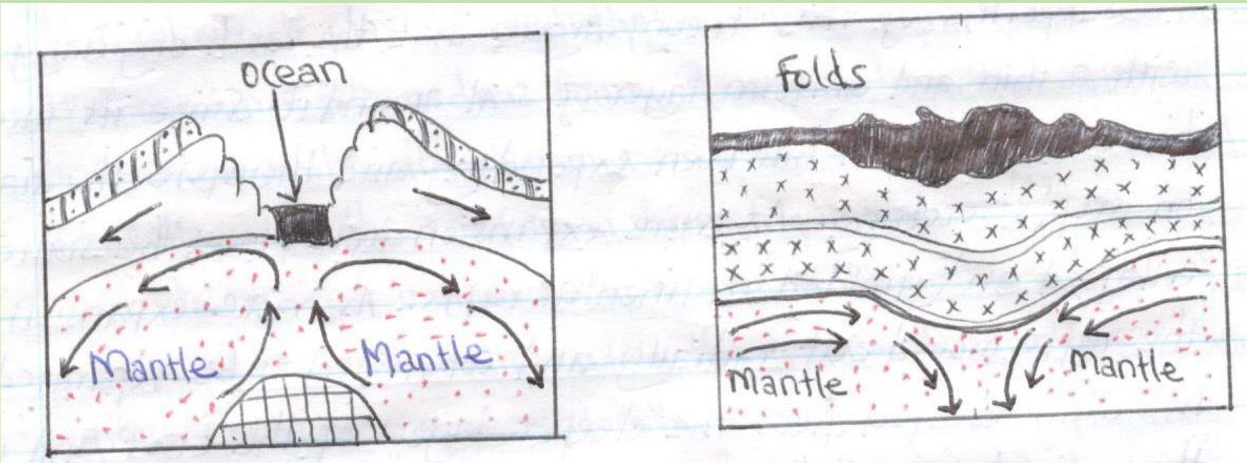
4.The convection currents Hypothesis; The core is the hottest Layer of the earth while the crust is the coldest. The mantle between them is the only layer composed of molten materials(magma). Because of this difference in heating, convection currents which more from the hottest core to the coldest crust are generated. Transfer of heat by convection was discovered by **count Rumford** in 1797 while subcrustal currents within the earth were suggested by **William Hopkins** 1839 and their relevancy to continental distribution by **Esmond Fisher** in 1881.

According to this theory, when subcrustal currents rise and reach the crust, they become cold and hence heavier making the to move out radially and finally back, into the interior. They are again heated up rise up again and the process continues.

Where they move out radially, they drag the crust in opposite directions making it break. As expansion continues, basic materials accumulate under and become ocean floors, it is here that the depressions of oceans are formed. It is this theory which was then improved to explain the sea floor spreading theory. At points where the currents fall back into the interior, rocks are accumulated and therefore the crust folds.

Convection currents and their role in crustal separation and folding:

Convection currents ride and pull the earth apart. convection currents fall back and cause folding



THE THEORIES JUSTIFYING CONTINENTAL DRIFT

Continental drift is a hypothesis that states that continental masses have changed their relative positions as a result of fragmentation and apart of original land masses. It is now widely believed that continents moved through time and still moving even today. Several theories of continental drift have been advanced as discussed below.

1. The expanding Earth theory is one of these theories. According to the theory, the earth was at one time a small planet with a thin continental layer at the surface. The interior of the Earth expanded and forced the outer crust to crack. The crust was therefore divided into separate crustal blocks (continents). As the Earth continued to expand, the cracks widened and the gaps grew wider as crustal blocks moved away from each other. The widening gaps became oceans, while the crustal blocks became continents (Note: This theory was originally advanced to explain distribution of oceans and basins but since it involves horizontal movement of the crust, it can also pass as a theory of continental drift.)

2. In 1910, F.B Taylor came up with another theory of continental drift. According to this theory, originally there were two big land masses, namely, Laurasia and Gondwanaland. Laurasia was located near the present-day North pole from where it later drifted southwards towards the equator. Where there was resistance, the crust stretched and split forming troughs that become ocean basins. Taylor suggested that the basins of the Atlantic and Indian oceans were left behind between the drifting continents.

Taylor explained the force that caused the movement in terms of the moon's gravitational pull. He contended that the moon came very close to the earth and exerted an enormous gravitational pull that caused Laurasia and Gondwanaland to move towards the equator away from their positions near poles. The movement is said to have taken place sometime in cretaceous period about 135-70 million years ago. According to Taylor when Laurasia and Gondwanaland met, the Atlas and Alpine fold mountains were formed. Taylor's theory, however seems to have some weaknesses. In the first place, it does not explain the formation of earlier fold mountains like the Caledonian system of siluro-Devonian times and the Hercyrian system of mid-Permian and carboniferous periods. In the second place, it seems highly doubtable that the moon could ever exert enough force to pull the gigantic continents!

3. In 1915, Alfred Wegner, a German climatologist and Geophysicist published a book titled "Origin of continents and ocean basins" in which he argued that continents changed their positions over time. This led to what is now known as Wegener's theory of continental drift. According this theory, the present-day continents originated from one landmass known as "Pangea". This single siatic landmass is thought to have been positioned somewhere near the south pole and was surrounded by a big expanse of water known as "Panthalassa". This landmass later split into two super continents known as Laurasia (Atlantis) and Gondwanaland. The two were separated by a narrow water body known as the "Sea of Tethys". Wegener believed that Laurasia lay across the Equator while Gondwanaland lay near the south pole. Gondwanaland is believed to have

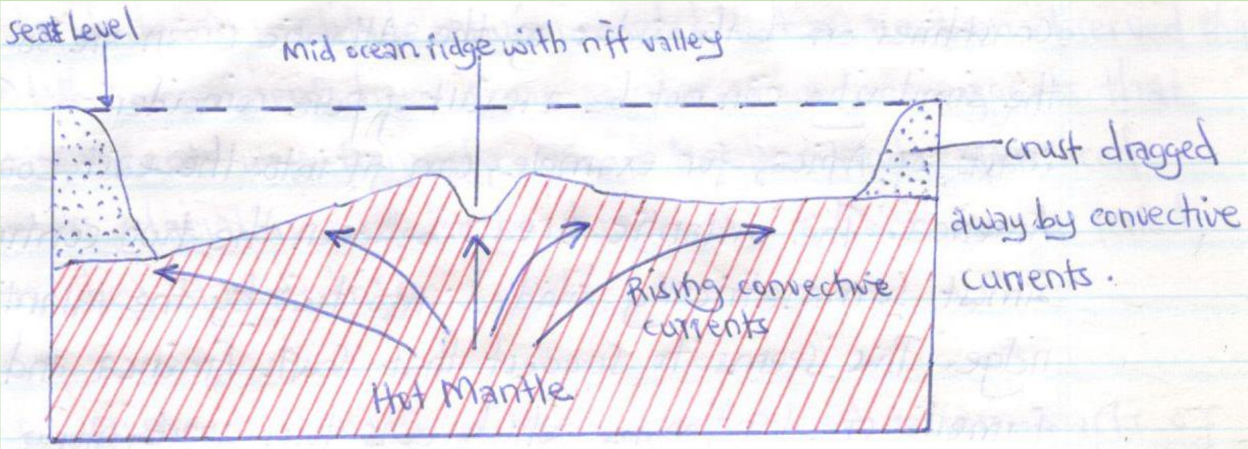
experienced largescale glaciation during the carboniferous period, that is approximately 345-280 million years ago.

During the late palaeozoic and early Mesozoic eras, numerous cracks developed in landmasses leading to separation and consequent drifting. Finally, during the cretaceous period, approximately 137-70 million years ago, the land masses completely broke up.

Gondwanaland gave rise to the "southern continents" namely, Africa, south America, Antarctica, Australia, the sub- continent of India and numerous islands in the southern hemisphere. Laurasia broke up to give rise to North America, Europe, Asia and other land masses in the northern hemisphere such as Green land and ice land.

Wegener contends that the Himalayas were formed when the sub-continent of India collided with the Asian landmass. Wegener suggested that breaking-up was due to centrifugal force but this explanation was dismissed by some geologists as unconvincing. Nevertheless, his theory was exciting and was later followed up other scholars.

4. Another attempt to explain continental drift is the **sea floor-spreading theory**. One of the modern theories of the continental drift, the sea floor spreading theory is basically the work of a geologist by the names of H. Hess. It was propounded in the 1960's. according to the Hess, the interior of the earth is in the molten (semi-fluid) state because of great heat resulting from radioactivity and geo-chemical reactions. This tremendous heat causes melting or near-melting of rocks tend to rise from within the mantle in form of convective current. As they reach the base of the earth's crust, they flow horizontally beneath and drag the crust in the direction to which they are moving. This therefore causes movements of the crust, hence continental drift. Where the current is moving towards the earth's surface, new rocks are deposited. This is what happens at mid ocean ridges. The newly deposited rocks displace the old ones and ocean floor therefore widens, that is, the sea floor spreads apart.



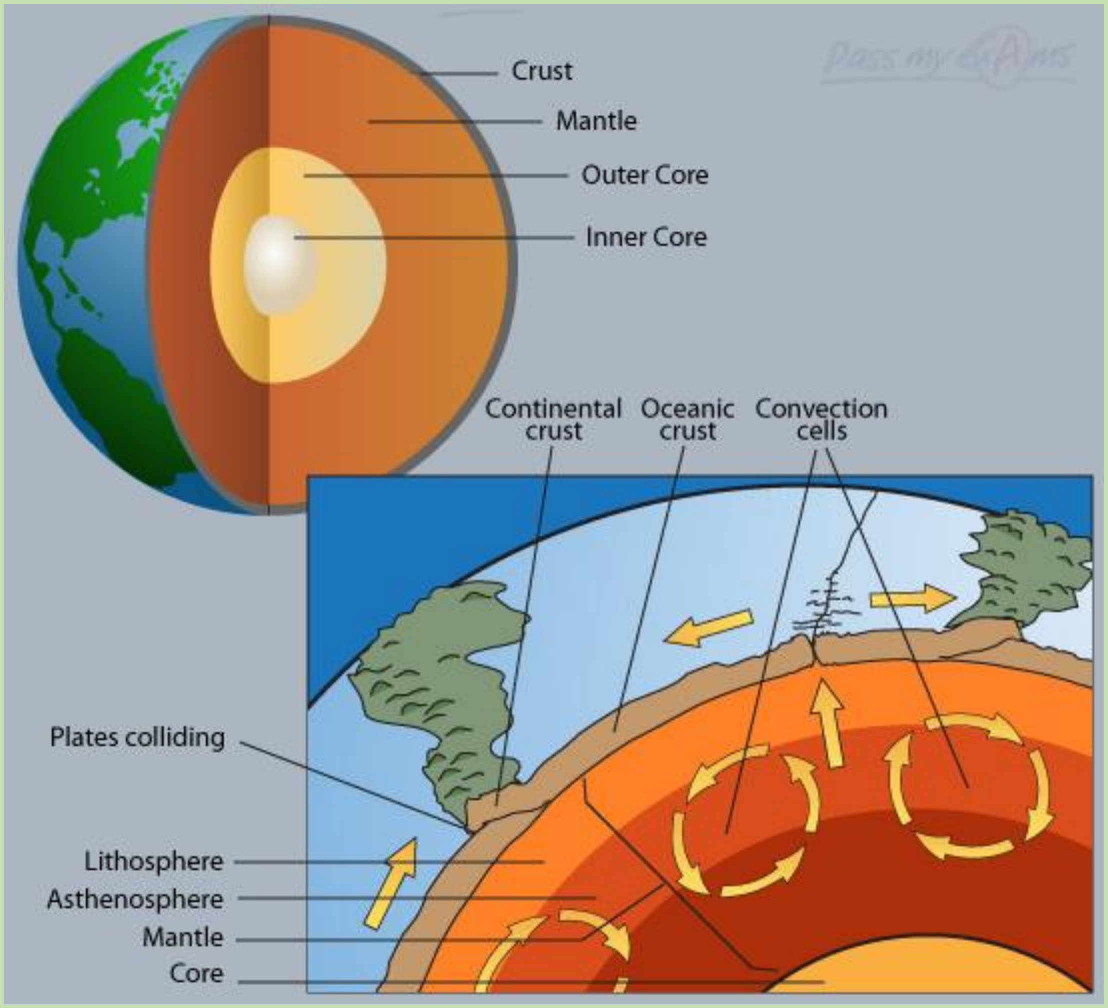
5. **The plate-tectonics theory**. The theory of plate tectonics was put forward in the 1960's. It coincided with a time when a large amount of research was being conducted

about the ocean floors. Since then better understanding and technology have refined the theory to explain how the Earth has been shaped. Plate tectonic theory involves processes to which parts of the earth's crust breakup and slide horizontally on top of molten rocks of the upper mantle.

The theory assumes that the Earth crust is not in one piece but is divided in to a number of separate parts called **Tectonic Plates**. These plates are mobile, floating on the partially molten rocks of upper mantle. The lighter continental / SIAL rocks rest on top of mobile Tectonic Plates

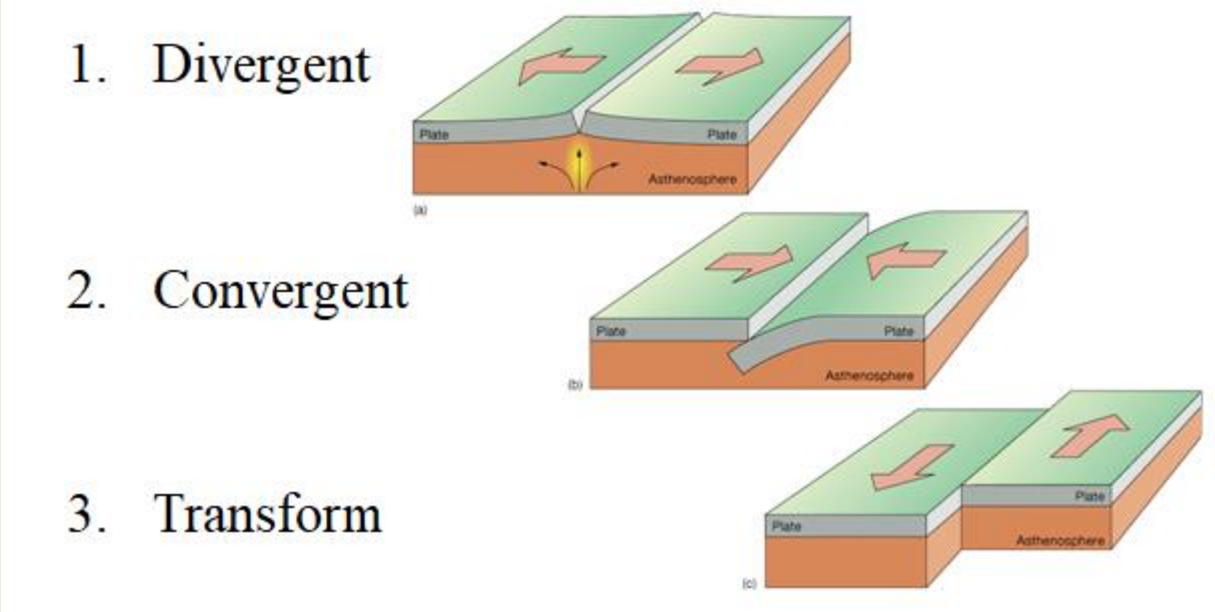
There are 6 main plates and about 12 minor ones but the important regions are the boundaries where plates meet or move apart. Major plates are pacific, the African, the Indian / Australian, the Eurasian, the North and South American and Antarctica plates.

Horizontal movements take place due to internal forces that is Geochemical, geophysical and radioactivity reactions generate heat that melts rocks giving rise to convection currents that drive the plates.



Plates change overtime in terms of position, size and shape. As plates move, continents on top also move following the direction of plate movements.

Plates margins are seismologically active creating three types of margins / boundaries ie **Constructive** margins / **divergent** boundaries, **Destructive** margins /**convergent** boundaries and **Neutral** or **conservative** margins / **Transform** boundaries.



The movement of the Tectonic plates results in the movement of continents / landmasses and water bodies change their positions relative to each other.

All the continental landmasses and oceans are moving closer to the North pole. The Indian/Australian plates are moving North East wards; the pacific plate is drifting North wards as well as the North American landmass. The South American land mass is moving west wards.

There are 3 types of plate movements / boundaries caused by convection currents which influence the distribution of continents. These are;-

Divergent movements caused by Tectonic plates moving away from one another. These lead to faulting and warping of crustal landmasses. On the sea floor, this spreading process produces Mid-ocean-ridges and islands. For example The Mid-Atlantic Ridge is a divergent plate boundary where sea floor spreading occurs. Iceland sits atop a divergent plate boundary where continental rifting occurs

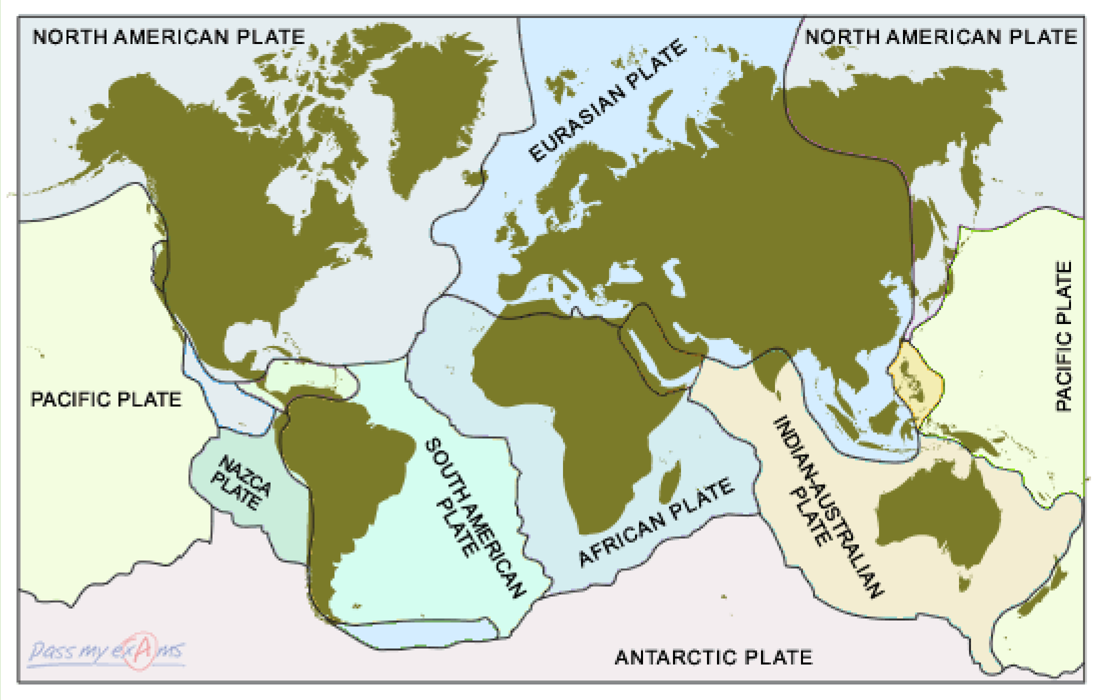
Convergent movement caused by Tectonic plates moving towards one another. And as a result:-

- Continental landmasses may move towards each other getting closer; collision may occur leading to folding and formation of fold mountains e.g. the Himalayas due to the collision of India and Asia.

- Continents may move towards oceanic plates causing subduction of denser simatic rocks. Collision of plates and subduction leads to formation of Trenches, volcanic and fold mountains eg Nazca, Java and Tonga trenches etc.

- Oceanic crust may move towards each other causing narrowing of ocean basins and continents move nearer; leading to formation of trenches and volcanic arcs eg pacific and Eurasian plates led to Mariana trench and Japan arc.

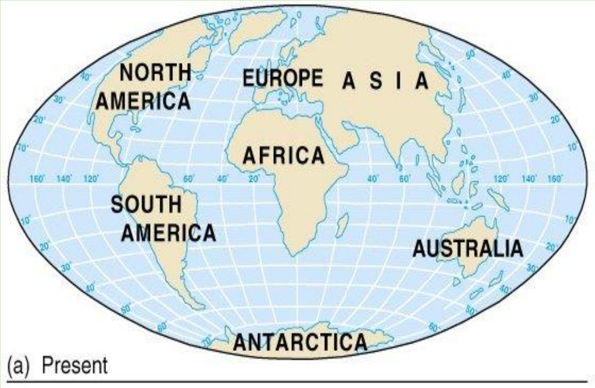
Transform movement where plates move past each other hence no collision or diversion. They offset sections of continents, ridges and trenches e.g. North American Plate moved against Pacific Plate forming San Andreas fault in California causing offsetting of land to the west, Owen fracture near the Gulf of Aden and Romanche fracture off west Africa.



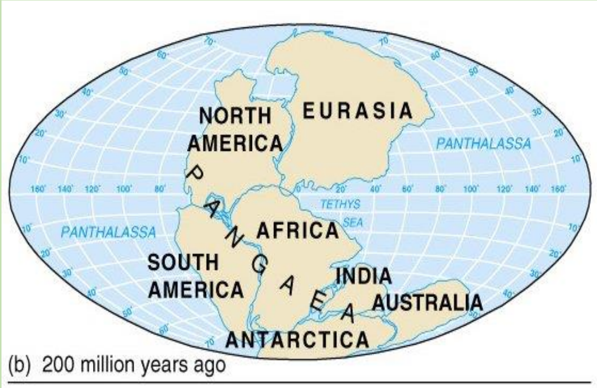
NB: lateral Earth Movements are diastrophic / large scale differential movements that operate horizontally within the Earth Crust. They are caused by internal forces (divergent forces) with resulting strains and stresses in the rocks. They lead to folding and faulting of the crust. Vertical Earth movements are diastrophic movements that operate vertically exerting pushing force on to the crust either upward or downward along a radius from the centre of the earth to the surface. They usually occur on a large scale hence called epeirogenic (slow large scale uplift) and may involve vertical uplift or subsidence, possibly the result of isostatic readjustment, or warping and tilting. May be on a local scale especially around the coast, thus affecting the relative level of the land and sea and therefore the nature of the coastline. Also lead to warping and tilting.

EVIDENCES OF CONTINENTAL DRIFT

There are several lines of evidence to prove that continental drift is reality. Geometrical fit of coastlines (jig-saw fit) is one of the earliest evidences. It has been studied and observed that some coastlines on both sides of the Atlantic Ocean are so similar that the similarity can not be a result of pure coincidence. The west coast of Africa, for example, can fit into the east coast of South America. The Atlantic Ocean between the two continents is even almost symmetrically divided into two by the Atlantic mid-ocean ridge. This seems to suggest that South America and Africa were formally one landmass which was torn apart along the Atlantic mid-ocean ridge to give rise to this similarity of coastlines.

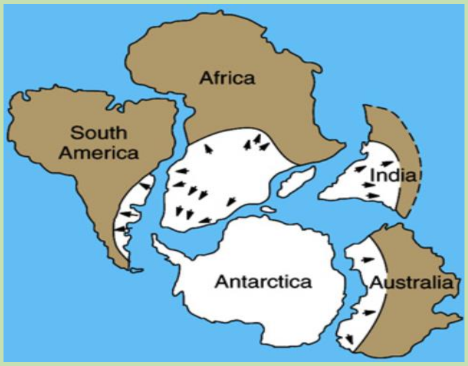


(a) Present



(b) 200 million years ago

Similarity of rocks is evidence used to justify continental drift. There are remarkable similarities between rocks found in different land masses of the southern continents. In Africa, the rocks of Ghana and Cameroon share common characteristics with those of Brazil in South America. This suggests that Africa and South America were formerly one landmass but later drifted apart with the similar rocks drifting along on each of the continents. Also Rocks in the Appalachians of North America and the Caledonides of Britain and Norway are very similar and are also similar in age. When we fit Europe and North America together, we find that The Appalachians and Caledonides could form a single mountain chain.



Studies from paleoclimatology have proved further evidence that justifies continental drift. This is in connection with glacial deposits. Carboniferous glacial deposits exist in tropical and subtropical lowlands. They for example exist in Congo basin and in southern Africa where they are known as Dioyka tillites. The existence of these deposits in tropical and therefore hot lowlands is sure proof that landmasses must have at one time been positioned in cooler latitudes where glacial conditions existed. (Note that glaciation can only occur either in very high latitudes or altitude environments). It has also been observed that all southern continents have signs of glaciation. This suggests that these continents were formerly joined together and experienced common glaciation, most likely during the carboniferous period. Before they started drifting apart.

The occurrence of laterite in North America and certain parts of Europe shows that these regions once upon a time enjoyed tropical climatic conditions which were conducive to the formation of laterite. (Note that laterites from under hot, dry and wet conditions of the tropical lands). The laterite could have formed when Laurasia was still lying a side the equator. Therefore, the location of laterite in a cold place suggests that such environments moved from warmer positions which movement is clearly indicative of continental drift.

The existence of coral reefs in cold green land is another sure proof to backup continental drift. Coral polyps and the resultant coral reefs only thrive in hot, tropical, marine environments. They do not essentially form in cold areas. Their existence in cold green area can only be explained by the fact that green land was at one time positioned in the ho tropical latitudes for corals to form. Green land must therefore have moved from lower and warmer latitudes "carrying" with it the already formed reefs. That movement was in a manifestation of continental drift.

The existence of Fold Mountains justifies movement of plates and therefore continents. Fold Mountains only form when there are compressional forces acting in the same direction. These mountains must have formed when crustal plates moved towards each other. For example ranges in Canada match Norway and Sweden and Appalachian Mtn. match UK Mountain. The fact that crustal plates moved therefore proves that continents also moved and are perhaps still moving.

Similarity of oil beds is yet another evidence of continental drift. It has been found out, for example, the oil beds of Brazil are the same as those of Angola. This has been interpreted as being indicative of common origin and evolution of oil generating organism. The two areas (Brazil and Angola) must have been one geological unit with common oil beds that drifted apart with each area "carrying" with it the already formed reefs. That movement was a manifestation of continental drift.

The existence of big amounts of salt evaporites in some cold part of USA, Britain, Germany and Russia is another evidence of continental drift. Some water contains salts in solution and when the water evaporates, beds of these salts are left behind. Such rocks which are known as evaporates, form under hot and dry conditions which currently are not possible in these cold areas. These evaporites are believed to have formed long ago when Laurasia was still enjoying hot and dry tropical conditions. This further proves that continents have moved away from their original positions.

Tectonic activity and instability are considered to be most modern evidence of continental drift. It has been proved that the gap between Africa and south America gradually gets wider and at an average rate of about 4cm/year. Frequent earth quakes around oceanic ridges and oceanic trenches in Japan, Calfornia, Peru, Chile, Islands of East Indies suggest earth movement. Earth quakes and the processes of faulting and vulcanicity and the resultant land forms created are all signs of instability within the earth's interior which ultimately causes movements within the crust and hence drifting of continents.

Computer Photographs: The use of Laser Geodynamics Satellite (LAGEOS) to measure the movement of continents show that small cracks of the rift valley are always widening at a rate of 2-3cm per annum. If widening continues at this rate, then the eastern parts of Ethiopia and Kenya will at one time be torn off from the rest of the African continent suggesting that more plates will be formed as earlier ones formed.

Fossil Evidence: fossils are remains of living things that lived long ago. Distribution of other Reptiles and Plants Similar fossils (reptiles and plants) are found on the different continents. For example Mesosaurus that lived about 250 million years ago. Fossils of Mesosaurus are found on both sides of the Atlantic in South America and Africa. How could they have crossed the oceans? they didn't, the continents were part of the same landmass about 200-300 million years ago.

Paleomagnetism refers to ancient or fossil magnetism in rocks. It is established from geological laboratory research on rocks of the earth's crust which are always magnetized by the earth's magnetic field at the time of formation. Paleomagnetism is based on the fact that igneous rocks when cooled retain or preserve some magnetic properties which at time of magnetization, point to earth's north-south poles. It follows that if young rocks are formed, they are magnetized and their magnetic poles point north and south at the time of magnetization. Research on rocks in India, Australia and south America has duly shown that magnetic lines in these rocks no longer point in a north-south direction as expected. This has led researchers to conclude that continents must have moved away from their original positions, such that in the process, they got twisted. It is as a result of this twisting that the magnetic lines deviated from the north-south orientation and now point in different directions.

Conclusively, several theories have been advanced to explain continental drift. Like all theories, some of them suffer from defects and have been criticized. Other seem to be quite reasonable and even have scientific proof. Modern evidence based on paleomagnetism and movement of plates will definitely stand the test of time.

QNS

1. Discuss the theories of continental drift. What are the evidences to justify continental drift?
2. Justify the continental drift theory using the evidence from the southern continents.
3. To what extent can the theories sea floor spreading and plate tectonics explain the present relief landforms of East Africa.?
4. Explain how Wegener's theory of continental drift explains the formation of the major relief features in East Africa.
5. (a) what is meant by continental drift?

5. (b) Explain the relevance of Wegener's of evolution of continents

6. To what extent have tectonic movements been responsible for the development of Relief and landforms in East Africa?

(a) What is meant by continental drift?
(b) Explain the factors responsible for the present distribution of continents and ocean basins.

7. Justify the view that the present-day continents have drifted from their original positions. (**NB:** Give the continental theory: Alfred Wegener).

8. Examine the relevance of Wegener's theory in the distribution continents and ocean basins.

9 (a) Distinguish between lateral and vertical earth movements

(b) Explain the relevance of plate tectonic theory in the understanding of the present day distribution of oceans and landmasses.

EFFECTS OF CONTINENTAL DRIFT ON EAST AFRICA'S RELIEF AND LAND FORM:

From the above evidences, one can easily see that continental drift is a reality and some of the illustrations have been quoted from East Africa. This therefore means that many of the landforms in East Africa and the processes that lead to their formation can directly or indirectly be related to continental drift. Each of the land form processes has got its unique relationship to continental drift. These are;

1. **Continental drift and features of faulting:** faulting is simply a process by which rocks develop lines of weaknesses/cracks called Faultlines resulting into displacement of rocks. Faulting occurs when there are either compressional or

tensional or differential uplift forces. When this happens, numerous landforms are formed

(a) **Fault scarps.** A steep scarp formed when there is a vertical displacement of one block along a line of fault

(b) **Rift valley.** Along narrow depression formed when there is a subsidence of a middle block between two fault lines, up thrust of opposite blocks living the middle block low or upward of the faulted landscape but with a slow uplift in the middle and a fast uplift in the extremities.

(c) **Block/Host mountain.** A high land with fault scarps on one or all of its sides formed when there is either subsidence of opposite blocks of a faulted landscape leaving the middle standing higher up or by fast uplift of a middle portion of faulted, landscape and a slow uplift of the opposite blocks forming a highland or a compression of a faulted landscape forcing it to rise high up.

(d) **Fault guided valley.** A valley whose orientation follows nature and direction of a fault line.

2. **Continental drift and landforms of folding:** folding occurs when continental plates are being compressed within themselves. When the landscape is made up of young rocks it will fold producing features e.g. **synclines:** valleys found in a folded landscape and **anticlines:** hills found in a folded landscape.
3. **Continental drift and landforms of warping:** warping is also a process which is produced along a convergent boundary where sinking convective currents drag a landscape downwards into a saucer shape (down warping) on a large scale or at a divergent boundary where rising convective currents produce an extensive upward force rising an extensive area up (up warping). these processes always follow each other

   When down warping occurs basin landscapes e.g. Lake Victoria and kyoga basins are formed.

   When up warping occurs a plateau e.g. the east African plateau is formed

4. **Continental drift and land forms of vulcanicity.** At convergent and divergent plate boundaries, compressional and tensional forces are respectively generated resulting into fault lines. When this faulting has occurred and is followed by movement of magma through fault lines, we say vulcanicity has occurred. Vulcanicity produces two types of features; intrusive and extrusive features: intrusive features are formed when magma cools within bedding planes after failing to reach the surface. They include;

   a) **Batholith:** this is formed when magma cools within very deep layers of earth on an extensive scale.

b) **Laccolith:** formed when magma is very viscous and cools near the surface forcing it into a dome shape.
c) **Lapolith:** formed by the cooling of basic magma near the surface later on sinking due to the weight of overlaying rocks and producing a saucer shape landscape.
d) **Still:** formed when magma cools horizontally within bedding planes. Mostly by basic magma which can curve.
e) **Dyke:** produced when acidic magma cools vertically within bedding planes.

Extrusive features are formed when magma cools on the earth surface. This produces two types of features volcanoes (and their related features) and geothermal landforms.

Volcanoes are high lands produced by accumulatio of explosion materials(magma). These include; Acidic cones, Basalt domes, Stata volcanoes, Ash and cinders cones, explosion craters, ring craters, calderas, volcanic plugs, cumulo domes, lava-plateaus, composite volcano cones.

Geothermal features include; hot spring, geysers and fumaloles.

OTHER PROCESSES INDIRECTLY RELATED TO CONTINENTAL DRIFT

5.**glacial features and continental drift:** glaciation is a process that involves the movement of ice from a high ground. In east Africa, glaciation occurs on mountain Rwenzori (block mountain), Mount Kenya and Kilimanjaro (volcanic mountain) whose formation is already explained in relation to continental drift above. Land forms produced are either erosional or depositional.

Erosional feature includes; collies or cirques, pyramidal peaks, eretes, hanging valleys, u shaped valleys, waterfalls, rock montonees, crag and tail, truncated spurs and tans.

Depositional feature includes: kame terraces, erratics, outwash plains, drumlins, esker, moraine, and kettle holes.

6.. **Fluvial features and continental drift:** fluvial activity refers to the work of the rivers and the features they produce. Rivers usually begin from the highlands e.g. mountains where their catchment areas (sources) are and slope downstream up to where their mouth are in lakes, seas and oceans. So, the fact that rivers come from highlands and highlands are a product of plate movement process as already seen above indicates that fluvial landforms are either indirectly related continental drift. Fluvial landforms are either erosional or depressional.

Erosional landforms include; waterfalls, potholes, interlocking spurs, gorges, rapids and meanders

Depositional landforms include; deltas, deferred river tributary, alluvial fans, levees, food plain, oxbow lakes, braided channels, alluvial cones and bajadas

7.Mass wasting and continental drift; mass wasting is a general term that includes all forms of slope failure ranging from slowest process to the fastest landslides. Like fluvial activity and glaciation mass wasting operate in high lands whose formation is directly linked to convectional currents, plate movements and finally continental drift. Being a denudational process it does not produce a lot of landforms. However, it produces some, e.g. Terracettes, straight slopes, scars and slide-dammed lakes.

8.**weathering and continental Drift;** weathering is a process which uses the agents of weather mostly of weathering and continental drift is about the genesis of rocks. Rocks change from one state to another rotating between igneous to sedimentary and to metamorphic rocks, but their genesis is in igneous where the first-class rocks are produced the cooling down of magma. Magma escapes from deep layers to the earth as a result of plate movement under pressure from convectional currents.

In the process the outer shell of the earth (crust) can crack (fault) creating gaps within which magma will escape to cooler parts of crust; cooling into igneous rocks. These igneous rocks can later on yield to sedimentary and metamorphic rocks provided conditions are contusive. These will be weathered producing landforms such as exfoliation domes, inselbergs, stalagmites, stalactites, caves, pillars and dry valley.

9.**coastal features continental Drift:** lakes, seas and the way they interact with their coastals produce a number of landforms. Lakes, seas and oceans are syndines and depressions whose formation is linked to continental drift.

According to FB Tylor seas and oceans were formed when there was resistance to the outward flow of landmasses during the movement of Laurasia and Gondwanaland from poles to the equator the crust would flow out in lobes rising mountain ranges in front while behind in stretched and thinned out in some areas splitting to form troughs that become oceans. The collision of Gondwanaland and Laurasia formed a depression that became the Mediterranean Sea.

According to Alfred Wegner, the Red sea emerged from sea of Tethys that developed when Laurasia was beginning to drift from Gondwanaland

Lake Victoria and kyoga are basin lakes formed in areas of down warping. Waves within these waterbodies produce both erosion and depositional features.

Erosional features include; spits, bay bars, tombolos, beaches, cuspate forelands, lagoons, sand dunes, mudflats, salt marshes and berms. All can be seen along the East African coast and on the coast of internal lakes e.g. Lake Victoria.

THE ROCKS OF THE EARTH

A rock is an aggregate of mineral of minerals, existing in a solid state. The minerals which make up a rock are formed from elements like potassium, calcium, iron, aluminum and silion. Some minerals such as gold, quartz and bauxite have more than one element. Rocks can therefore be defined by their mineralogical composition nut not necessarily by hardness. Therefore, although rocks are usually the stony, hard and solid parts of the earth's crust, the term rock also includes substances like clay and sand. Rocks of the earth's crust are commonly classified according to their origins into their origins into three major types namely; igneous, sediment ally and metamorphic.

Igneous material, also described as "fire-formed" rocks, are formed by the cooling down of molten magma, derived from deep in the earth's interior by the process of vulcanicity. As a result of cooling in cooling in different parts of the earth's crust magma forms different rocks.

Igneous rocks formed at the earth's surface are referred to as volcanic or extrusive. The molten rock, that is the magma rises through the crust until it reaches the surface. It cools down rapidly to form small crystalled rocks. Examples of volcanic rocks are rhyolite, andesite, basalt and obsidian.

Rocks formed at great depth within the earth's crust are called plutonic or abyssal. They are also described as being "deep-seated". The magma that forms these rocks rises for a short distance and cools in the crust very far from the earth's surface. This magma cools extremely slowly resulting into compact and coarse structures. Because the rate of cooling is low, there is all the time for large crystalled minerals to form. The rocks that form include granite and diorite.

Igneous rocks formed at positions intermediate or between volcanic and plutonic are referred to as hypabyssal. Like plutonic, hypabyssal rocks are intrusive but they form nearer to the surface of the earth than plutonic. A good example is dolerite. All pure igneous rocks do not contain fossils.

Geologists classify igneous rocks according to their composition and their depth of cooling. If categorized according to their silica(si0_2) content.

If a rock has over 60% of silica content, it is acidic e.g. granite (intrusive), rhyolite (extrusive). If its silica content is between 52-66% silica, it is intermediate e.g. Diorite (intrusive) and andesite (extrusive)

If it is between 45-52% silica the rock is basic e.g. Gabbro (intrusive) and Basalt (extrusive) where if silica is below 45%, the rock is ultra-basic e.g. peridotite (intrusive) and supentinite (extrusive)

A second major rock type is that sedimentary rocks. These rocks are formed from sediments which are either worn down from an original rock or which are remnants of another rock material. The sediments are then transported and deposited elsewhere. It is for this reason that these materials are also referred to as “derived” or “secondary” rocks. These rocks are subdivided into three categories according to the origin of sediments.

Sediments may result from mechanical process particularly rom agents of erosion, that is rivers, and, ice and waves. These agents cause erosion on one part of the earth crust and transport and deposit the eroded particles on another. The deposited material accumulates and becomes compact. As time elapses, the deposited material turns into hard rocks. Wind deposition creates rocks known as loess; river deposition creates alluvium while glaciers deposit materials generally termed as moraine.

Sediments may also result from chemical precipitation in hot tropical regions. Some water contains salts in solution and when the water evaporates, beds of salts known as evaporites are left behind. An example is a deposited carbonate. Limestone is soluble and can be dissolved and transported in solution as calcium hydrogen carbonate. Thus, water can transport limestone in solution for long distances.

If and when water evaporates, the limestone is left behind as a deposit as more water evaporates, limestone dries up into a hard rock known as travertine which is hardened crystalline calcium carbonate. Deposited carbonates are rocks out of which karst features like stalactites and stalagmites are made. These features are associated with underground caves in limestone areas.

Similarly, iron-containing rocks develop in areas experiencing deep chemical weathering and leaching. On breaking down, iron is washed down in the crust in form of solution. It later precipates in deeper layers of the soil profile. As the solution water evaporates, the iron hardens into a rock. This process of rock formation is sometimes known as “secondary enrichment”. It is in this way that haematite iron has been formed.

Lastly, sedimentary rocks also result from organic action. Such rocks are actually remains of former living plates and/or animals. A good example of organically formed sedimentary rocks is coral reefs are derived from coral polyps which are small marine animals which live in salty, warm, sediment-free and plankton rich water and whose skeletons are made of limestone. The skeletons which are cemented by solutions of other marine creatures and compressed by their own weight, with time into hard rocks known as coral reefs.

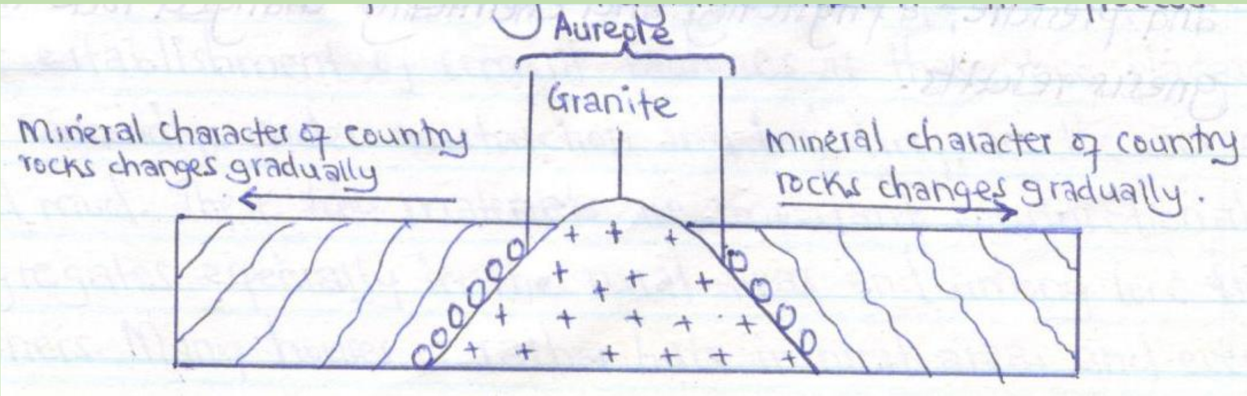
A coral reef is therefore an organic limestone rock which can be differentiated from chemical (volcanic) limestone such as that found at Tororo or Hima in Uganda. The organic coral limestone is common along the East African coast where it forms a fringing reef. In general, all rocks with limestone content are described as calcareous.

There are also organic rocks known as siliceous. These are remains of organisms such as sponges and radiolarian whose hard parts contain silica. When the animals die, the hard parts fuse together to form rocks. A good example of siliceous rocks is diatomite.

Organically formed rocks include coal and because of their carbon content they are collectively termed as carbonaceous. Coal is a result of decomposition of plants buried underground. Plants which are buried underground over a long time decompose and harden into hard substances in form of coal. Intense pressure and heat are responsible for the formation of this rock. Examples of carbonaceous rocks include lignite, bituminous and anthracite coal. Coal is valuable mineral in such places as the Appalachian and Ruhr regions of USA and Germany respectively.

The third and last group is that of metamorphic rocks. Metamorphic rocks are crustal materials which have undergone physical and/or chemical alteration. They can be formed from either igneous or sedimentary rocks. Metamorphism is brought about by intense heat and pressure. Metamorphism due to heat can be caused by hot molten material. When magma rises in the crust, the "country-rocks" with which it comes into contact are melted. With time, the magma cools and therefore the country rocks also cool down.

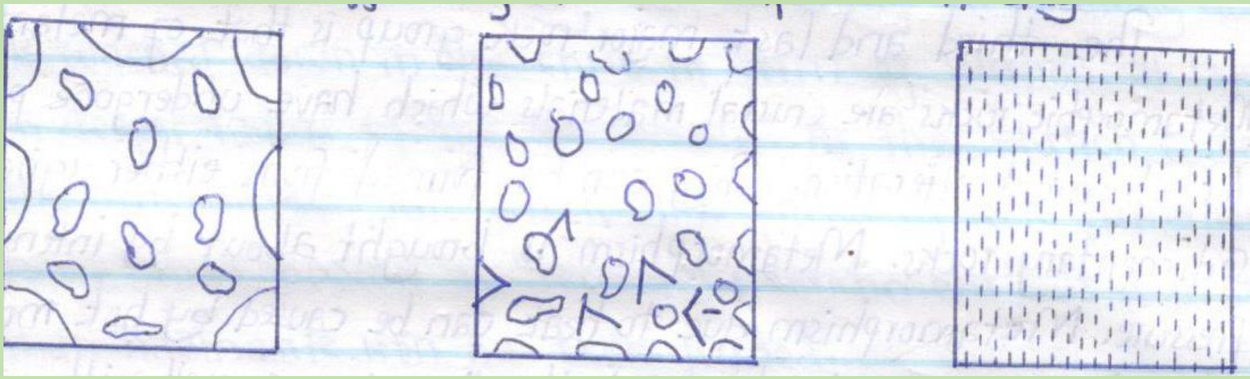
Re-crystallization and formation of new minerals take place as rocks cool down. Rock chemical character changes hence metamorphism country rocks are said to have been granitized or made "granite-like" by the intrusion of the granite. Consequently, around a granite rock, there is usually a zone of alteration in the character of the minerals. There is a gradual change in character of the country rocks as new minerals form. The zone where mineral character changes is known as aureole. The following diagram illustrates the process.



Metamorphism can also be brought by pressure. A layer of any type of rock can be compressed by the weight of overlying rocks or by movements within the Earth's crust. The compression changes the physical characteristic of the rock depending on the intensity of pressure, it is possible to change the character of any rock whether soft or hard.

Metamorphic rocks are usually harder than those from which they are derived. This can be explained in respect to clay. When clay is subjected to pressure, the particles are squeezed and the rock becomes hard and brittle. This is known as shale. When more intense pressure is applied to shale, it becomes shate. The particles are tightly packed together and the rock is extremely hard. This is illustrated in the following diagrams

Effect of intense compression on clay



Soft, pliable rock	particles squeezed,	particles tightly
Particles lying Haphazardly	rock is hard and brittle.	packed rock is Very hard.

Other examples of metamorphic rocks are quartzite which is a metamorphosed form of sandstone. When limestone is subjected to forces of change it is metamorphosed and changed into marble. When coal is subjected to great pressure and heat, it is metamorphosed into graphite.

Lastly, when granite is influenced by extremely high temperatures and pressure, a physically and chemically changed rock known as gnesis results.

ECONOMIC SIGNIFICANCE OF ROCKS IN EAST AFRICA:

Rocks vary in their chemical and physical characteristics and consequently affect economic activities in various ways. The rocks of the earth's crust can affect economic activities either positively or negatively.

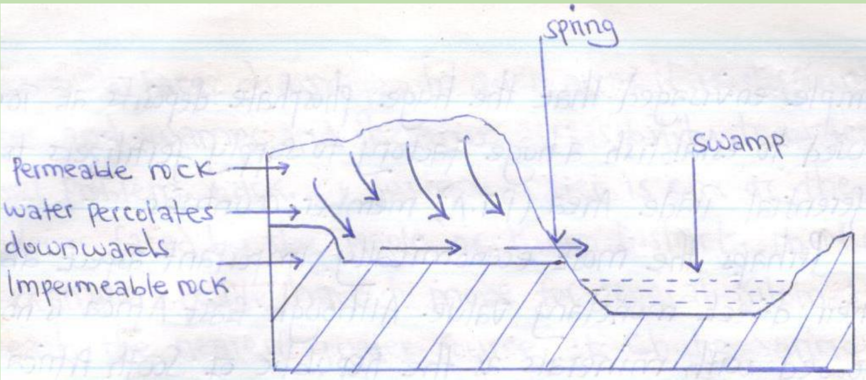
Rocks are important factors of soil formation. They constitute the parent material out of which soil particles come. The particles are formed through the processes of weathering and erosion. The resultant particles accumulate to form soil. The nature of any soil partly depends on the nature and character of the parent rock itself. A quartz rock, for example breaks down to yield poor and sandy soils. An old pre-Cambrian rock also yields poor soils because it has been exposed to process of change (for example leaching) for quite a long time. Such a rock is therefore likely to have lost most of its nutrients, on the other hand, a young volcanic rock gives rise to fertile soils after thorough weathering. It is hoped, for instance, that the hard lava of Kisoro area constitutes a high potential for formation of fertile soils in future.
Rocks are important aggregates in the construction and building industry. The importance of rocks in this respect can be seen in about five ways. In the first place, limestone is used to manufacture cement. In East Africa both organic and chemical limestone exist. Organic limestone comes from the skeletons of dead marine animals known as coral polyps. These skeletons contain limestone and when the polyps drop onto the continental shelf, the limestone accumulates and hardens to form rocks known as coral reefs. This type of limestone is used in the manufacture of cement at Bamburi cement factory near Mombasa. Chemical limestone is associated with vulcanicity. Limestone at Tororo and Hima in Uganda is in this category and is partly responsible for the establishment of cement factories at these two places.

Secondly, near construction and building, are the uses of sand and mud. These two materials are important constructional aggregates especially in the rural areas and among low income earners. Many houses or rather huts in rural areas and even urban slums are built of mud. On drying, mud acts like "cement" and binds other building materials together. The mud and wattle walls are plastered over with sand. Temporary mud-built house abounds in all the rural areas of Uganda as well as urban slums such as Wabigalo, Kamwokya, kisenyi, Kibuli and Nsambya in Kampala city.

Thirdly, rocks are important in the building and construction industry because clay is used to make bricks and tiles. Today, there are many clay works in the swamp-filled valleys of Buganda, Ankole, Kigezi and parts of Northern Uganda. This has led to the mushrooming of small-scale brick and tile making factories. Modern factories have also been established including one at kajansi-Jinja road and at Nakawa on Kampala-Jinja road. Many buildings in Kampala city and other towns are now constructed using locally manufactured bricks and tiles.

Fourthly, rocks are important in building and construction because hard ones like granite are quarried and used as aggregates in the construction of tarmac roads and concrete structures. Crushed stones are therefore some of the ingredients used to make the tarmac roads and concrete materials of strong buildings. Buganda stone quarry at Bweyogere and Muyenga Tank hill quarry are some of the many quarries supplying crushed stones in the country.

Rocks are important also in controlling and storing underground water in areas where permeable rocks overly impermeable ones. When rains, water percolates through the permeable rock until it reaches the impermeable surfaces deeper down in the crust. If the impermeable surfaces are gently sloping, water flows along those surfaces underground and finally opens out on the side of a hill to produce a spring as shown in the diagram below. Springs have been vital sources of water in many rural areas of Uganda. Even Kampala, springs which are now protected can be seen in Kyebando, Katanga and Namuwongo.



Tourism is an industry which is based on rare, fascinating or beautiful environment. Common phenomena rarely attract tourist. Tourists will not travel for long distances exclusively and purely to see a feature they have always seen in their neighborhood- unless of course such a feature has rare qualities about it. some rocks are not common and wide spread all over the world. A good example is a coral rock. Coral rocks are found in few tropical areas and as such have aroused curiosity in the minds of those people who may never have seen them before. This curiosity has promoted tourists from both within and outside East Africa to go and view or study such rocks. Coral rocks are therefore some of the tourist attractions that help to enhance economic development.

Some rocks often act as sources of energy. Hot rocks underground can be harnessed to provide geothermal energy. When water comes into contact with such rocks, it is also heated up. The heated water sometimes rises from the underground and when it arrives at the surface of the earth, it vaporises under lower pressure conditions. The force of the resultant steam can be a vital form of the energy because the steam can be used to turn turbines and therefore generate electricity. In Kenya, a geothermal power station is already in place at olkaria in the rift valley area. The numerous hot springs in Bundibugyo district of Uganda offer a great potential for geothermal power development. Furthermore, some rocks which include coal and petroleum are important for domestic and industrial purposes.

Rocks are also useful in the manufacture of fertilizers. Lime can be manufactured to neutralize acidity and rocks containing phosphates can be used to make phosphate fertilizers. It is for example envisaged that the huge phosphate deposits at Tororo could be used to establish a huge factory to supply fertilizers to all Preferential Trade Area (P.T.A) member countries.

Perhaps the most economically important aspect about rocks is their direct monetary value. Although East Africa is not richly endowed with minerals as the republic of South Africa, Germany, Russia or USA, it nevertheless has some precious minerals. Tanzania has diamond and gold deposits. Kenya and Uganda also have traces of gold. For a long time, local businessmen have been mining gold on small scale in the swampy valleys of Kabale Rukungiri and Bushenyi districts. It is believed that traces of gold deposits also exist in Karamoja area. Other minerals include iron, copper, wolfram and salt.

Rocks in East Africa and indeed any other part of the world may be obstacles to development by hindering economic activities. A hard and stony area for example hinders cultivation partly because the stones destroy hoes and tractor discs during the digging exercise. A case in point is in parts of Kisoro district where massive lava flows have covered a large part of the area. The lava rocks are not yet completely weathered and offer a resistant “table-land” to digging/ploughing machines. Special “forked” hoes have to be used to pierce through the rocky ground. In this area, huge heaps of a rock, fragments that have been literally quarried to create cultivable land are a common sight.

Some rocks also hinder road construction. Operating heavy earth-moving equipment is easier on softer rocks than on hard ones. Sometimes it becomes inevitable to use explosives for purposes of breaking down the hard rocks and clear the way for road construction. This is not time energy consuming but also expensive. In addition, mechanical breakdown of earth moving equipment is also rampant.

Rocks can influence drainage positively and also negatively. If rocks are permeable and porous, rain water percolates downwards and then disappear underground resulting into loss of surface drainage. In such areas it is difficult to have rivers and swamps and therefore accessibility to water becomes a real problem. Lack of surface water is one of the greatest problems faced by the people of Kisoro district.in Nyarusiza area for example, people have to move for several kilometres in order to reach the nearest water source at chuho spring. During the dry season, people and animals converge on this water source. The massive movement of people and livestock is not only tiresome but also leaves the land eroded. Besides, people spend a lot of their time walking instead of doing other productive work.

Rocks are characterized by landslides and mass wasting which destroys life and property for example on wanale slopes, kigezi high lands and Kilimanjaro region.

Lastly, rocks sometimes break down to form poor or infertile soils. Reference has already been made to how quartz breaks down to form sandy soils. Limestone also gives rise to soils which are generally poor and porous. These may not effectively support a variety of plant life. Limestone soils are generally those of deficient drainage and cannot therefore support water loving crops.

In conclusion rocks can enhance economic development but at the same time they can retard it. Man is forced to spend in order to overcome problems posed by those rocks. The expenditure drains the economy.

THE INFLUENCE OF ROCKS ON LAND-FORM DEVELOPMENT

All Important geomorphological processes already seen and yet to be seen do alter and shape the earth in different ways producing various landforms. They all however operate on already formed rocks. Rocks therefore have got an important impact on landform development. Each type of rock has got its unique influence on landform development

1.IGNEOUS LANDFORMS: As already seen above, igneous rocks are formed when magma cools. Thus, these are rocks that result from vulcanicity. The land forms they therefore produce are both intrusive and extrusive:

(a)intrusive landforms. These land forms which are produced when magma fails to open up to the earth surface and therefore cools within the bedding planes. Igneous intrusive rocks have led to the formation of the following features.

- **Batholiths:** these are large irregular coarse-grained rocks covering hundreds of square kilometers. They are formed when magma solidifies slowly at great depth to form large irregular features. A batholith is an intrusion with a cross-sectional area of more than 100km (39sqmi), usually consisting of granite granodiorite and diorite. Deep batholiths are often concordant, while shallow batholiths are usually discordant. Examples include Mubende, Singo and Kiwungere in western Uganda, Tanganyika batholith that outcrops between Mwanza and Iringa, Parabong hills in Kitgum district of northern Uganda.
- **Sills:** these are tabular sheet like body formed when magma solidifies within the parallel layers of pre-existing bedded rock. They range from few centimeters to hundreds of meters. They are formed when magma rises inside the crust and spreads horizontally. Examples can be traced in Thikaland west of lake Turkana in Kenya. The best example of dolerite sills is the three sisters in cape province in south Africa.
- **Dyke:** these are vertical or steeply incline sheets intruded into the crust to form walls of solidified magma. Sometimes they extrude by denudational forces to form trenches. dykes are discordant intrusions formed when magma up wells through the fissures in the crust and solidifies before reaching the earth's surface. When dykes form in groups, they are called ring dykes. Examples can be traced in Thinka west of Lake Turkana, Mwadui-kimberlite rock in Tanzania, Rungwa complex in Kenya, isingiro ridges in western Uganda and usukulu hills in Tororo eastern Uganda.

- **Lopoliths:** these are saucer-shaped concordant intrusions. They may be up to 100km (60mi) in diameter and 8km (5mi) thick. Lapoliths which are usually basaltic in composition are frequently called layered intrusions because they are strongly layered. Lapoliths are formed when magma rises into the earth's crust and spreads horizontally as more and more magma accumulate. This magma reaches a point where it cannot continue spreading thus pilling and depressing the underlying rocks. The best example is Umvuke ranges in Zimbabwe where they form a line of hills.
- **Laccoliths;** these are dome shaped volcanic intrusive features. they are usually small features with a flat base and a domed ceiling, and are concordant with the neighbouring rocks; they are formed when magma rise into the crust; reaches a point where it cannot spread far and begin to accumulate thus forcing the overlying rocks upwards to form a dome shaped intrusive features.
- **Inselbergs;** are produced when some of the above-mentioned intrusive features are exposed to the surface and they stand out as resistant out crops- granite tors.

(b)Extrusive Land forms. These when magma cools after reaching the earth surface. Extrusive igneous rocks have led to the formation of the following features.

- **Volcanoes;** These are high hills or mountains formed when acidic lava erupts through a central opening vent (vent) and bunds up at this vent to form a cone shaped feature with a funnel like depression on top called a crater. If the pressure system is not enough, and lava fails to reach the crater at the mountain top, it may force its way to the surface through other fissures and build parasitic cones on the slopes of the main volcano. Examples of volcanoes include Mount Elgon, Mount Kenya, and Mount Kilimanjaro.
- **Volcanic plugs;** These are formed when acidic which is viscous is forced out as a rigid cylindrical feature by explosive eruptions. Much of the magma may be intruded but later extruded by denudation forces. Examples include Tororo plug in Eastern Uganda and Madara mountains in Cameroon.
- **Volcanic necks;** A volcanic neck is a central core of solidified lava in the vent of volcano. The solidified lava is then exposed by denudational forces especially weathering and erosion of the surrounding core thus leaving a residual plug called a volcanic neck.
- **Cumulo domes;** These are steep sided domes of acidic and intermediate lava. A cumulo dome is formed when viscous lava does not flow far but instead it piles around the vent where it hardens quickly. The subsequent extrusions may not reach the surface but may force the initial layers of solidified lava outwards. There are no craters on such domes. Examples include Ntumi dome and Rungwa dome in south of Mbeya town in Tanzania.
- **Cinder cone;** cinder cones are volcanoes that made up primarily of cinders, a loose volcanic material. When cinder cones erupt, the cinders tend to pile up and form the shape of a small mountain. Cinder cones are generally not very tall, only a few hundred meters, because the loose cinders tend to slide off of

the sides because of gravity. Most cinder cines are located in geologically young regions examples include nyabuyatom, lokaiyu and teleko south of lake Turkana in Kenya.

- **Basalt domes;** These are large convex topped domes with gently sloping sides. They are formed when lava flows from numerous fissures rather than a single vent and it runs from long distances. Examples include Virunga and Muhavura ranges in south western Uganda
- **Lava plateau;** These are uplands with generally up summit made of successive layers of lava. A lava plateau is formed by the eruption of very fluidly basic lava from a large number of fissures onto the earth's surface. Examples include Yatta, plateau, Loita plateau, lake Nakuru Hannington area, Mau ranges and Aberdares as well as Athi plains all in Kenya. There also exist plateaus in Kisoro between lake mutanda and Mount Muhavura.
- **Geothermal landforms;** These are landforms produced when underground water comes into contact with hot rocks and it gets heated up. They include Hot springs, geysers, and fumaroles.

2. SEDIMENTARY LANDFORMS: These are landforms produced from deposition of either eroded materials, organic materials or precipitation of certain chemicals from sea water. They include:

\+ **coral reefs;** A coral reef is a limestone rock made up of skeletons of very small marine animals called coral polyps. These animals have skeletons made up of calcium carbonate and when the organisms, die, the skeletons sink to the bottom of the sea where the accumulate and harden after millions of years to form layers of carbonate or limestone rocks called coral reefs. Examples can be traced at the east African coast.

\+ **Karst topography;** This is a topography characterized by clints and grykes are produced as a result of chemical weathering of carbon bearing rocks

\+ **Stalagmites and stalactites;** These are rock protrusions that are seen in chemically weathered limestone bearing rocks.

\+ **Alluvial features; T**hese include fluvial (riverine) e.g. deltas, alluvial fans, levees, flood plains, etc. These are all sedimentary rocks produced mechanically by running water.

\+ **Moranic land forms;** These are produced from glacial depositional rocks e.g. erratics, drumlins, kame, esker, out wash plains, kame terrace and moraine itself.

\+**coastal wave Landforms;** Wave deposition on coastlines produces sedimentary features like splits, bars, cuspate forelands, tombolo's etc.

3.METAMORPHIC LANDFORMS: These form the ancient shields in East Africa. They are very old geologically, over 300 million years. The landforms of these were produced when these rocks were folded and faulted following strong metamorphism. Thus, **folds** have been formed from metamorphic rocks producing synclines and anticlines.

When these metamorphic rocks were faulted, various features for example block mountains, rift valleys, fault scarps and fault guided valleys were formed

Revision questions

1.Giving specific examples, examine the influence of rock structure in the development of Land forms in East Africa.

2.Examine the processes responsible for the formation of various rock types in East Africa.

3(a)Account for the formation of sedimentary rocks in East Africa.

(b)Assess the relative importance of rocks in East Africa.

4(a)Account for the formation of igneous rocks.

(b)Examine the influence of igneous rocks on the relief structure of East Africa.

5(a)Distinguish between igneous and metamorphic rocks.

(b)Assess the relative importance of metamorphic rocks to the people of East Africa.

EARTH (TECTONIC) MOVEMENTS

The effect of convection currents is the plate movement. Therefore, the term earth movements include all dynamic processes of endogenic origin e.g. Earthquakes, Faulting, Folding, Warping and vulcanicity. Other terms used under earth movements are diastrophism and tectonism.

The origin of the earth movements is convection in the earth's interior. Whenever convection currents are generated in the mantle, they rise up towards the crust. This rising causes **epeirogenic** uplift which results into slow but large-scale uplift of the earth crust. After reaching in contact with colder earth crust, they move literally in opposite directions thereby stretch causes the crust to fracture due to the generated tensional forces. This fracturing is called **faulting.**

At a point where convection currents meet and sink back into the earth's interior, compressional forces are generated which push the continental plates together. This results into **folding** of the earth crust and increased folding, faulting may also occur within the over folds. The faults produced may lead to escape of hot magma from the mantle a process called **Vulcanicity.**

When rocks fracture, they release the pressure which had accumulated in them for along time. This sudden change in rocks result into shock waves within the earth crust causing tremors normally called **earthquakes.**

As convection currents sink back into the earth's interior, a sagging force on the crust above is generated. This causes wide spread and extensive **down warping.**

A EARTH QUAKES.

An earth quake is a strong vibration in the earth's crust. It is an impact that is often caused by collision of plates. The collision of plates causes an impact that causes vibrations within the crust. The movement of molten rock below or within the crust may also cause earth quakes. An earth vibration which is mild is known as an **earth tremor.**

the point in the Earth's crust from which the vibration or shock waves originate is called a **focus**. The point on the surface of the earth above the origin of an earth quake is called the epi-Centre. When an earth quake occurs, the shock waves are transmitted quickly through the earth's crust surface. The shock waves decrease in strength as they travel away from the focus. The intensity of an earth quake is measured by an instrument known as the **seismograph** which may be equipped with a **Richter scale** to indicate the intensity of the earth quake.

Causes of Earth quakes.

Origin or causes of earth quakes is attributed to plate tectonism. The collision of plates causes an impact that triggers off vibrations within the crust.

Plates are light and float on the upper mantle. They may also be rigid within consistent boundaries sea ward and land ward. Plates are mobile and may move vertically or horizontally.

Due to radio-activity and convectivity of silicate minerals, convectivity currents are created within the mantle.

The convergence movement of the crustal blocks converge by convectional currents. As plates converge, deformation occurs on either side of the edges/Faultline or within the mantle.

As plates are dragged, the rocks become plastic and elastic storing energy (like bent wooden stick).

Frictional resistance holding the rocks together is over come along the faults/edges due to compression.

Because of too much heat at the edge, the friction is reduced making the edges slippery.

Further displacement exerts pressure and stress along the Faultline/edges.

Additional friction, increases in slippage storing a lot of energy.

Rapid release of the edge makes the energy radiated in all directions from the focus in form of waves (explosive energy)

Slippage allows the deformed rocks to snip back (Reverse movement) or readjustment thereby vibrations as earth quakes.

Rock elasticity returns to its original shape (elastic rebond). Major earth quakes may generate smaller ones after a few days or years.

The waves travel from the Centre of disturbance as one wave shock. Earth quakes may also occur due to transform plate movements, isostatic movement and where there is excessive vulcanicity (tectonic in nature).

The point in the earth's crust from which the vibrations or shock waves originate is called the focus/Hypocentre while the epi-Centre is the point on the surface of the earth above the origin of the earth quake. (vertical point above the origin/focus).

Shock waves are transmitted quickly through the earth's crust to the surface where the earth quake occurs. **Note:** that shock waves decrease in strength as they travel away from the focus.

Magnitude of the earth quake is measured by the seismography, equipped with Richter scale to indicate the intensity of the earth quake.

In the world areas that experience earth quakes include California, China, Japan, India, Mexico, Peru, Uganda (Toro/Kabarole, Bundibugyo)

EFFECTS OF EARTH QUAKES:

The effects of earth quakes depend on their strength. Earth quakes measuring 5 and higher on the Richter scale have devastating effects.

The great vibrations associated with strong earth quakes usually result in landslides. The vibrations of the ground shake unconsolidated rock particles which may be resting loosely on the steep surfaces. These vibrations trigger-off movement of those particles. This is common in steep slopes of mountain environments.

Strong earth quakes are known for their destruction of life. Earth quakes have caused death of thousands of people in many parts of the world. The deaths occur when houses tumble over people, rocks roll over settlements or when sea waves capsize boats. Fatal earth quakes include the 1927 earth quake in China in which 100,000 people lost their lives, the 1966 Toro earth quake in which over 150 people died, the 1985 Mexico earth quake in which over 55,000 people perished.

When an earth quake occurs some people may survive but their homes may not. Consequently, a number of people may be left homeless after the destruction of their homes. Where homes still exist, some people may initially hesitate to go to their homes for fear of another earth quake striking. Earth quakes therefore leave a number of people either homeless or displaced. The 1970 earth quake in Peru left 1 million people homeless. In Uganda the relatively recent earth quake in Toro in 1994 left quite a number of people displaced.

When a strong earth quake occurs in an ocean, great ocean waves may be caused. These earth quakes generated ocean waves are known as **Tsunamis** and are common in the North China sea and off the coast of Japan where crustal instabilities abound. These great waves are hazard to shipping and have frequently resulted in destruction of life and property. They have also had far reaching geomorphological results on the coast.

Earth quakes have adverse effects on buildings and other forms of infrastructure. Some buildings may have their walls cracked or may be pulled down completely. Railways may be displaced and gaping cracks may develop in roads. The 1906 earth quake greatly destroyed the infrastructure in the Californian city of san Francisco. The 1964 earth quake in Toro destroyed property worth millions of shillings. This earth quake which measured 6.2 on the Richter scale and whose epicenter was at Kisoro about 25 kilometers south of fort portal town, caused a black out and development of cracks in buildings. Some of the damaged buildings include Virika Hospital, the catholic cathedral and the Boma complex which houses government Departments.

Apart from affecting human features, earth quakes also affect the crust itself. The 1899 earth quake in Alaska caused an uplift of the coast while the 1923 earth quake in Japan changed the level of sagami bay in addition to killing about 20,000 people.

Earth quakes in many parts of the world therefore have a number of outcomes. The effects are largely negative and result in great loss of life and property.

Revision questions:

1(a) What is meant by the term “earth quake”?

(c) With reference to specific examples, outline the effects of earth quakes.

2(a) Explain the causes of Earth quakes.

(b) Examine the effects of Earth quakes on the people of East Africa.

B FAULTING

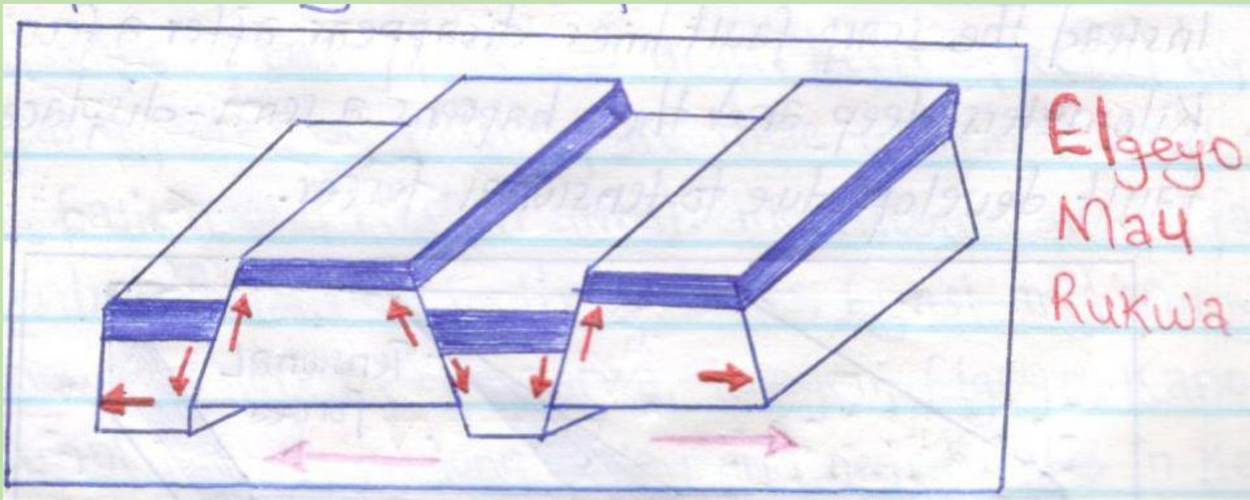
Faulting is an endogenic process in which the earth’s crust is fractured and rocks are relatively displaced. In other words, where faulting occurs, movement of rocks also takes place. A fault is any displacement of rocks in a plane of weakness in the earth crust. The earth surface is crossed by many types of fault lines all resulting from stresses caused by earth movements. Faulting is one of the most important ways that stress is released from rocks.

Faulting is therefore a process by which a rock (crust) develops a line of weakness resulting into displacement of rocks. In geological terms, rocks are not solid. They behave like stiff plastic. When stress develops, the rocks absorb it until the rapture point is reached. This rapture is what is called a Faultline and the process of rupturing and displacement is called faulting.

Faulting is a sign of crustal instability and is found in areas experiencing tectonic activities. The faults or fractures along which movement takes place are of several types.

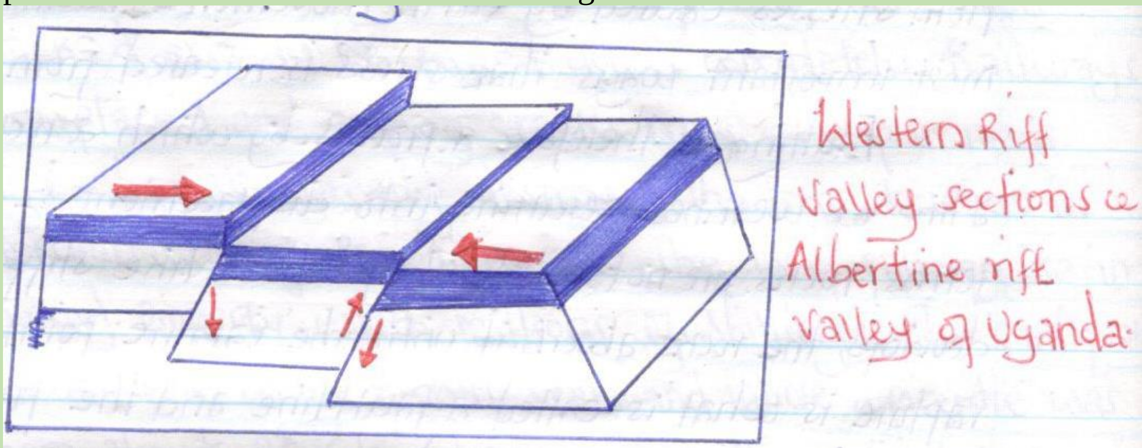
TYPES OF FAULTS:

1. **Normal faults:** these are faults which develop at a divergent plane boundary where tensional forces are generated stretching the overlying earth crust until it reaches it's rapture hence faulting. The intrusion of rocks such as basalt or granite may create strong tensional forces that may stretch the overlying rocks creating faults. Such faults produced by tensional forces are called normal faults. Normal faults produced as a result of downward displacement of the dismembered wall blocks along lines of weakness produced by tensional forces.

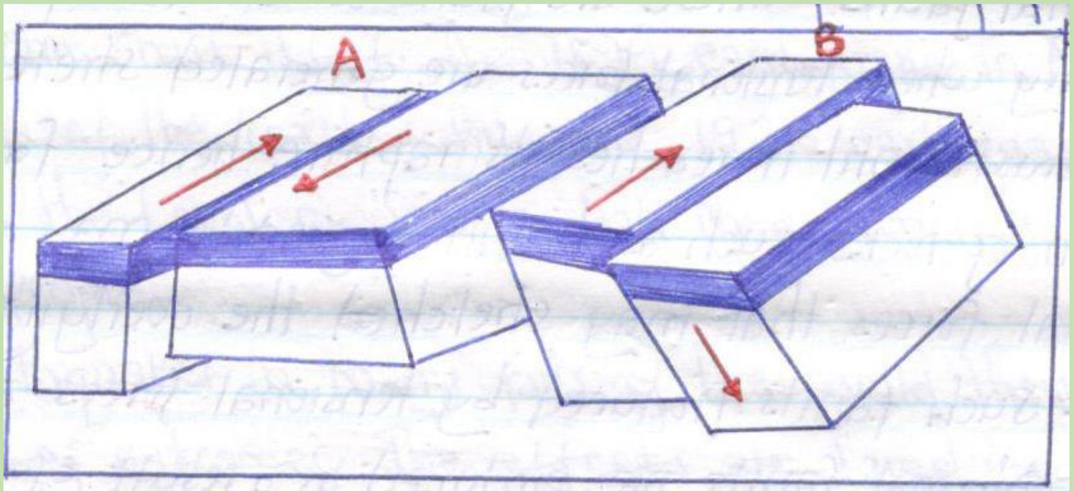


Normal faults.

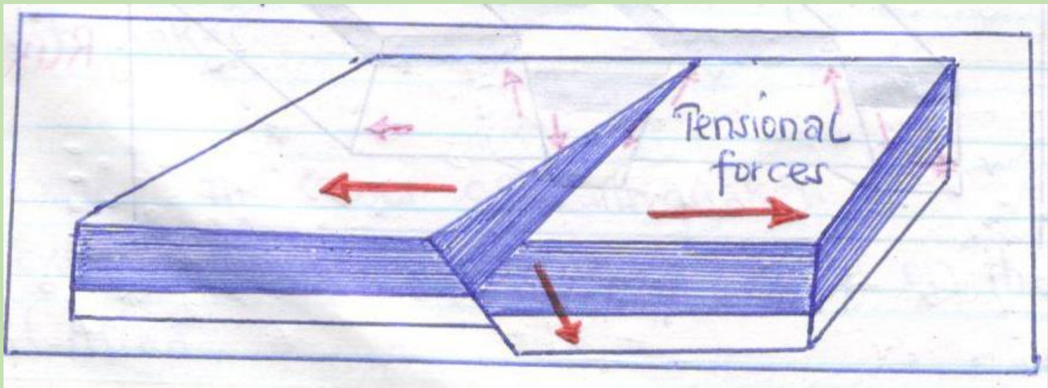
2.Reverse; these are produced by compressional forces. As the crust is being compressed a time will reach when one block will over ride another. This may result from a high angle or low angle compression. Reverse faults occur when compressional forces cause one block to thrust/over ride the opposite block. The angle between the fault plane and the foot wall is less than 45^0 degrees.



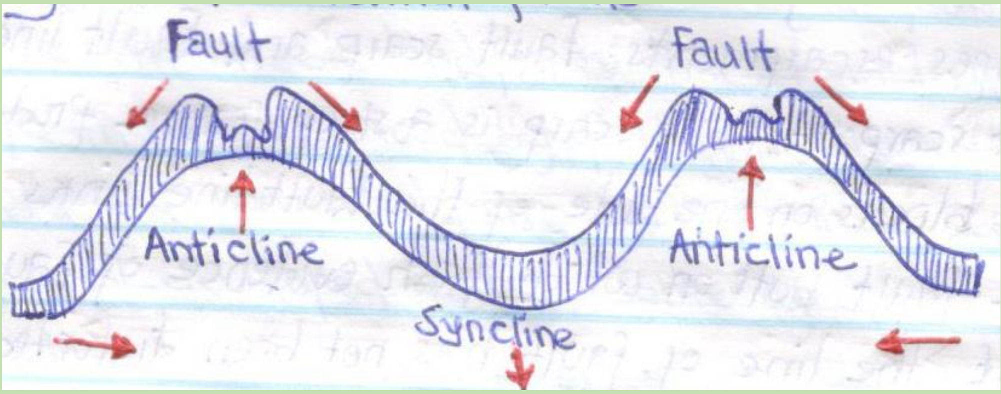
3.Tear faults: These are faults involving only horizontal movements. These are formed when the stresses come from opposite directions but act obliquely to each other. Tear faults involve horizontal movements only (A). when displacement is both horizontal and vertical (B) the fault is called an oblique slip fault.



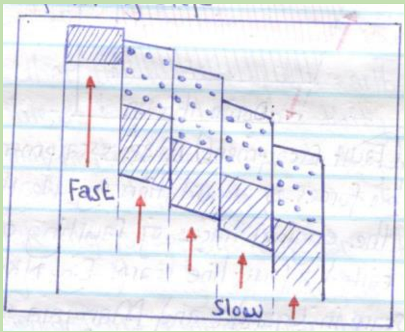
4.Trap Door Faults: These are produced when the Earth crust fractures but the fracturing does not cut through the whole rock, instead the scarp fault lines disappear after a few meters or kilometers deep and there happens a semi-displacement. Trap door fault develops due to tensional forces.



5. Anticlinal Faults. When the crust is up arched and it bends (during folding), the landscape produces anticlines; with more up arching, the apex of these anticlines may crack producing lines of weakness normally called anticlinal faults.



6.Step Faults: There could be a general uplift of the land but the rates of uplift could be different such that some parts are lifted up faster than others. This will cause a number of faults that will develop at the margins of different uplifted blocks. The landscape will be in form of steps.



The step faults can also develop when tension allows each rock section between parallel faults to slip relative to their neighbourings. Bench-like-landscape are a reflection of step faulting.

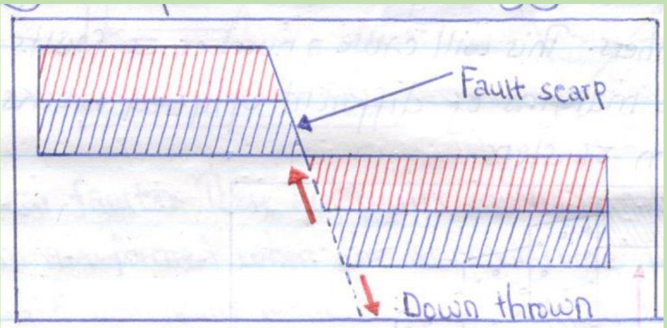
FAULTING IN EAST AFRICA

The landscape of East Africa has much been affected by faulting. Major areas affected by faulting are those within the rift valley region (both the East and West arms). The Aswa valley (fault guided valley), central Tanzania south of Lakes, Eyasi and Manyara (Trap door), Songwe region of Tanzania, Tugen, Elgeyo, Kano and Mau (normal faults), Kedong valley and near Kijabe in Kenya (step faults). It has led to the formation of various landforms including fault scarps, horst or block mountains, rift valley, grabens, tilt blocks and fault guided valleys.

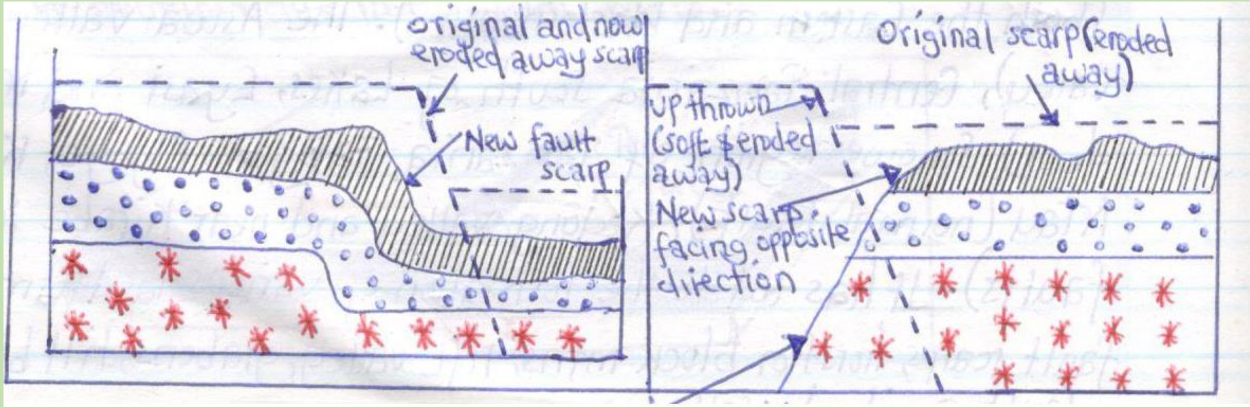
LANDFORMS OF FAULTING

1.Fault Escarpments; the escarpment is a steep step like face produced by fracturing (faulting) of the rock, followed by the displacement of block on the opposite of the Faultline scarp.

- **Fault scarp;** A fault scarp is a steep feature produced when one of the blocks on one side of the fault line sinks down along a line of fault but on which fresh evidence of faulting is seen. In short, the line of has not been distorted completely by weathering and denudation. Examples of fault scarps are Chunya scarp in Tanzania and Elgeyo scarp in Kenya.



- **Fault line scarp** (fault Escarpment) if an escarpment has been greatly distorted by forces of denudation e.g. weathering and erosion such that the original traces of faulting cannot be seen, an escarpment is called a Faultline scarp. E.g. Nkrumah fault in Kenya, Butiaba scarp in Uganda and Manyara scarp in Tanzania. If a fault line scarp still faces in the direction it is called a **consequent** fault line scarp. If on the other hand, the rocks on the down thrown block are more resistant, erosion will undermine the up thrown block faster than the down and will soon form lowlands. This means that the scarp will face the opposite direction of the original scarp and it will be called an **obsequent** Faultline scarp.



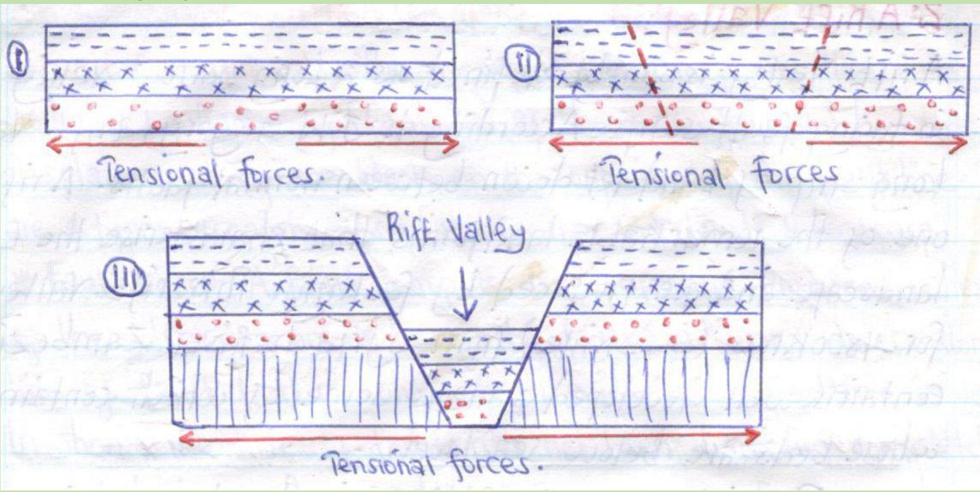
Down thrown block

2. A Rift Valley; a rift valley is simply defined as a long narrow valley bordered by in facing fault scarps. According to J.W. Gregory, a rift valley is a long strip of land let down between normal faults. A rift valley is one of the remarkable landforms that characterize the East African land scape and are produced by faulting. This rift valley extends for 4800kms (3000 miles) from Syria to river Zambezi. The belt contains well developed valleys some of which contain lakes whose beds are below sea level.

The rift valley in East Africa has two sections and these are western rift valley in Western Uganda and Tanzania and another eastern rift valley in central Kenya and central Tanzania. The formation of the rift valley is explained by the process of tensional and compressional forces.

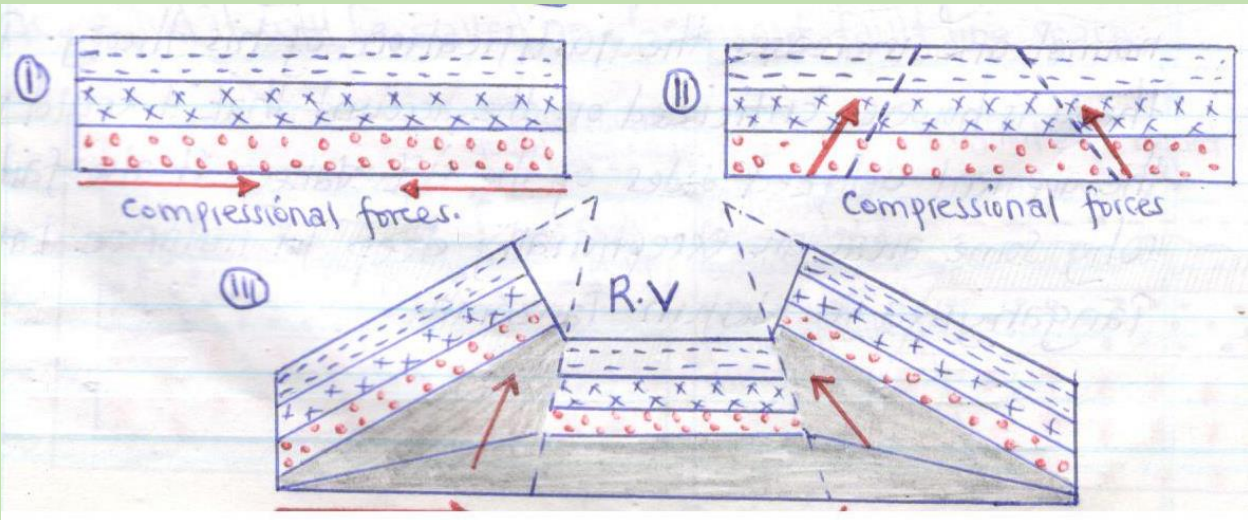
Tensional theory; The tensional theory was advanced by J.W Gregory. It states that the interior of the earth exists in a molten state and there is tense heating by radio activity and geo chemical reactions. This internal heating therefore tends to generate rising convective currents in the asthenosphere that reach the bottom part of the crust following laterally to opposite directions. This lateral flow of the currents generated strong tensional forces that caused normal faulting. The tensional forces pulled away the side blocks from central block thus making the central block to subside (sink) below the surrounding blocks forming from a rift valley. The theory is called the dropped key stone of the arch theory.

He advanced his theory from earlier works of other scientists e.g. De-Lapparent (1887), sues (18941), uhlig (1912) and the fact that Songwe fault scarp in Rukwa valley was found to be a normal one increases the justification of his theory. The tensional theory is however criticized on the account that it could not explain the apparent uplifted sides of the lift valley. It also fails to explain why some areas are exceptionally deep for instance Lake Tanganyika in western Tanzania.

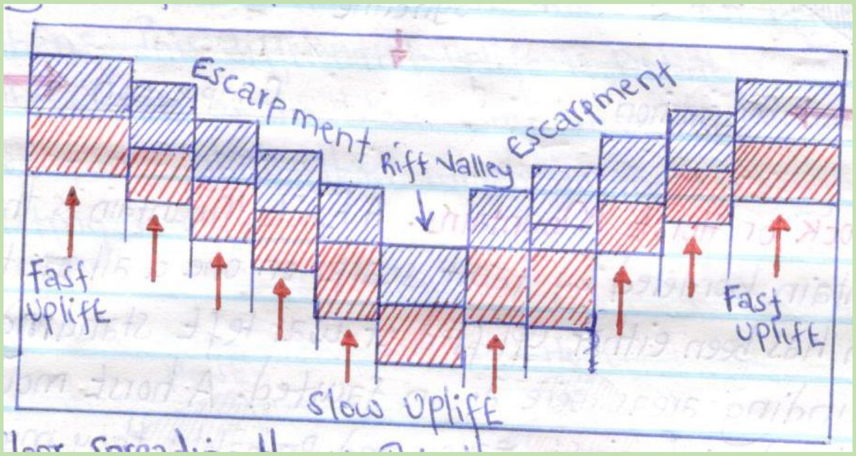


Compressional theory; compressional theory was put forward by E.J Wayland and Wills. According to the theory, the interior of the earth exists in a molten state and there is immense heating by radio activity and geo-chemical reactions. This internal heating therefore generates rising convective currents in the asthenosphere that reached the bottom part of the crust and begun flowing laterally towards each other. This created strong compressional forces that led to reverse faulting. The side blocks were forced towards the central block thus making them to over ride the middle block to form a rift valley with steep and sharp edges.

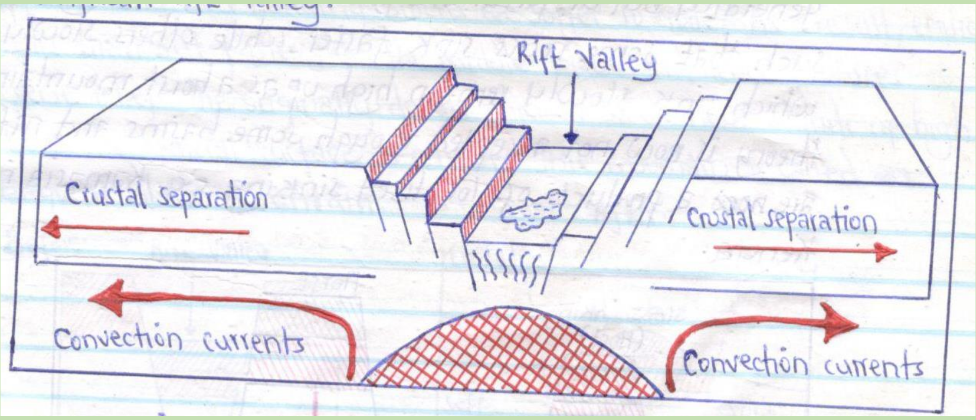
The overhanging sharp edges of the rift valley were later weathered eroded and deposited into trough. This applies to the western rift valley section in western Uganda. Whereas this theory was supported by other geologists like Bollard (1936) and Willis (1928), it has been disapproved because deep bore holes sunk in the Albert Valley floor have shown that the rift boundaries slant in a typical normal manner which means that this rift valley was formed by normal faulting.



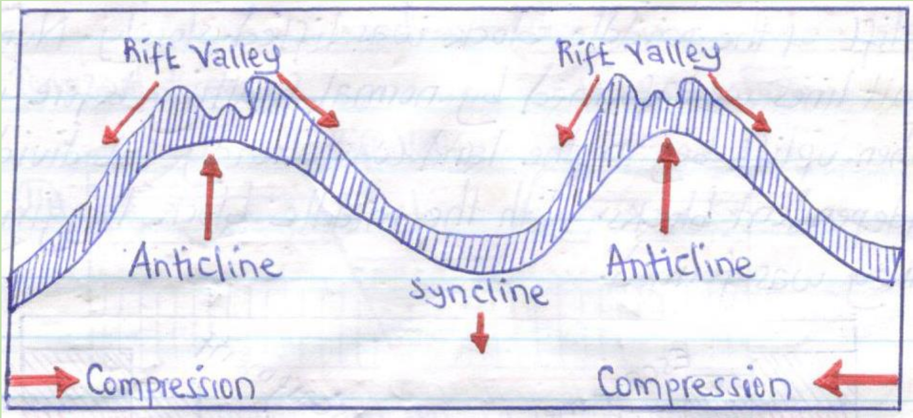
Differential Uplift theory; This theory was advanced by **Dixy**. According to him, supported by Troup, rift valleys were formed by the general uplift of the middle block was lifted slowly. Numerous parallel fault lines were formed by normal faulting before uplift such that when uplift began the land was already subdivided into independent blocks. With the middle block lagging behind a rift valley was formed.



Seafloor spreading theory; this theory of sea floor spreading was advanced by **Girdler** following **H. Hess** theory of crust separation and spreading. According to this theory, the great East African rift valley represents the first stage of movement in which East Africa is breaking away and drifting from the main African land mass. The separation of Arabian block from Eastern Kenya and Somalia block shows clearly the closeness to continental drifting that seems to be taking place in the East African rift valley.



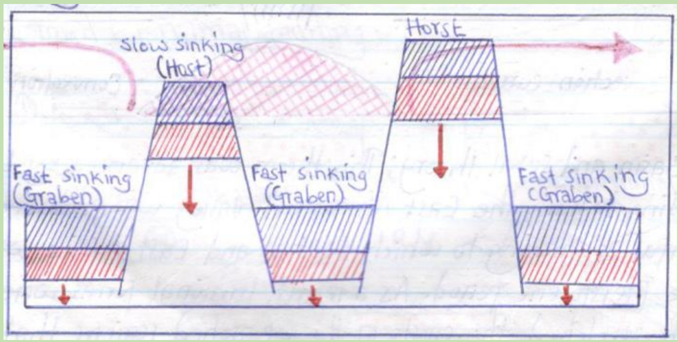
The basin and swell theory; This theory was advanced by **L.C. King.** according to him, the East African rift valley was produced by powerful up arching to which central and East Africa was subjected since pleistorene period. As a result, tensional forces were produced which stretched the crests of the up arched regions that later cracked open. As more up arching continued, the crests continued widening and finally produced a **rift valley.**



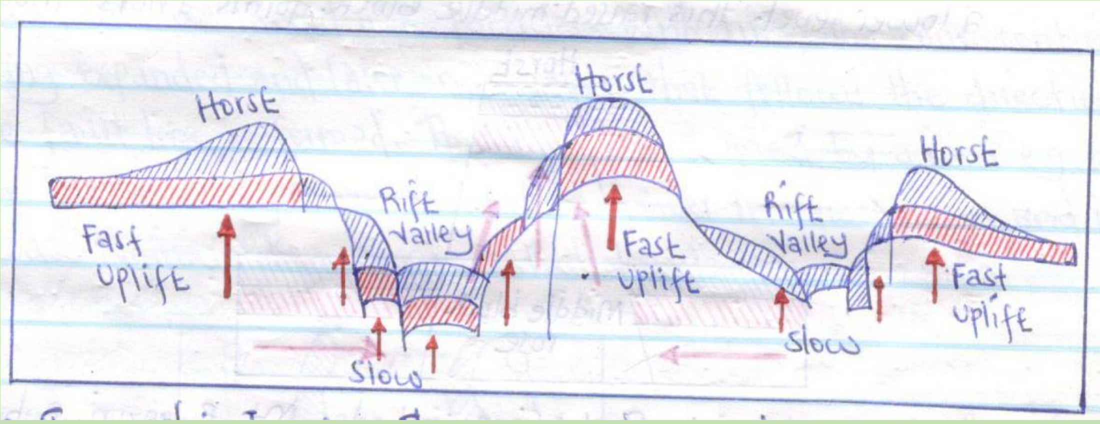
3.Block or Horst mountains. A horst mountain is a type of mountain bordered by fault scarps on one or all of its sides and which has been either uplifted or was left standing up as the surrounding areas were down faulted. A horst mountain is associated with a rift valley and probably they may be formed together. Like a rift valley, several theories have been advanced to explain the origin and formation of a horst mountain and these include;

The theory of relative sinking; This theory was advanced by **suess** who believed in the theory of the contracting earth.

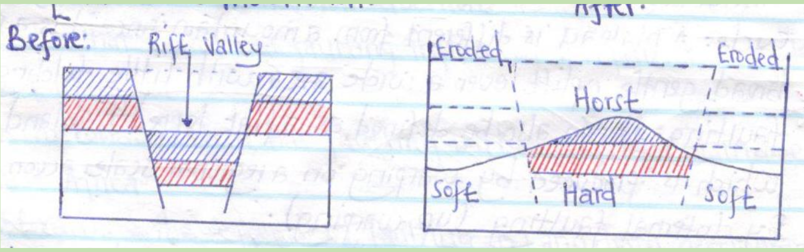
According to him, as the earth contracts down wards forces are generated but unfortunately, the rates of sinking are different such that some rocks sink faster while others slowly. Those which sink slowly remain high up as a horst mountain. This theory is now not accepted though some basins and rift valleys are a product of localized sinking e.g. Kamasia ridge in Kenya.



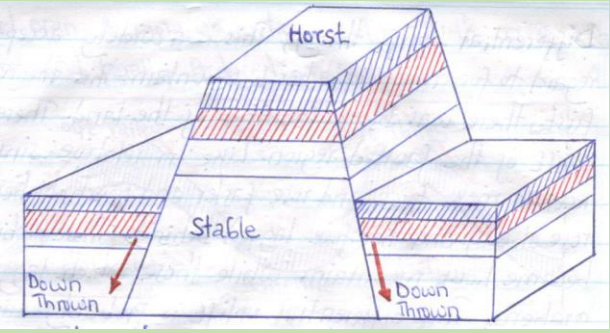
Differential uplift theory; This is a widely accepted theory with regard to formation of a horst mountain. This theory asserts that a first, there was block faulting of the land. There followed a general uplift of the faulted region. Like in relative sinking, some regions received more force and rose fasted and much higher while other regions rose slowly and therefore lagged behind. Those, which rose faster, became horst mountains while those which lagged behind became grabens. This differential uplift if probably caused by differences in the weight of the blocks such that those which are light are lifted faster while those which are more heavy slowly. This uplifting is vertical.



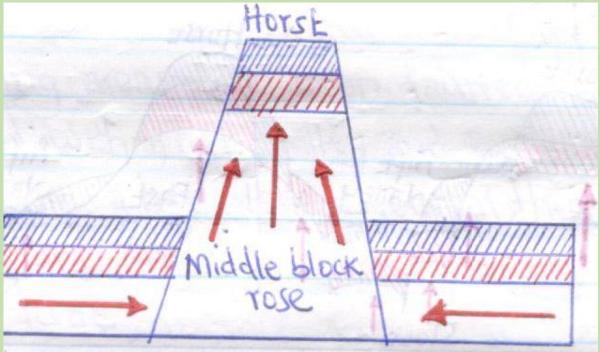
The topographic inversion theory; According to this theory, normal faulting produces a rift valley. The block of land that sinks down to produce a rift valley is composed of harder and more resistant rocks while the two opposite and over hanging blocks are softer to erode. As a result, erosion wears them out faster than the middle block and hence produces reverse relief. The originally down thrown block now stands up high above the general surface as a horst. This mountain is called **an obsequent block mountain.**



A horst mountain can also be formed when there develops **block faulting** within the crust. Later on, the peripheral blocks are made to sink leaving the middle block stable and hence standing high up above the general surface as a horst mountain.



The compressional theory; Compressional forces that develop the earth crust result into some faulting. With compression, the middle block may be forced to rise up high leaving the peripheral blocks at a lower level. This raised middle block forms a horst mountain.



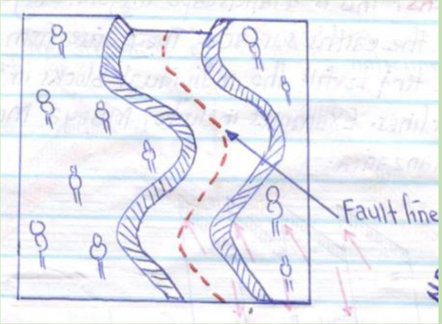
Horst mountains in East Africa include; Mountain Rwenzori, Bunhweju hills, Bunyaruguru and Bunyoro-Toro uplands, Apach hills and Masindi hills all in Uganda. In Kenya, they include; Abedare ranges, Ndoto, Nyiru and Mathew's ranges, while in Tanzania, they are; Pare, Usambara, Ulunguru, Mahenge, Iramba, Kungwe, Mbeya, Iringa and Ufipa ranges.

4.Platues and basins; A plateau is simply an elevated plain. Is similar to a mountain in that the rock cycle is ahead of a water cycle. A plateau is different from a mountain since it is as a result of broad gentle uplift over a wide area with little folding and faulting. It can also be defined as flat toped high land area which is produced by warping on a regional scale accompanied by internal faulting (up warping).

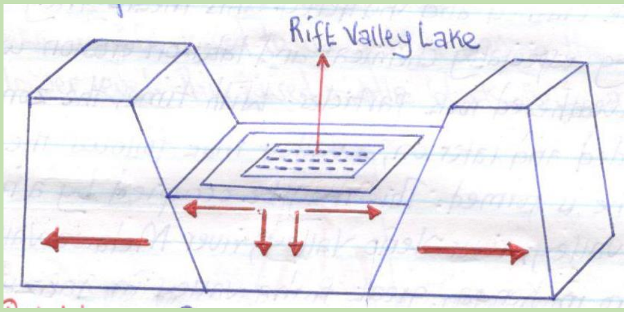
A basin on the other hand is a depression that is round-shaped produced by large scale (regional) down warping that follows up warping. These two processes move together due to isostasy (a state of equilibrium). East Africa is on a plateau land which now has been interfered with by tectonic forces.

The East African plateau and Lake Victoria basin. The East African plateau is thought to have formed in the sub Miocene periods when an extensive up warping has happened in central Kenya. The formation of this up warp was in the late Miocene followed by the formation of a linear down warp in the now East African lift valley.

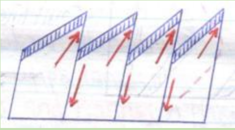
5.A fault guided valley; This is a valley as the name suggests that is guided by the fault line. This means they easily fall prey to weathering especially chemical and later on erosion which wears away the weathered rock particles. With time, the zone continues being expanded and later on, a valley that follows the direction of the fault line is formed. This may be occupied by a river e.g. the river Aswa valley, river Veno valley, river Melawa valley and river Ewaso Ngiro in Kenya, great Ruha valley in Tanzania.



6.Rift valley Lakes; (Grabens) these are lakes formed at the bottom of the rift valley. Due to secondary faulting at the rift valley bottoms, small depressions called **Grabens** were created and when the depressions got filled up with water, they formed lift valley lakes. Examples of such Lakes include; Lake Albert, Lake Edward, Lake George, Lake Tanganyika in the western lift valley also Lake Turkana, Lake Baringo, Lake Nakuru, Lake Magadi, Lake Eyasi, Lake Manyara, in eastern rift valley. such Lake tend to be long narrow and deep and tend to be surrounded by fault scarps.



7.Tilt blocks; This is a land scape with angular ridges and depressions created on the earth's surface. They arise from strong compressional forces that tend to tilt the individual blocks in the angular shape along fault lines. Examples include; Mbeya mountain range in southern Tanzania.



8.Waterfalls and rapids; This is an indirect effect where by faulting along sections of a river profile have led to the elevated landscapes and resistant rocks along the river profile thus leading to the development of waterfalls and rapids for example Murchison falls along Victoria Nile between Lake Kyoga and Lake Albert.

9.Drainage reversal. Large scale faulting has indirectly led to reversal in the drainage patterns especially rivers. For instance, rivers like Katonga, Kagera, Kafue, which used to flow towards Congo basin were forced to reverse the course of flow towards central Uganda and Southern East parts. On addition, tear faulting across a river tends to off set the river profile at a point when it crosses a fault line.

Revision questions.

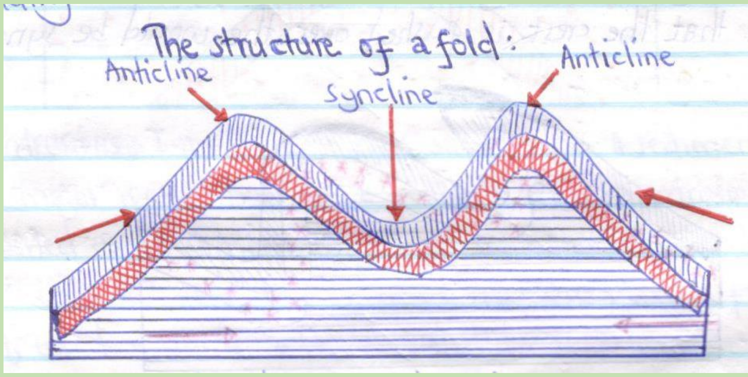
1. To what extent has faulting influenced the formation of high lands in East Africa?
2. To what extent has faulting influenced the drainage of East Africa?
3. Examine the effects of faulting on land form development in East Africa.
4. To what extent was faulting responsible for the formation of relief land forms in East Africa?
5. Describe the theories which have been put forward to explain the formation of East Africa rift valley system.

C 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 develop undulating structures. Although sedimentary rocks were assumed to form in horizontal layers, according to the principle of original horizontality, when these rocks are exposed to earth surface, they often appear tilted or folded. These are across section of factors that cause a rock to fold ranging from diastrophic, to intrusions and to surface process.

These processes are very rapid geologically. Rocks that fold are normally geologically young so that they are relatively soft and compressible. Folding principally produces two structures i.e. an Arch or Anticline and a trough or syncline. The manner of folding varies with the way pressure is applied. For example, it may build up generally in strength or be short lived but intense. The temperature, wetness, and type or rock influence the degree of folding.

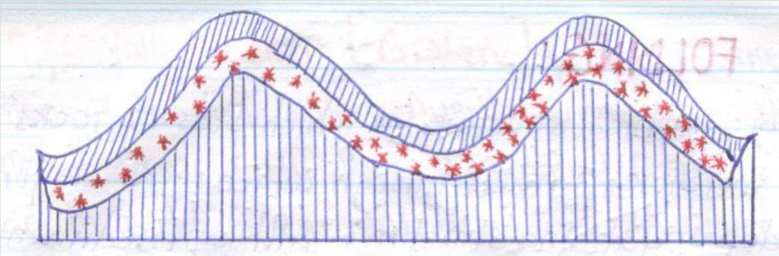
The structure of a fold:



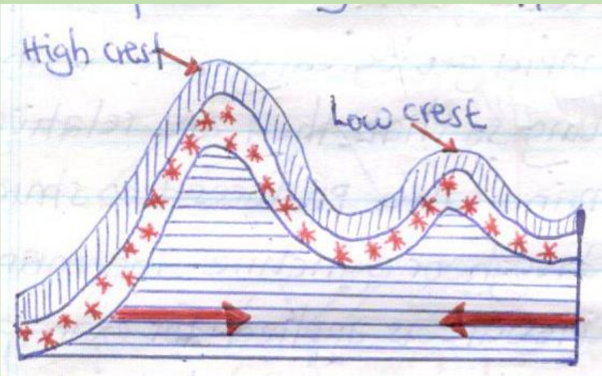
In East Africa, folding has occurred in the following areas. The Genesis complex of Northern Uganda, Toro, Karagwe, Ankole and Buganda areas (Hills). In Kenya, folding has occurred in Nyanza-Kavirondo area, Bukoba, Ukamba. While in Tanzania folding occurs in Dodoma and Usagaran.

Types of folds:

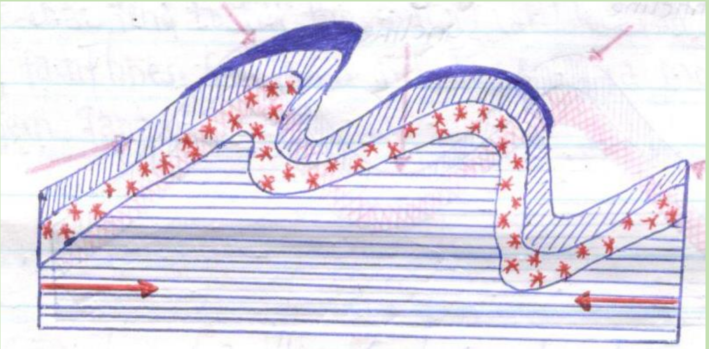
- **Simple folds (symmetrical)** These are symmetrical folds formed by gentle compression that forces the rock strata to develop simple crests and synclines that are similar and uniform.



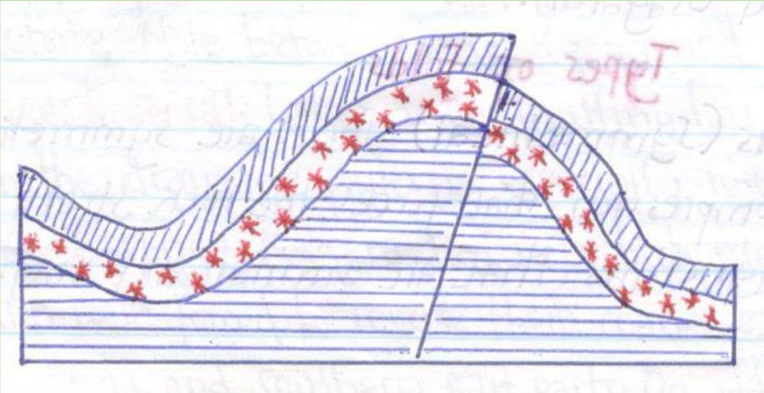
- **Asymmetrical folds;** These are produced by an increase in the degree of compression and particularly when the pressure on one side is greater than it is on the other side. Hence one crest is steeper than the other. Folds are asymmetrical i.e. not uniform e.g. folds in KIgezi, Kampala-Mityana road, Arua and Buganda Toro rocks.



- **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 would-be syncline.

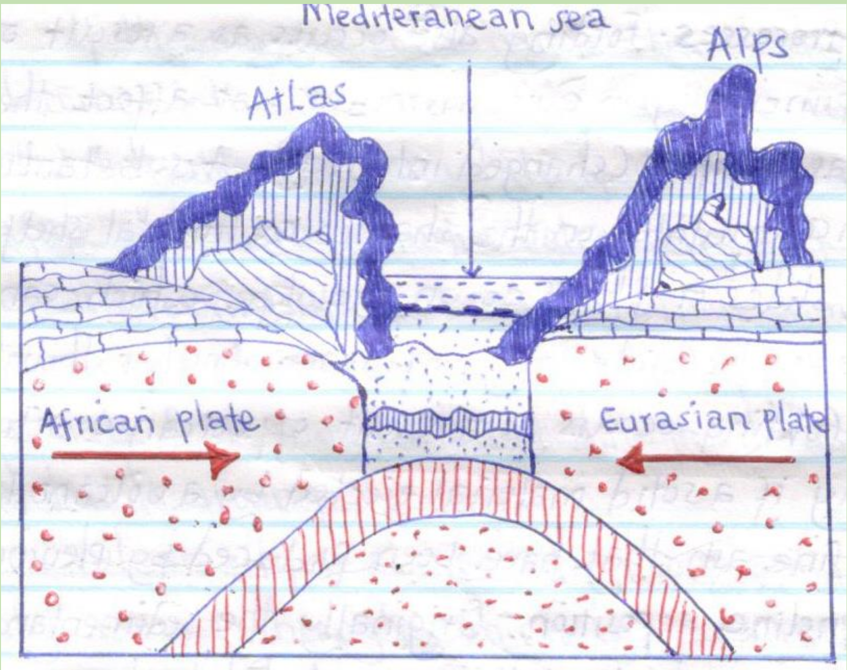


- **Over thrust folds;** Are folds produced when the degree of compression is so intense that faulting occurs in the over riding crest. Then the crest was separated and one block jumped over the other.



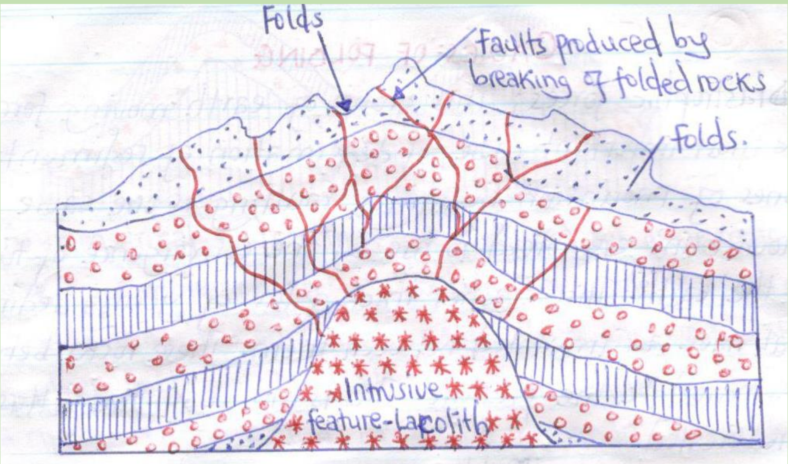
CAUSES OF FOLDING

1. **Diastrophic forces;** This group of earth moving forces is by far the most important cause of deformation of sedimentary rocks. In zones of mountain building, faulting is one cause of folding. Mountains are forced to rise by the convergence of two rigid plates of the earth. These crashes thick piles of young sedimentary rocks that have accumulated between them. These rocks bend to accommodate the pressure. This is the way the Atlas and Alps were created.



2. **Intrusions;** igneous and rock salt (itself a sedimentary rock) are the major rocks that cause folding through intrusion. Rock salt is deposited as a sedimentary when salt water evaporates. As other sediments are deposited on top of this, they exert pressure on this salt, which forces it to flow. A mobile salt layer has got a low specific gravity hence is lighter than enclosing rocks which encourages it to rise. Eventually, it finds a weak point in the rocks and it forces its way through forcing the overlying rocks to arch into an anticlinal structure hence folding.

   A similar process occurs when molten rock-magma mixed with gases forces its way up into the rocks. The pressure they exert together with high temperatures of the magma allows it to rise vertically through overlying rocks. This produces folding effects similar to those of salt intrusions.



3. **Surface processes:** Folding also occurs as a result of surface process principally in circumstances that affect the sediment before it has lithified (change into rock). A substantial amount of sediment accumulates on the shallow continental shelf area of the ocean and slides or flows down the slope, which can produce fold structures at wide range of scale. Another though insignificant cause of folding occurs as a result of volcanic activity particularly if a solid material ejected by a volcano lands on the layers of fine ash that have been produced by previous erruptions.

4. **Geo-syncline deposition:** Originally the sedimentary rocks must have laid down in horizontal layers which later become folded through compression. To begin with earth movements must have caused part of the earth crust to warp down into large depressions called **Geosynclines** which became sites of seas. Deposition in these geosynclines begun and as it increased, the weight also increased and exerted compressional forces that forced the rock to develop anticlinal structures.

5. **Gravity gliding:** According to this, all sedimentary rocks that are inclines or have inclined bedding planes will be forced down slope by gravitational pull. The friction that will be exerted at the leading edge down slope will make rocks to fold.

D VULCANICITY.

Vulcanicity is one of the processes that are indirectly produced by faulting. When the earth crust develops a line of weakness (Faultline), the already mobile and molten rocks (magma) under intensive pressure from overlying rocks will over flow through this weakness (Faultline) and move upwards from the mantle into the rocks of the earth crust. The process of movement of this magma from the deeper layers of the earth into or top of the earth crust is what is called **vulcanicity.**

If this magma cools inside the bedding planes of the earth, it becomes **intrusive vulcanicity**, and the features it produces are called **intrusive features**, while if it reaches and cools on the earth surface it becomes **extrusive volcanicity** and the features produced are called **extrusive features.** the most common of these features is a volcano. A volcano is a landform produced when molten materials from magma erupt through the surface of the earth and builds around the vent.

Vulcanicity is also called igneous activity because it's the only process through which igneous rocks are produced. Radioactive materials in the earth generate high amount of heat automatically which keep the earth interior in a semi-fluid form. Hence it is mobile and can easily flow.

Global distribution of vulcanicity.

The major volcanic regions of the world are these areas where seismic activity especially along plate margins exist. This is here that plate convergence or divergence occurs. These are;

1.The circum pacific Belt (the ring of fire regions) stretching from the Andes of South America to the Rockies of North America, to the Eleutian islands, to Kamchatka region of Japan, Papua New Guinea, to the Phillipians, to the Solomon Islands, New celedonia and Newzealand.

2.The North Africa, Middle Eastern, East African and Madagascan Belt.

3.The Pacific Ocean region covering areas of Hawaiian Islands, Galapagos islands and Juan Fernandes islands.

4.The Indian ocean region covering areas of Java, Bali and Sumatra.

5.The Mediterranean and Asian Belt region covering areas of Azores, Canary Islands, through Italy, mountain Ararat.

6.Other minor and isolated volcanic regions of the Caribbean e.g. Parana plateau, in South America, Kimberly plateau of Australia, Drakensberg of South Africa.

Illustration of major volcanic features.

Diagram

The volcanic material;

The nature and type of volcanic features, their shape and characteristic of magma ejected. Majority, magma is categorized according to the degree of scatter or spreading after exposure on the earth's surface. This degree of viscosity or fragility is determined by the amount of silica. If silica content is high, the material becomes **acidic**. If it is average, the material is **basic** while if it is very low it becomes **ultra-basic.**

Silica content ($Si0_2$)	**Type of lava**	**Example of rock**
66% + $Si0_2$	Acidic	Granite Rhyolite
Between 52-65% $Si0_2$	Intermediate	Diorite, Andesite
Between 45-52% $Si0_2$	Basic	Gabro, Basalt
Between 45%$Si0_2$	Ultra-basic	Peridotite, Serpentinite

VULCANICITY IN EAST AFRICA.

East Africa is region whose landscape has been seriously affected vulcanicity. vulcanicity has been active throughout geologic time. However, the most important time when East Africa was hard hit by volcanic activity was from Tertiary (Miocene) up to Holocene. The Miocene period was characterized by eruption of mount Elgon, Kadan and Napak (between 25-50 million years ago). The rest erupted in the last geologic period (within 5million years ago) and others are continuing to erupt.

The latest mountains to erupt were Nyamulangira (1981), Nyirangongo (found in Kivu area of Virunga mountains) of Eastern Zaire erupted in 2002 and mount Oldonyo Lengai in 1966. Despite the fact there are no common active volcanoes in East Africa, by Virtue of there recency, volcanicity is not entirely extinct. A series of vulcanic mountains show signs of activity e.g. Mufumbira ranges (south western Uganda), Chyulu range, Simbi and Manengai ranges in Kenya and Oldonyo Lengai in Tanzania. Active vulcanicity is now commonly restricted to geo-thermal regions with features e.g. Hot springs, Geysers and Fumaroles, save for a few mountains e.g. Nyirangongo which has just erupted.

Landforms of Vulcanicity.

A. Intrusive features; these are called plutonic land forms and the are formed when magma fails to reach the earth surface and therefore cools within the bedding planes. These includes:

1.Batholith: This is the largest of all intrusive vulcanic landforms. It is a very large mass of magma that often forms the root of the mountain. It is composed of granite and once exposed to the surface by erosion of overlying rocks, it forms large features e.g. Tors, Kopjers and inselbergs and uplands covering hundreds of square kilometers. Examples of batholith are Mubende batholith in Uganda, parts of Acholi have got exposed batholith that produced inselbergs e.g. Labwor, Parabongo, Lalongo, Otuke, Aloi and Akia, Singo batholith in Tanzania, batholiths are found between Mwanza and Iringa and the whole of Sukuma land.

Vulcanicity or vulcanism is a total process by which gases and molten rock from the interior of the Earth are intruded into the Earth's crust or extruded onto the Earth's surface. When the molten material, that is magma is intruded into the crust, it solidifies giving rise to intrusive features. when the material reaches the surface of the Earth, it solidifies to form extrusive features. these are the features referred to as volcanic.

The molten rock or magma originates from upper mantle and asthenosphere in the interior of the Earth. This material is kept in a semi-plastic form by pressure exerted by overlying rocks. Through the natural processes of radioactivity, heat is spontaneously generated. This makes the rocks even more plastic and fluid. Any increase in heat can trigger off upward movement of the molten rocks. Additional heat can come from friction along plate boundaries.

When temperatures rise, the lighter elements of the mantle melt and begin to rise towards the surface. The upwelling is made possible if there are lines of weakness like cracks or fault. Vulcanicity will also take place because of reduced pressure above the molten rocks. Gases in the interior escape to the surface creating fissures within the crustal blocks. The magma then forces its way to the surface along these fissures and forms various landforms an reaching the surface.

When magma erupts at the surface and loses its gases, it is known as lava. It is the escaping gases which, because they expand rapidly due to the lower pressure, cause many of the eruptions to be very explosive. Lavas vary considerably in their composition particularly in their silica content. The nature of lava partly affects the type of landforms.

Basic lava, for example is fluid and largely mobile and therefore forms extrusive lava plains and large shield volcanoes. On the other hand, acidic lava is viscous and largely immobile and consequently solidifies quickly to form steep landforms. Sometimes acidic lava solidifies quickly and blocks fissures resulting into explosive eruption thus lava is ejected in form of particles of various sizes known as pyrocdasis.

Illustration of a batholith.

Diagram

In Kenya they are found the Maragoli area of western Kenya

2.Laccolith: This is a dome shaped feature produced by intrusion of viscous magma which does not spread but builds up and therefore arches up the overlying rock strata into a dome shape. If it is exposed to the surface by erosion, it produces a rounded hill surrounded by circular scarps. Laccolith can be seen in voi in Kenya, Funjay and Ambereny massifs in Madagascar.

Diagram

3.Lapolith: this is formed in more less the same way as the Laccolith except that whereas the Laccolith is made up of viscous material that forces the crust into a dome shape, Lapolith is made up of basic materials which after intrusion sags down due to the weight of overlying rocks. Hence as it sags; it produces a saucer shaped feature. This can be seen in Belingwe in South Zimbabwe and in Singo/ Mubende hills.

Diagram

In Zimbabwe, there are series of Lapoliths intruded into the basement complex. These extend across much of the country. Erosion has however formed a line of low hills out of them. These reach their highest in the Umvukwe range north of Harere. Other good examples are found in the bush veld basin of Transvaal province in south Africa.

4.Dyke: A dyke is formed when a mass of magma cuts across the earth crust and forms a wall like structure. It may be vertical or steeply inclined. They may occur in a group. Some dykes are hard than surrounding rocks and hence after erosion, they may be exposed as ridges while if they are less resistant, they form shallow depressions. Dykes can be seen in Western Lake Turkana (Mbarali), thicker falls, Rangwa complex in Kisumu, and around Tororo rock (Ring complex in Uganda.

Diagram

Other examples of dykes are found in the Jos plateau in Nigeria, Malawi and in Lesotho.

5.Sill: This is formed in more less the same way as a dyke except that where as in a dyke magma cools in inclined bedding planes, a sill is produced when magma cools in horizontal bedding planes. It is formed from basic magma that can easily penetrate rocks and curve. They can be seen along Pakwach-Arua road in Uganda (Karuma falls), Thika area in Kenya.

Diagram

The three sister Sills in south and the great whin Sill in Northern England are also remarkable examples.

6.Ring Complexes: these are circular intrusions of one or many ring dykes. Ring dykes are concentric ridges of igneous rock that are formed when the land around the circular dyke system subsides (cauldron subsidence) exposing circular and ring like features called ring complexes.

Diagram

B. Extrusive features:

These are landforms of vulcanicity that are formed when magma reaches the earth surface. These are features of volcanicity i.e. a process through which magma escapes from the interior of the earth up to the surface.

1.Volcanoes. A volcano is a hill or mountain produced by eruption of magma and piling up of the pyrocrasts of magma around the vent until a highland is built.

Types of Volcanoes.

i. **An acidic lava cone.** Acidic lava as already seen above has got 66%+ of Silica and therefore is more viscous. It is this viscous magma which after erupting that forms acidic cones. This cone has got steep and convex sides (sides that bulges outside). The base of this cone is small but is very high in altitude. Examples of acidic cones are mount Mgahinga (Western Uganda) and mount Rungwa in Tanzania. they have small craters.

Diagram

ii. **Strato volcanoes:** This type of volcano is composed of alternating layers of lava and ash. It is formed by violent eruption such that lava is blown to great heights and it breaks into small fragments that fall back and build a layer of ash. As eruption becomes less violent, the gentle lava settles on top of ash to form a layer of lava. It is called strato because of being composed of strata of ash and lava. Examples of composite cones are examples of strato volcanoes in East Africa. They include Mgahinga, Mount Kilimanjaro, Muhavura, Elgon, Longonot, Oldonyo

Diagram

iii.Ash and cinder cones: These are small and symmetrical cones composed of pyrocrasts. When lava is violently ejected it is blown to great heights and it breaks into small fragments. These fall back to the earth and builds up a cone. This sides of this cone is greatly concave due to the spreading of the material around the base.

Diagram

iv.A basalt dome: This is made up of basic magma that therefore is able to flow far and spread widely before solidification. It is also called a shield volcano. As the material erupts, it spreads and therefore produces a volcano that is low in altitude but with abroad base. The sides are concave, examples are Mt Virunga, Muhavura (Mufumbira), Mt Kenya, Mt Longonot and Nyamulangira (E. Zaire).

Diagram

V.A composite cone; This is a volcano that is composed of more than one cone. After the formation of the main cone, lava may solidify in the vent and therefore block all subsequent eruptions. When it wants to erupt again magma will find the main vent blocked and it will find alternative ways through the sides and hence create other secondary cones called parasitic cones. This cone has got characteristics of both acidic and basalt domes with the lower slopes gentle and the upper slopes steep. Examples of composite cones are mt. Kilimanjaro (with mawenzi and shire peaks are conlets), mt Muhabura has Mgahinga as a conlet, mt Elgon, mt Longonot, Oldonyo Lengai and Vrunga.

Diagram

vi. A dissected volcano: This is a volcano whose sloping sides are deeply dissected by radial valleys. Erosion begins first on the upper slopes and slowly but surely incises these slopes finally producing a volcano whose slopes are made up of ridges and valleys. Examples of dissected volcanoes include; Mt Kenya and Mufumbira.

vii. Volcanic plug/neck: When magma is very viscous, it will form a rigid volcanic plug. The material is so viscous that is just pushed out of the ground without flow but as a rigid and consolidated plug. Eruptions are very explosive and they are intruded together with clouds of hot ash and cinders, examples are Toro rock in Eastern Uganda, Alekilek in Napak Caldera, in South Karamoja, Batian and Nelion peaks on mt. Kenya, Tinderet, Loldiani and Timborora in Kano plains of Western Kenya.

Diagram

viii. Craters. A crater is a depression on top or on the side of volcanic cones. It is bow or funnel shaped or circular shaped in nature with in facing escarpments. Its depression is generally less than 1 mile (1.2km) in diameter. It is formed as a result of successive eruptions such that after the first eruption, the vent is properly blocked. Any successive eruption will find it impossible to flow out. As a result, pressure will build up inside and finally it blows off the top forming a crater. Such craters include; Manengai, Suswa, Shomble, Kilimanjaro, Elgon, Sabinyo.

Ix A ring craters. A ring crater unlike other ordinary craters is formed as a result of less violent eruption. If explosion consists of mainly gases and some few pyrocrasts, the explosive eruption of gases drills a hole in the ground and the pyrocrasts then gently pile around the hole (cent) to form a low rim around the vent forming a ring depression called a ring crater or explosion vent. This process of crater formation is called **fluidization**. Examples of ring craters are Lake Katwe, Nyamunuka, Nkugute and Kasenyi (in Fort Por98tal Uganda), Lake Saka, Kyegere. In Tanzania are Galama and Ndoto craters N.E of Singida. Ring craters will not necessarily form on top of mountains. if these craters are filled by water, they form lakes called crater lakes. Examples given above for craters have lakes.

Diagram

x. Caldera: This is more-or-less a crater except that unlike a crater, a caldera has got a more extensive depression more than 1 mile in diameter. Like in a crater above, the secondary eruption may blow off the top of a volcano hence creating an extensive depression called a caldera.

Alternatively, a caldera can be formed by a process called **cauldron subsidence** or basalt wreck. According to this, a caldera is formed when during eruption, a lot of magma is poured out due to high pressure such that there is a big empty chasm left under the volcano. After eruption, this chasm is left unoccupied and later on the weight of the volcano on top sinks (subsides) down into the chasma leaving a wide depression on top.

Examples of calderas include; Ngorongoro caldera (Tanzania), Napak caldera (Uganda), Enbagai caldera (Tanzania), Longonot (Kenya) and Suswa in Kenya.

During Explosion

Diagram

After Explosion

Diagram

During eruption

Diagram

After eruption.

Diagram

Xi Cumulo dome: This volcanic feature is formed by volcanic eruption of viscous magma. This viscous magma does not flow as other features form but instead the pressure forces the material to bulge outwards forming the dome shaped feature. After the formation of an acidic cone, the surface quickly hardens while the interior is still fluid. Further uprising within already hardened layer forces these layers outwards (as a pumped ball expands).

Consequently, forming a more-or-less rounded feature without a crater called a cumulo dome-or **memelon.** If it forms into a crater, it is called a **thalloid.** Examples of cumulo dome are Ntumbi cumulo dome in Tanzania and Tsavo National park. Athalloid is also found in a caldera on top of mt Rungwe.

Diagram

2.Lava plateau: A plateau is a flat-topped highland area. A lava plateau therefore is a flat-topped highland area made up of lava. When basic magma flows out of the linear fissures or a series of them, extensive sheets of magma will be produced covering large areas. Such a flow is quiet and not explosive called **fissure eruption.** It may be formed as a result of inter connected cones over an extensive area.

Examples of lava plateaus are Yatta plateau in Kenya, Loita, Athi plains, Kapti phonlite, Kencho, Laikipia, Kano and Uasin Gishu in Kenya and Bunyonyi in Uganda. Also, the chain of extinct volcanoes West of mt. Meru in Tanzania is thought to be a result of fissure eruption.

Diagram

3.Other forms of volcanic activity: These are other minor igneous features produced by **geo thermal activity.** Within volcanic active areas there are hot springs, gysers, fumaroles.

i. Hot spring; This is a feature produced by constant flow of hot water from a rock. As it rains, water seeps into the rock and finally reaches a super-heated rock. If this water accumulates on this rock, it will be heated up. If this heated water reservoir is connected to fissure, this hot water will flow out as a hot spring.

Examples of hot springs are Ihimbo and Kisizi (Rukungiri) and Kitagata (Bushenyi), Sempaya, Lututura and Kananorok all in Uganda, Njorwa, Maji yamoto and Lake Hannington in Kenya, Ambooni and Maji moto in Tanzania.

Diagram

ii.Geysers; A geyser is formed almost in the same way as a hot spring except that in a geyser hot water with stream are ejected out with a great force and periodically. They periodically emit powerful jets of hot water. Water collects in an underground rock cavity with a sump that boarders a very hot rock and traps steam behind it. As the steam increases its pressure builds up to a point where it pushes water out with violence.

The sump fills up with boiling
Water entering from joint rocks.

Diagram

Hot water and steam are ejected out.

Diagram

Alternatively, geysers can be formed when water collects into under ground cavervans that are bordered by very hot rocks. The opening of the cavern is very small such that it restricts the amount of steam to escape. High pressure in a cavern will force water with steam out with force. Examples of geysers in East Africa are in Lake Hannington area (at lake Bogoria) in Kenya.

Diagram

Diagram

iii.Fumeroles: The formation of a fumeroles is not any different from the above two. The only difference however, is that with a fumeroles, steam only escapes continuously under low pressure. If this steam and other gases are sulphurous it becomes a solfatara. Fumaroles are also found in Lake Hannington area, in Longonot craters and between Lake Elementaita and Lake Naivasha, Manengai and Eburi area in Kenya. In Tanzania, fumaroles are found at Amboni and Kilimanjaro.

Revision questions.

1. To what extent does the nature of materials ejected influence the formation of volcanic relief landforms?

   Approach and Brief solution.

   Define: Volcanic relief landforms as features formed as result of ejection of liquid, solid or gaseous materials on to the surface of the earth.

   Describe: the nature of materials ejected and the associated relief landforms;

   The liquid materials ejected consist of molten magma which reaches the surface as lava. Some lava (acidic) contain much silica, with a high melting point, very viscous and so solidify rapidly in the vent causing recurrent explosive erruptions. The resultant landforms include;

   1) Cumulo domes e.g. Ntumbi in Tanzania.
   2) Volcanic plug volcanoes e.g. Kilimanjaro.

When the lava is basic that is poor in silica but rich in iron and magnesium materials, it flows for a considerable area before solidifying producing flatter cones of greater diameter. It is associated with the formation of;

1.Basalt domes/shield of volcanoes e.g. Nyamulangira-part of the Virunga ranges.
2.Lava plateau/plains e.g. Kisoro, Yatta, Kapiti, Nyabondo etc.

Gases compounds emitted during eruption include; Sulphur, Carbondioxide, Chlonde etc. including steam. The gases interreact generating great heat within the lava. This affects the rate of cooling, lava flow and the shape and type of volcanic landform formed.

Gases and solid materials are ejected during violent eruptions producing the following relief landforms;

- Ash and cinder cones/scoria cones e.g. Shozi, Sagitwe in Kisoro, Teleki and Likaiyu in Kenya.
- Strato/composite volcanoes e.g. Kilimanjaro, Muhavura.
- Caldera e.g. Napak, Longonot, Menengai, Suswa etc.
- Explosion craters e.g. Katwe, Nyamunuka, Nyungu etc. in lowlying areas and mountain craters e.g. Muhavura crater, Kilimanjaro crater, Shozi crater etc.

However other factors which bring about volcanic relief landforms should be cited e.g.

1.Nature of the passage;

Central or single vents lead to the formation of steep sided cones e.g. plugs and composite volcanoes.

Numerous fissures tend to produce gently sloping cones, usually low in height with a large base e.g. basaltic domes and Lava plains/plateaus

Fault lines provide passages for the information of volcanic cones e.g. Suswa, Longonot.
2.Number of times of emissions.

Successive eruptions lead to complex composite volcanoes, basalt domes.

Simple/single erruptions lead to formation of small cones.
QN2: Examine the influence of tectonism on the drainage of East Africa.
Solution:
- ✓ Define drainage
- ✓ Identify forms of drainage
- ✓ Define tectonism and origins
- ✓ Identify the tectonic processes and the resultant drainage features.

QN3. With reference to any country in East Africa examine the influence of volcanicity on the landscape.
Qn4: With reference to any country in East Africa account for the formation of volcanic features.
QN5: With reference to specific examples, examine the effects of intrusive volcanicity on the development of relief and landforms in East Africa.
QN6(a) Draw a sketch map of East Africa and on it mark and label the major extrusive volcanic landforms.
(b) Discuss the economic significance of extrusive volcanic landforms, to East Africa.
QN7: To what extent are the highlands of East Africa a result of volcanic activity?
QN8: Explain the processes responsible for the formation of intrusive volcanic landforms in East Africa.
QN9: Referring to specific examples, discuss the view that volcanic features depend on the nature and type of ejecta and lava material
QN10: Examine the influence of vulcanicity on human activities.
<u>Refer elements of physical Geography by A. Nzabona pg 118-122.</u>

ROCK WEATHERING

Introduction:
When rocks are found, they are strong, considerated and cohesive. With time however, this strength, consolidation and cohesiveness reduces and the hitherto consolidated rock particles loosen and the rock starts to crumble. When this happens, we say that the rock has been weathered down.

Weathering refers to the disintegration and decomposition of rocks into increasingly smaller particles or granules in Situ; that is in one place with no movements involved.

Rock disintegration is majorly affected by agents of weather mostly rainfall and temperature hence the name weathering. Other agents of weathering are frost, wind, living organisms, lightening, gravity and crystallization.

TYPES OF WEATHERING.

Weathering takes place in three types of physical, chemical and biological processes.

- **Physical (Mechanical) Weathering;** is the disintegration or rocks into smaller fragments without any change in the chemical composition of the rock. It occurs due to the physical changes of pressure and temperature that puts the rock on stress and leads to rock breakdown. Physical weathering occurs under conditions of temperature fluctuations mainly in semi and areas that experience wide hide high temperatures during day and cold rights as well as the cold mountain peaks of Rwenzori, Kenya and Kilimanjaro. It takes place in form of exfoliation, block disintegration, granular disintegration, pressure release, frost action and frost heaving.

  Therefore, this type of weathering works on rocks to make little ones out of big ones without changing the chemical composition of the rock. i.e. rocks disintegrate into smaller particles but maintain their previous chemical characteristics. What changes is only the physical size. It is mostly affected by temperature changes.

  Chemical is the decomposition of rocks into residual materials resulting in partial or complete change in the chemical composition of rocks. It is due to chemical reactions between rock materials and the atmospheric elements such as water ang gases like oxygen, carbon dioxide and hydrogen among others. Chemical weathering takes place under conditions of high humidity, high temperatures and heavy rainfall that facilitate the chemical reactions.

  It occurs in form of oxidation, carbonation, solution and hydrolysis among others. Basically, as it rains, rain water reaches the earth surface in a mixture of various gases e.g. oxygen, hydrogen and carbondioxide. This solution creates across section of chemical reactions with greatly weaken the rock and therefore make it decay. Therefore, new chemical compound is produced. This is what is called chemical weathering. It is mostly affected by rain water.

  Biological weathering; refers to the breakdown of rocks into smaller particles due to the influence of plants and animals. It takes place in areas of thick vegetation cover and dense settlements. It involves the action of bacteria, plant roots, burrowing animals and human activities.

FACTORS AFFECTING THE TYPE AND RATE OF WEATHERING.

The rate of weathering is the amount of rock disintegration per unit time. It is the '**pace'** at which a rock breaks down. Physical and chemical rock break down are the major two types of weathering are a function of several factors acting in conjunction rather than in isolation. The nature of the rock is one of such factors. This factor, however, works hand in hand with other factors to influence the rate and type of weathering.

(a) Nature of the rock; The nature of the rock refers to rock structure or physical and chemical make up of the various rocks. It refers to rock attributes such as colour, the hardness and softness, minerals forming the rock, rock texture, the rock structure and joints, permeability among others, like age, texture, size, layering etc.

- Rock hardness and softness; This is relative difficulty and ease with which the rocks can be stretched. Hard rocks are very resistant to physical and chemical weathering process compared to the soft rocks that are broken down easily.
- Mineral composition; igneous rocks with low silica content when exposed to the atmosphere disintegrate at relatively faster rate compared to the acidic rocks rich in silica content. This therefore implies that rocks rich in silica are much harder to weather as compared to those deficient in silica like limestone and carbonate rocks. Calcareous rock such as limestone is broken down very fast when they react with water containing carbon dioxide through carbonation.
- Colour (luster) of the rock; Luster is the intensity of light from the rock surface. Mineral rocks with shiny surface or light colour reflect more solar energy than absorb and this makes them to heat up solely thus reducing the rate of rock break down. On the other hand, dark surface rocks absorb alot of solar energy and heat up to expand very fast during day and loose a lot of heat to contract at night. The repeated expansion and contraction of such rocks makes them to break down at faster rate in form of exfoliation and block disintegration.
- Rock texture; This refers to the crystalline of rocks as well as the particle size. Rocks are either coarse grained or fine grained. Coarse grained rocks break down faster than fine grained rocks.
- Permeability and impermeability of the rocks; Permeable rocks allow water to go through them and break down very fast while the impermeable rocks do not allow water to percolate them thus do not weather easily.

- Rock structure and joints; Rock joints increase the surface available for rock decay thus accelerating the rate of rock weathering. Therefore, rocks with very much joints tends to break at the faster rate since such joints enable water and the plants roots to penetrate into lower and deeper layers. The joints also facilitate the frost action of physical weathering. On the other hand, rocks with fine structure or few joints do not break down easily.
- Layering of rocks determines the rate and nature of weathering. Rocks with layers, especially shallow layers on top rapidly undergo exfoliation while those, which are not layered, will undergo limited exfoliation weathering.
- The age of the rocks has also a bearing on the rate of weathering. Rocks, which are aged, are more susceptible to breakages (faults) whenever exposed to tectonic pressure while young rocks fold instead of fracturing. These breakages and cracks become zones of expansion and contraction (physical weathering) or through which water enters rocks for rapid chemical weathering.
- The size of the rock also matters when it comes to weathering. Rocks which are massive, will not very much yield to weathering like small rocks. Therefore, the bigger the rock the lesser the weathering, effect and the smaller the rock, the more the weathering effect.

(b) **Climate;** This majorly stress the influence of rainfall and temperature conditions on rock weathering. It can be examined based on various climatic zones for instance;

Equatorial climate with high temperatures and heavy rainfall tends to catalyzes the chemical weathering process like carbonation, solution, hydration and others. This is because the heavy rainfall provides water that reacts with the rock minerals while the high temperatures catalyze the chemical reactions. Therefore, regions experiencing modified equatorial climate like the Lake Victoria basin are characterized by high rate of chemical weathering.

In and semi-arid areas of East Africa, the climatic conditions of low cloud cover, high absolute temperature and high durnal temperature range tends to increase the effectiveness of physical weathering. The very high temperature during day and very low temperature at night leads to rapid expansion and contraction of rocks. Physical weathering processes such as exfoliation and block disintegration are therefore predominant in these regions such as Karamoja and northern Kenya.

Cold climatic conditions tend to promote frost action or freeze thaw processes of rock weathering. The freezing water tends to widen the rock and consequently facilitate rock break down in form of frost action. This occurs on the snow-capped mountains of Rwenzori, Kenya and Kilimanjaro.

(c) **Relief/Topography;** This id the physical appearance of the landscape. It is manifested in slope angle and altitude (height above sea level)

- Steep slopes tend to witness rapid removal of weathered material thus exposing underlying rocks to the constant agents of weathering like air and water thus promoting physical weathering processes like pressure release.
- Gentle slopes experience less erosion and some deposition of heavy granules, the deposited materials tend to protect the underlying parental rocks from the atmosphere thus reducing on the rate of weathering.
- Lowlands/valleys experience deposition of weathered materials associated with water flooding. The accumulation of water on parent rocks in such areas facilitate chemical weathering process like solution and hydration.
- In addition, relief creates condition of lee ward and wind ward effects which influence the rate and type of weathering. Physical weathering process tend to be dominant on the lee ward side due to and conditions while chemical weathering processes tend to be dominant on the wind ward side of the mountain due to heavy rainfall received.

(d) **Influence of Living organisms;** Like plants and animals, when the living organisms die, they decompose into humus. The humus reacts with water to form humic acid which chemically reacts with rocks to facilitate rock break down.

- Vegetation cover especially trees act as agents of rock weathering due to the reaction of their roots. As the roots increase in size and grow deep into the ground, they tend to open up the joints or rock cracks and consequently facilitating deep weathering of rocks.
- Burrowing animals such as rodents, rats, moles, termites and others tend to loosen and break the rocks thus facilitating physical weathering and biological weathering.
- Human beings also tend to accelerate the rate of weathering. Activities like ploughing, mining, construction and others accelerate the rate of chemical weathering by either directly break down rocks or open up the inside layers of rocks to the atmospheric elements which consequently lead to break down of rocks.

(e) **Time;** This is the duration in which the rock is exposed to the weathering processes. Time is a passive factor that stress its role that old rocks or those which have been exposed to weathering agents tends to have a faster rate of rock break down compared to the newly formed or recently exposed rocks. In principle the longer the duration of rocks exposure to weathering agents, the more advanced the rate and type/ character of rock weathering.

Guiding Question:

To what extent does the rate and character of rock weathering depend on the nature of the parent rock?

Approach.

- Define weathering
- Identify the type of weathering
- Examine how the nature of the rock influences the rate and character of rock weathering.
- Depending on the above facts, the statement that the nature of rocks is the most important factor of influencing rock weathering is therefore valid. However, rocks on earth surface would still weather even if the mentioned characteristics were unfavorable. This is because there are other factors that cause disintegration and decomposition of rocks and these include; climate, relief, time etc.
- Discuss the influence of other factors.
- conclude with a stand point.

In conclusion therefore, the rate and character of rock weathering is a function of many factors. The nature of rock is one of them, which is believed to have the greatest effect on the speed and character of rock break down. However, the role-played by climate, topology, living organisms and time should never be underestimated.

Conclusively, even if rock characteristics were to offer tremendous resistance to the weathering process, a rock would still break down in the long run. Very hard rocks may only slow down the pace but not stop the process of weathering. This is because, a part from the nature of the rock, there are several factors that contribute to rock break down.

PHYSICAL WEATHERING PROCESSES:

As already defined, physical weathering is the mechanical disintegration of rocks into fragments or development of cracks within rocks. This type of weathering occurs in various ways as shown below:

I. **exfoliation:** This process is caused by repeated heating and cooling of the rock surface due to high insolation and terrestrial radiation. During day, the rock surface is intensely heated by the incoming solar rays thus making it expand and develop cracks. At night, temperatures rapidly fall to cold levels due to outgoing surface radiation and this makes the rock to contract rapidly thus cracking the rock.

The repeated process of rock expansion and contraction created by wide temperature fluctuations makes the rock cracks t widen to a few centimeters thick and consequently begin to peel off into screes (rock debris). After the peeling off of the outer rock layer, a new rock surface is exposed to the atmosphere in form of oval shape called an exfoliation dome.

In Uganda, exfoliation domes can be traced in Karamoja, Kitgum, Mubende and Soroti. In Tanzania, they can be seen in Songea, Rongwa, Serengeti and Dodoma. In Kenya, they are found in northern eastern Kenya and Turkana land in the northwest.

Diagram

II. **Block disintegration;** This occurs in areas where there are jointed rocks which experience extreme temperature fluctuations during day and at night. The high temperatures during day and cold nights lead to rapid expansion and contraction of rocks thus making the rocks to fracture into rectangular blocks a process known as block disintegration.

Diagram

Joints are opened up by expansion and contraction of the rock.

This type of weathering produces granite tors (inselbergs). These granite tors or inselbergs are of two types; i.e. catellated tors and tors and finger type inselbergs.

Castellated tors are produced when there is both horizontal and vertical joints in a rock such that disintegration is both horizontal and vertical e.g. Kachumba rock in Kumi, Mubende tors in western Uganda, Kit Mikai in Sema location of Lukenya in Kenya and Bismarck rock in Mwanza-Tanzania.

Finger types or sugar loaf inselbergs are formed when only vertical joints appear in a rock. Hence rock disintegration is vertical producing columns of rocks called sugar loaf inselbergs. Such inselbergs can be seen in ihonga, Mrui (Iresi area) of Kamenge Kenya.

Diagram

Castellated tor

Diagram

Sugar loaf inselberg (tor)

III. **Frost shuttering;** This type of weathering is experienced in areas that fall below 0^0c and in East Africa these are the mountains peak of mt Rwenzori, mt Kenya and Mt Kilimanjaro. During the day, water enters into the cracks of the rocks. During the nights this water freezes and exerting pressure with in the cracks. Water in such mountains freezes almost every night and then thaws the next day. It is said that water once frozen, expands by approximately 10% its liquid volume. It is the expansion in these cracks that makes rock particles within the cracks to break off as screes and the rock to disintegrate.

During day

Diagram

During night

Diagram

This type of weathering is also called congelifraction. It produces angular screes that may cover extensive areas which are called falsmeer. This can be seen on Batia and Nelion peaks on Mount Kenya, Upper Mubuku valley, around Margherita, Stanely, and Baker peaks on Mount Rwenzori.

Iv Pressure release; (unloading process). This occurs when the overlying weight on the parent rock is removed by denudation especially soil erosion thus causing the underlying rock to be relieved. When such weight is removed, rocks begin to expand and develop curved joints parallel to the rock surface. These joints widen and deepen and eventually facilitate rock break down. It occurs on exposed batholiths, sills and dykes and can lead to the formation of Inselbergs.

Pressure release process occurs in the regions of poor vegetation cover where there is severe soil erosion. Examples can be witnessed in Turkana Land, Karamoja region and Ankole-masaka corridor, panyjok in Apach, Mayanjo in Kampala, between Mwanza and Iringa, Serengeti and Rukwa region of Tanzania.

Denudation exposes the underlying rocks thus making them to develop cracks and weather.

Diagram

Diagram

V Granular Disintegration: Granular disintegration takes place almost in the same way as exfoliation except that in this type, rock disintegrate into small particles called granules. Granular disintegration is produced in two ways:

a) By differences in thermal expansion and contraction: some rocks are composed of minerals and particles that respond to temperatures differently. If a rock is for example made up of white and black particles will absorb more temperature than the white particles and both will expand at different rates. The same applies when the rock has got minerals that expand and contract differently with thermal heating. This will cause strains and stresses within the rock and it will break up into its granules.

b) Frost heaving; This type of granular disintegration is common in ice capped margins where freezing and thawing occur. It also occurs in porous rocks such that when temperatures are high (day), ice melts and water enters the rocks. When temperatures drop below 0^0c, this water freezes within the rock particles and expands hence detaching these particles a part. The rock crumbles into small particles (granules).

Frost heaving leads to the formation of stone polygons or patterned ground seen in valleys e.g. Teleki valley on Mount Kenya and also on mount Rwenzori. Alternatively, frost heaving is called congeliturbation.

Vi Crystallization: This is one of the physical processes of weathering in which some rocks may absorb salty water. This salty water will later collect in rock cavities and pores. This water may later start to evaporate and hence salt crystals will begin to form. As these salt crystals grow bigger and expand in size, they exert pressure on surrounding rock particles hence making them peel off. It is a common process in arid areas and coastal areas of East Africa.

Elsewhere, it is cited around Lake Katwe, Lake Nyamunuka and Lake Kasenyi in western Uganda. It is also common around Lake Magadi, Natron and Nakuru (which are salty lakes).

Vii Organic activity: This is the physical activity of biological organisms namely plants and animals. Plant roots searching for minerals and water grow into the rock. As the roots increase in size, they wedge the rock apart. Burrowing animals further break down the rock by moving fresh material to the surface and underground rocks where they live. Wild game and large domestic animals contribute to physical rock disintegration as they trample on the ground in the course of their movement across the range-land.

QN: (a) Distinguish between physical and chemical weathering

(b) Giving specific examples, describe the physical weathering processes taking place in East Africa.

Approach.

- ❖ Define weathering
- ❖ Explain clearly with examples
  - ▪ Physical weathering
  - ▪ Chemical weathering
- ❖ Describe the physical weathering processes
  - ▪ Giving illustrations where possible
  - ▪ Giving examples where possible.

CHEMICAL WEATHERING PROCESSES.

The process of chemical weathering or rock decomposition transforms rocks and minerals into new chemical products. This transformation (change) is usually assisted by the presence of water and air, particularly, oxygen. In chemical weathering, the internal structures of minerals may be charged decomposition is camed out in several ways. The key weathering processes are described below.

Oxidation; This is a process which involves the absorption of oxygen in the atmosphere by rock mineral especially iron and aluminum compounds. For example, the iron compounds react with oxygen in water to form iron oxide which forms a rust line over the rock. The rusting of the rock indicates the decomposition process. Rocks are mostly affected by oxidation process include Olivine, feldspar and mica. Below the water table the ferrous compounds in the clay give it grey or blue colour but in the zone above the infiltrating water, the oxygen oxides ferrous compounds into red brown compounds.

In central Buganda, the process forms hard crust on top of the hills which are laterites (duricrusts). Oxidation also takes place in Kigezi and Tororo where there are rocks with iron ore.

$4Fe0+0_2 \quad = 2Fe_{2+}0_3$

Ferrous oxide+ oxygen =Hematite

Oxidation of a rock can result in a series of reactions and processes taking place. E.g. The oxidation of olivine rocks results into production of magnesium hydroxide, ferrous oxide and silica acid as shown by the equation below.

$Mg\,FeSi0_4 + 2HOH \longrightarrow Mg(0H)_2 + Fe0 + H_2Si0_3$

(Olivine) + (Hydroxy) (Magnesium hydroxide) + (Ferrous oxide) + (silica acid)

Hydration; This is a process of weathering by which rocks absorb water and expand in size. This expansion reduces the cohesiveness of the rock particles hence internal stress is created in the rock and therefore a rock crumble. Some rocks e.g. hematite and anhydrite completely breakdown after hydration and produce new compounds. Calcium sulphate (enhydrite) is after absorbing water into Gypsum as shown by the equation below.

$CaSO_4 \quad + \quad 2H_20 \quad = \quad CaSO_4.2H_2O$

(anhydrite) + (water) (Gypsum)

Reduction; This is a chemical weathering process that is a characteristic of waterlogged swampy soils where the amount of oxygen ions are removed and hydrogen ions added. In these waterlogged areas, spaces in rocks are filled with stagnant water coloured ferric compounds (Fe_2O_3) are chemically reduced or given away to a gray, blue appearance of ferrous oxide (FeO_3).

That is a reason as to why clay soils or swampy soils have a gray colour. Whenever such rocks (soils) are exposed to dry ground, a reddish colour appears at the surface simply because the ferrous oxide (FeO) has been oxidized to form rust/ferric oxide (Fe_2O_3)

called hematite. Reduction occurs in all swampy and water logged areas e.g. at Kajansi, Aswa valley, Tana, Pangani and Athi areas.

Hydrolysis; This is a chemical process that occurs in rocks, which absorb water. Hydrolysis is a reaction of hydrogen and some minerals within certain rocks. This reaction undermines the strength of the rock and also turns it into new compounds. Hydrosis is common in granite rocks that are rich in field spar, which feldspar is turned into whitish clay called Kaolin as shown by the equation below.

$K_2.AI_2O_3.6SiO_2$ + H_2O = $AL_2O_3.2SiO_2.2H_2O$

(Feldspar) + (water) (Kaolin)

This clay occurs near opete in Kilungu hills of Machakos and Karatin in Kenya. The kajasi clay in Gulu, and in Amatafali (South of Lira town) are all products of hydrolysis.

Solution; This is a process where certain rock minerals dissolve in water thus resulting into fundamental chemical changes it is common among rocks with sodium chloride, calcium chloride, magnesium chloride, calcium sulphate and common salt as witnessed at Lake Katwe in Uganda and Lake Magadi in Kenya.

Carbonation; This is a process which involves the decomposition of rocks by carbonic especially on carbonic carbonate rocks such as Lime stone and dolomite. Carbonic acid is a weak acid formed when rain water reacts with carbon dioxide in the atmosphere. Carbonic acid changes calcium carbonate rocks into bi carbonate which is easily removed in solution form by running water.

CO_2 + $H_2O \longrightarrow H_2CO_3$

(carbon dioxide) (water) (carbonic acid)

H_2CO_3 + $CaCO_3 \longrightarrow Ca\ (HCO_{3)2}$

(carbonic acid) (limestone) (calcium hydrogen carbonate)

When carbonation affects the rocks, various land forms are created. For instance, part of the rocks are dissolved in water to form grikes separated by sharp ridges of resistant rocks known as clints. Similar reactions occur underground to form stalactites on the roof of the underground cave and stalagmites on the floor of the caves. They form when calcium carbonate rocks are dissolved and transported downwards in solution form as calcium bi carbonates. When the water evaporates, the limestone is left as deposit on either the roof of the cave or the floor. Such features can be seen in Nyakasura, Kiliffi on the Kenyan Coast, Kajansi on Entebbe road.

Chellation; This is a chemical weathering process that involves the exchange of minerals between the plants and the rocks. The plants extract mineral nutrients from the rock causing a change. The plants on the other hand release some minerals back into the rock that changes the mineral structure on the rock hence leading to chemical decomposition. This occurs due to the thick vegetation cover.

THE INTERDEPENDENCE OF PHYSICAL AND CHEMICAL WEATHERING.

Weathering as earlier pointed out can be either physical, chemical or biological, Biological weathering however, is either physical or chemical and hence can not form an independent category of its own. Therefore, we remain with two major types of physical and chemical weathering. For purposes of clarity, the two processes were considered in isolation, they are not always exclusive and are therefore interdependent because one can lead to another as illustrated/described below.

a) The joints, crack and weaknesses found in a rock as a result of physical weathering allow deeper penetration of water hence providing a favourable ground for rock decay (chemical weathering).

b) Some rocks are dissolved in water and weathered away in solution. The solutions formed may later undergo precipitation leading to crystal growth. When crystal growth happens in rock cavities, they will exert a lot of pressure that will disintegrate the rocks physically. This occurs in chlorides, carbonates, sulphates etc.

c) Hydration (a chemical process) results into rocks absorbing a lot of water e.g. hematite, Limonite and montinorillonite which makes these rocks particles to pill off in a physical process called spheroidal weathering.

Spheroidal weathering: This process involves the expansion of the outer shell of the rock when there is water penetration. The penetration of rain water forces the outer shell to pull successively away from the rock and this loosens the rock thus contributing to its decomposition.

d) The physical process of frost shuttering opens up and crashes the rock and when these cracks are occupied by water chemical weathering takes place e.g. carbonation.

e) Roots of plants which expand within bedding planes of rocks and burrowing animals which drill holes in rocks all allow water entry into these rocks which accelerates chemical weathering.

f) Chemical weathering weakens rocks making them easily disintegrate by physical weathering.

LANDFORMS OF WEATHERING.

Weathering like other earth processes produces some features on the earth surface which include;

1. **Grikes;** These are landforms found in chemically weathered limestone rocks. Chemical weathering especially carbonation weathers down the surface of these rocks to produce deep narrow grooves which are called grikes.
2. **Clints; These** are formed together with grikes. As grikes are being dug deep into the rock, some flat or round topped ridges remain separating the two adjacent grikes. These ridges are called clints. These can be seen on western side of Tororo rock, Karasuka region of Karamoja, Tanga region in Tanzania and Kilifi in Kenya.

Diagram

3. **Stalactites.** These are features found on karst landscape (limestone) region. They appear as whitish or grey protrusions found on the roof of a chemically weathered limestone cave. Its formed when rain water combines with carbondioxide gas in the atmosphere to form weak solution of carbon acid.

   The carbon acid dissolves the limestone rock on the cave and the solutions start dripping onto the floor. When water evaporates, dripping stops leaving behind protrusions on top of the cave. These harden to form stalactites. Examples are found at Nyakasura in Uganda and Tanga in Tanzania.

4. **Stalagmites;** These are formed together with stalactites in limestone regions. They are whitish or grey protrusions on the base of a cave in limestone regions. They are formed from accumulation of dripping bicarbonate (dissolved limestone) after the process of solution. When water evaporates from the limestone, it leaves behind a dry and compact mass of limestone which protrudes upwards forming a stalagmite. Examples are seen at Nyakasura.

5. **Pillars;** These are verticle stands of calcium carbonate which form after the accumulation of stalactite and stalagmite accumulate and converge/meet to form a stand pillar. Examples are found at Nyakasura and Tanga.

   Illustration of Stalagmites/pillars/stalactites.

Diagram

6. **Underground caves;** these are natural underground chambers in the limestone rock usually joined to the land surface by a system of interconnecting shaft and galleries (pillars). They are formed due to solution effect and mechanical erosion by underground streams and occasional rock collapse.

   Ground water circulating in the zone below the water table dissolves limestone and forms cavities by attacking joints and bedding planes. As the water table falls, water percolating down through the rock continues the process of enlarging the cavities. Finally, rivers taking underground course may increase the size of the cavities by the stream erosion.

7. **Inselbergs;** These are hills formed by the weathering and eroding away of the surface rock leaving the hard-resistant granitic rocks. They are therefore remnant of older higher peneplains which have been removed except for these island hills that have proved more resistance within the basement complex.
   They cab be seen in Mubende, Kangole in Moroto, Nakasongola in Uganda, seme near Kisumu, Bismark rock near Mwanza-Tanzania and Koma near Nairobi.

   Illustration of an Inselberg.

Diagram

8. **Dry valley;** Rivers flowing from non-limestone regions may finally enter limestone rocks, which are very permeable and may disappear underground only to re appear on the ground again at the end of the limestone rocks. Within the limestone permeable rocks where the river disappears, remains a former valley where river disappeared deep down as a dry valley.

Diagram

9. **Exfoliation domes;** These are smooth and rounded topped hills found in arid and semi-arid regions like chalbt desert in Kenya, near Olduvai Gorge in Tanzania, Moroto and Kotido in Uganda. They are formed to alternate expansion and contraction of rocks under different temperature extremes. During day it's too hot so the rocks expand, during right, its too cold, the rock contracts considerably. The rocks on the outer side start peeling off rock pieces leaving behind a smooth round topped hill called an exfoliation dome.

Diagram

10. **Tors.** These are pillars of rounded weathered boulders rooted in the bed rock. They are formed rooted in the bed rock. They are formed when block disintegration (physical weathering) weathers away jointed rocks like granites thus leaving behind

resistant rock structures rooted in the earth as tors. Examples of tors are Kitmikaye near Seme in Kenya, Kachumbala rock in Kumi, Bismarck rock in Mwanza-Tanzania, Mubende tor etc.

Diagram

11. **Core stones;** These are generally boulders and rocks left behind when weathered material that surrounded the are removed. They often appear isolated when left in a totally different landscape. They are often found near tors and examples can be found at Mwanza, Mubende and Nakasongola.

12. **Dolines;** These are shallow depression or hollows with gently sloping sides generally circular or oval in shape. They originate from water percolating under ground at the intersection of the major joints. The carbonic acid formed by carbonation slowly dissolves the rock to form a small basin which is later enlarged.

13. **Sink holes;** These are oval shaped holes that are formed when chemically decomposed rocks at the surface sink or collapse creating a steep sided depression or basin. Swallow holes may be enlarged into funnel shaped depressions called dolines and these may further be enlarged to give features known as uvalas.

    Through the process of carbonation or solution, limestone is dissolved and removed in solution from leaving behind deep holes which penetrate into the cave. They can also form due to sub-surface collapse.

Diagram

NB: Refer to the laptop for Grike, clints sink holes.

14. **Arenas;** These are large circulation depression on earth's surface. They develop in areas with alternating portions of soft and hard rocks or rocks with different mineralogical composition. For example, rock salt is weathered by solution; Limestone and dolomite are decomposed by carbonation and removed leaving behind a circular depression called an arena. Once filled with water they form ponds examples are found at Ntungamo and Mbarara.

Diagram

A SKETCH MAP OF EAST AFRICA SHOWING THE MAJOR WEATHERING REGIONS.

Diagram

NB: Equatorial regions experiences chemical weathering due to mostly luxunant climatic conditions of high rainfall (up to 2000+mm) and high temperatures of up to 25^0C.

In Tropical regions chemical weathering dominates in rainy seasons as well as physical weathering in dry seasons.

In arid and semi-arid climatic regions due to high temperatures and low rainfall in absence of vegetation cover favour physical weathering as the most dominant type of weathering however occasional showers and high radiational cooling provide moisture to rocks in deserts which make them undergo chemical weathering.

In montane climatic regions especially at higher altitudes where temperature falls below 0^0C and characterized by ice sheets frost shuttering is most common and pressure release due to steep slopes thus physical weathering is common in higher altitudes. Whereas in lower slopes, organic weathering occurs due to presence of forests.

IMPORTANCES OF WEATHERING.

- Landforms such as Granitic tors, stalactites, Stalagmites and caves at Mwanza and Nyakasura in Tanzania and Uganda respectively are tourists' attractions which generate a lot of foreign exchange.
- Weathering is the first process of soil formation. It produces different types of soils such as laterites which are used in civil engineering, clay or kaoline is also formed when feldspar reacts with water under the hydrolysis process. Such clay is used for house construction, domestic ware like cups, pots etc. at Kajjansi in Uganda.
- Weathering helps to expose minerals. Block disintegration and Granular disintegration along the Kimberly rocks in Mwadui-Shinyanga province in Tanzania exposed the existence of Diamonds in the volcanic plug. Similarly, the Tororo rock was exposed in a similar process and today is used in the processing of cement.

However, weathering has negative importance's as well. These are, frost shattering on steep slopes like mt Rwenzori and Kilimanjaro is followed by land slides which cause great damage down slope. The disintegrated rock pieces slide off and may freely fall down destroying crops and animals.

Infertile and moderate fertile soils which don't support agriculture have been formed by weathering. Such soils include laterites in Buganda and clays in Iganga and Bugiri along Naigombwa and Mpologoma wetlands which are usually acidic.

Weathering has left behind a ragged landscape in limestone regions composed of clints, Grikes and arenas. These limit agricultural practices as well as settlement in Tororo, Tanga and Nyakasura.

Weathering on steep slopes encourages soil erosion thus affecting land productivity in kigezi highlands and the slopes on mt Kilimanjaro in Tanzania.

Revision Questions.

1.Examine the weathering processes that take place in either the desert or the humid areas of East Africa.

2.Using diagrams, illustrations and examples from East Africa, write short notes on any five of the following processes

- Exfoliation
- Hydration
- Laterization
- Frost thawing
- Block disintegration
- Carbonation.

3a) Discuss the processes of chemical weathering

b) Giving specific examples, explain the effects of chemical weathering on the economic geography of either Uganda or Kenya.

4.To what extent does the rate and character of weathering depend on the nature of the rock.

5.Describe the landforms resulting from weathering in East Africa.

6a) Distinguish between physical and chemical weathering

b) Examine the effects of weathering processes on landform formation in East Africa

c)Assess the importance of weathering in East Africa

7a) What is chemical weathering?

b) Describe the landforms resulting from chemical weathering

8Account for the landforms produced by carbonation process in East Africa.

9Examine the influence of rock weathering on landform development in East Africa.

MASS WASTING.

This is another denudational process in which rocks on a slope are swept downhill under the influence of gravity. It is a large-scale (massive) movement in which the stability of the slope has failed. It is alternatively called slope failure.

Mass wasting is a general terminology, which includes all forms of movement on a slope ranging from the slowest to the fastest. It is a mountain/hilly-based process which mountains/hills are characterized by high rainfall. Water is very important because it is the one which acts as a lubricating agent for failure to occur.

Mass wasting therefore refers to the movement (sliding, falling, creeping or flowing) of rock materials produced by the agents of denudation, i.e. weathering and erosion, under the influence of gravity.

It is different from erosion in a sense that whereas in erosion, water physically transports away the soil particles, in mass wasting, water does not wash way but assists the rock to slide under gravity.

TYPES OF MASS WASTING.

Mass wasting can be categorized under three types.

1.Slow flowage (creep processes)

2.Rapid flowage processes

3.Slide processes

1.SLOW FLOWAGE:

Mass wasting processes, which move slowly are called creep movements. The are very slow in their motion and they may occur without being noticed unless a very keen observation of certain features is made. They can be categorized under.

a) Soil creep;

b) Talus creep

c) Rock glacier creep

d) Rock creep

e) Solifluction

a) **Soil creep;** This is the most common and mostly widely spread because it is found in both tropical and temperate climates. It occurs on slopes, which are less than 5^0 with masses of unconsolidated weathered materials. The movement is so slow that it may move a few centimeters per day. Soil creep can be detected by learing of trees, electric poles and fencing poles in the direction of the slope.

Soil and fine materials move slowly down slope. Trees and poles bend down slope. E.g. at Kololo hill, Nakasongola, Akia hills and Ngeta in Uganda. Terracettes can be seen on hills in Masaka, Kabale and Bushenyi hills.

Diagram

b) **Talus creep;** This is a down slope movement of mainly screes that are relatively dry. It moves almost in the same way as soil creep and it also occurs under tropical and temperature climates. It involves movement of weathered materials as a mass over moderate slopes where freeze-thaw is frequent. freeze thaw weathering process tears out rock particles from the surface. Such rocks move down slope under the influence of gravity and the thawing water/ice provides a lubricant.

Diagram

c) **Rock Glacier creep;** This involves movement of rock debris slowly down slope. Such rocks may move under soil creep. It is a slow process of slope failure in which individual rock boulders with very little soil but with some ice embedded within them slowly move downslope confined within a channel Examples of such can be traced at Kapchorwa and Sironko in Eastern Uganda.

d) **Rock creep;** This is limited to glaciated mountainous regions and cold climatic areas where thawing causes the saturated surface layer to creep as amass over underlying frozen ground. The subsoil is permanently frozen such that when the surface thaws, it can easily move down along a hard subsoil layer. It occurs in Kilimanjaro, Kenya and Rwenzori mountains.

Diagram

2.RAPID FLOWAGE PROCESSES:

Under this, we have;

a) Earth flows

b) Mud flows

c) Debris avalanches.

a) **Earth flows:** These are rapid down movements of clayish or sility soils (materials) along a slope that is steep. They usually occur after a heavy down pour where the rain water thoroughly lubricates the clayish materials making it easy to flow down along the rock beneath when friction is thoroughly reduced. A sudden movement will occur and the weathered lubricated materials flow rapidly down blocking roads and destroying other property e.g. along Gayaza road, Rippon falls cliff, Kisoro and Bunyaruguru hills, in Kisoro (Katuna road), Kenya high lands on mt Kenya and near river Mbako in Tanzania.

b) **Mud flows;** These flows are not very different from earth flows but the fact that they are muddy indicates that they occur on slopes that are more precipitous (receive more rain). They move very fast e.g. a mud flow in Columbia which occurred in 1956 when mt. Navado de Ruiz erupted and forced the ice cap to melt and soak the slopes triggering mudflows as fast as 80km/hr that buried Amero town its 20,000 people. Mudflows occur on mt Sabinyo, mt Rungwe, mt Meru and longonot in East Africa.

Diagram

c) **Debris avalanches;** This is the most rapid of the rapid flowage processes. It occurs on very steep slopes that occur in humid climates where slopes are of up to 40^0 in angle. The fact that slopes are very steep and there is enough rain to soak slopes make debris avalanches run faster than other rapid flowage processes.

3.SLIDE PROCESSES:

They are collectively called landslides; they are very fast and may often involve dry materials. They occur on slopes that are very steep more than 40^0 in slope. These slide processes fail under 4 types

- Slumping
- Debris slide
- Rock slide
- Rock fall

a) **Slumping;** This is the most common of all slide processes. In this form of sliding, a rock does not break up into different particles in the process of failure but materials just slide as a whole mass (block). It moves in a backward rotation such that the slumped strata which was originally horizontal is tilted backwards.

Slumping occurs when the base of overstepped cliff is laterally undercut by erosion such that upper slopes are left overhanging up. With time, these overhanging rocks will slide down wards hence falling e.g. on shores of Lake Magadi and Bunyaruguru (on the road side before lake Nkugute).

Diagram

b) **Debris slides;** This occurs in the same way as slumping except that under debris slide, only unconsolidated earth particles (debris) slide. Hence it is the rolling of unconsolidated earth debris from a vertical or overhanging face.

c) **Rock slide;** This is the type of sliding in which individual rock masses fall from vertical cliffs or faces of slopes or jointed cliffs;

Diagram

d) **Rock fall;** Here instead of rock masses sliding, individual boulders fall freely from a steep face e.g. in hills of Kaberamaido.

Diagram

CAUSES OF MASS WASTING:

Mass wasting is caused by an interplay of several factors. The factors include the nature of the geological structure and the influence of human activities. These factors are explained below.

1.The degree of slope; Mass wasting is caused by gravitational pull of the slope downwards. Therefore, the steeper the slope, the higher are chances of failure. Mass wasting is almost rill in gentle and flat areas.

2.The structure and Lithology of rocks. Alternating hard and soft rock layers on a slope can be a cause of slope failure e.g. a layer of clay on top of limestone layer can easily slide down.

If an impermeable rock underlies a permeable one, it is very probable that the permeable rock on top will get properly soaked and will slide off. The rocks with cracks and joints will easily absorb water, become heavy and lubricated and therefore can fall easily.

3.High intensity rainfall; In mountainous areas for example Kigezi and Tororo, heavy rainfall is sometimes received. The 'pounding' effect of the heavy rainfall shakes the ground and triggers off movement of rocks. Furthermore, rain water seeps into the ground and increases the overall weight of the weathered debris. This increases the potential for lighter ones under the force of gravity.

Rain water also acts as a lubricant and, therefore weakens friction between rock particles and the ground surface, thus, promoting chances of movement. In these ways, heavy rainfall in highland areas greatly enhances landslide occurrences.

4.Temperature changes; Temperature changes affect mass wasting by influencing freeze-thaw process in cold environments. When temperature rises, ice melts and water is added onto the rock particles in the active layer in peri-glacial environments. This increases the weight of weathered debris and enhances slippery conditions. Any external disturbance will get the debris rolling down slope under the influence of gravity. Furthermore, when trapped water below the surface of the earth freezes during a cold winter or night period, its volume inevitably increases, resulting in the exertion of pressure on the overlaying rocks a process known as congeliturbation. As this process goes on, the surface of the earth is raised to form low hills. These are known as pingos in per-glacial areas. As the ground raises, the weathered debris is forced to roll downwards under the influence of gravity.

5.Earthquakes; Earth quakes are significant causes of mass wasting in areas that experience crustal instability, such as some parts of Tororo, in the western rift valley, in Uganda. Once an earth quake occurs, the ground is shaken and ground vibrations are caused. This causes the disturbance sets the particles in motion. The particles move downslope at a rate which partly depends on the gradient.

6.Vibrations of moving objects; Moving objects such as lorries, buses and trains exert tremendous force on the ground. The ground tends to vibrate and this disturbs unconsolidated material resting loosely on the surface. such material can start rolling down slope. Vibrations from passing animals have same effect. Large herds of cattle on hill sides have this effect as they move down to watering points.

7.Reduction of vegetation cover on steep slopes; The roots of trees and other vegetation types bind the rock particles together. Therefore, when the vegetation coverage is reduced, the binding force reduces. The particles, therefore, become looser and more unconsolidated. Furthermore, trees and other shorter types of plants retard the rate of downslope movement of particles. Therefore, when they are cut down and removed, the rate tends to increase. This enhances the chances of landslide occurrence. Cultivation on steep slopes involves the removal of rocks. Once it rains, soaked rock debris slide down slope with hardly any resistance on the surface. deforestation is therefore a human activity that is likely to lead to occurrence of landslides in highland areas.

8.Cultivation along rather than across a steep hill side; Practices such as 'up and down' ploughing on hill slopes also increase the likehood of mass wasting. They lead to the formation of rills and even gullies which develop vertically on the slopes. This increases the possibility of occurrence of such processes like rock slide and slumping.

9.Inappropreate farming practices; Practices which include over cropping, monoculture and over grazing indirectly contribute to the occurrence of mass wasting in the long run. Over cropping or the continual raising of the crops on a fixed piece of land for along time is little or no rest at all leads to soil exhaustion. Monoculture or the persistent growing of a single type of crop on a piece of land also leads to soil exhaustion. Similarly, over grazing, the practice in which herbivious animals graze on a specific pasture land for a considerable time without that land being given any rest leads to the emergence of bare land. In all these aspects, the exhausted loose soil loses cohesion and probability of being dislocated downslope increases, particularly when an external agent acts on the slopes.

10.Over steepening; Loose, undisturbed rock particles assume a stable slope called the angle of Repose: This values from $25\text{-}40^0$. If the angle is increased, the rock particles will adjust by moving down slope. This can come about through:

a) Mining and quarrying. Open cast mining may result in over-steeped and unstable slopes that become prime site for mass wasting. During mining or quarrying, explosives are sometimes used to blast and break up rocks. The impact of these explosives shakes the ground, thus, triggering off movements of weathered particles resting loosely on the ground. Furthermore, mining weakens rocks and makes them prone to landslides. In addition, quarrying on hill sides created short steep slopes, that is, embarkments which enhance the chances on landslides occurrence.

b) Highway and railway construction; Construction of transport routes in hilly areas may involve road cuttings that create over-steepened road sides. This may cause rock fall and rock slide.

c) Levelling for building construction on a steep slope; The cut made in the slope causes a steep slope to develop.

d) Natural process of exogenic agents; Such as a stream undercutting a valley wall or waves pounding against the base of a cliff are other factors.

EFFECTS OF MASS WASTING.

- **Loss of life;** Mass wasting often causes loss of life. The severe landslides especially those associated with earth quakes and heavy rain fall result in rock falls in rock slides that destroy settlements and kill people living on lower slopes. Several people have been killed in Bundibugyo district, western Uganda as well as in Manjiya county, Mbale district in Eastern Uganda.
- **Destruction of property;** Mass wasting also causes destruction of property. The falling and sliding rocks of various sizes destroy settlements and the household property that may be there in contained. The 1966 earth quake in western Uganda, forexample, caused landslides that destroyed several houses on the lower slopes on mount Rwenzori.
- **Disruption of transport services;** Soil and large rocks resulting from mass movements sometimes block roads in highland areas. These materials roll down steep slopes before finally accumulating on roads which may be lying on the lower slopes of the highlands or in the valley. Such roads may then be rendered temporarily inaccessible. Blockage of roads sometimes occurs along kabale-kisoro road where huge boulders and soil may be found lying after heavy rainfall. it is also common in Bundibugyo District.
- **Destruction of crops and damage of agricultural land;** Agricultural land and crops are often destroyed in areas prone to landslides. On steep slopes, soil may be removed and crops may be washed downslope while on gentle or flat slopes in valleys, the crops may be buried by the debris from upper slopes. This reduces the productivity of the land.
- **Damming of valleys;** Mass wasting may cause the damming of valleys and cause temporary formation of lakes. This is what is reported to have happened in the Tukuyu area of southern Tanzania in 1955. In that year, there were heavy rains in this area which caused great landslides consisting mainly of waterlogged volcanic ash that slumped down over the impervious lava. Buckle (1979) observes that one of the landslides was so large (300,000 cubic meters) that it temporarily blocked river Mbaka for 8hours.
- **Deposition of soils on low lying slopes;** Dependable soil may, inadvertently, form at the base of a steep mountain. The soil particles removed from the upper slopes in processes like soil creep and solifluction ultimately get deposited at lower levels where they can be used for cultivation.
- **Tour and travel;** The effects of landslides can be a source of curiosity and concern. Curious and interested people may wish to view the massive rocks that

may have fallen or slid from the upper slopes of highlands. Similarly, the scars left on the hill sides as rocks break and roll away may constitute interesting sites. Terracettes left behind can similarly be a tourist attraction for local and foreign interested persons.

MEASURES FOR CONTROLLING MASS WASTING.

Landslides, being a natural phenomenon, occur naturally. However, the rate is often increased by human influences. While it is not possible to stop their occurrence, it is practical to reduce the frequency and magnitude of their occurrence through a number of interventions as stated below.

a) **Environmental awareness campaigns;** Increasing awareness on mass wasting issue is one of the measures which can be taken to control landslides. Positive change of people's attitudes is one of the most effective measures that bring about progress. In those instances where vegetation is destroyed because of ignorance, teaching the people concerned about the value of vegetation in controlling landslides could be a good step in the right direction.

b) **Quality engineering practices;** These include building retaining walls with drain pipes. Proper engineering is essential when the natural environment of a hill side is altered by construction. The retaining wall allows water to drain away rather than collect in the soil behind the wall.

A. Water trapped in the soil
causes movement;
pushing down retaining walls.

Diagram

Measures may also include removing rock that may slide. This will reduce the degree of Steepness and thus reduce the probability of rock falls on highways.

B: Water drains through
a pipe, allowing the wall
to stop the slope from moving.

Diagram

c) **Contour ploughing;** This is ploughing along lines of equal elevation rather than down slope on steep mountain sides. Each ridge and grove tend to retard downslope movement of rock particles.

Diagram

d) **Scaling down of work on unstable slopes;** Developers may be advised to settle for fewer buildings than planned. This is because too many structures will make the slope unsafe. Furthermore, fallowing may be recommended to reduce over cropping.

e) **Reforestation;** Increasing population and conservation levels have led to increased use of resources; including encroachment on forest resources. Almost all countries have lost a sizeable amount of their former naturally occurring trees. On those slopes where trees have been cut, tree planting should be encouraged to replace those that have been removed so that the soil bound together once more. Plants help to anchor the slope with aid of their roots.

f) **Afforestation;** Efforts can be made to increase forest coverage through tree planting. Policy makers working with communities can encourage the planting of trees on particular slopes frequently affected by landslides or where the risk of landslides occurrence is high. This would most likely check the rate of downslope movement of materials.

g) **Sound rangeland Management:** Controlled grazing and paddocking are particles which should be adopted in areas where overstocking and overgrazing have led to serious erosion.

This leads to better land management in which the degeneration and regeneration of vegetation and soils can be more effectively monitored. Therefore, the man-induced practices of overstocking should be discouraged or stopped and instead get replaced with controlled grazing.

h) **In-filling of quarry and mine depressions;** The extraction of aggregates, such as sand and hard-core stones often leave gaping, steep-sided depressions on the surface. this increases the like hood of mass wasting. To overcome this problem, mining or quarrying ought to be returned into the hollows so that the depressions are covered and the ground leveled.

i) **Enactment and enforcement of environmental laws;** Existing laws governing land use on fragile lands need to be enforced to protect such lands. In the event that laws are either absent or weak, it becomes necessary to put in place relevant laws that help in the protection of slopes from adverse human activities. Furthermore, zoning laws that prohibit construction in hazardous areas need to be considered.

GUIDING QUESTIONS (landforms of mass wasting)

1a) Account for the occurrence and effects of mass wasting in East Africa.

b) Describe the steps being taken to control mass wasting in East Africa.

2.Account for the occurrence of landslides in East Africa.

3.Account for the occurrence of landslides in any one highland area in East Africa.

4.To what extent is man responsible for the occurrence of mass wasting in East Africa.

5.To what extent does nature of relief influence mass wasting in East Africa?

6. Distinguish between an avalanche and landslides

b) Account for the occurrence and consequences of avalanches.

TYPES AND FORMATION OF LAKES.

A lake can be defined as a body of water occupying a hollow, that is, depression on the surface of the earth. Lakes from when water collects and accumulates in such depressions. In any effort of classifying information, the starting point is to determine the criterion of classification. Origin of lake basin is a popular basis often used to classify Lakes. Using this criterion, the following categories of lakes are classified.

Tectonic causes of Lake formation.

Faulting; Faulting has formed several Lakes such as rift valley/Graben Lakes and Tilt block Lakes. Rift valley Lakes formed secondary faulting takes place on the rift valley floor thus creating minor depressions. When these depressions are filled with water from rainfall, rivers and springs, Lakes are formed. This is how the numerous rift valley Lakes in East Africa were formed. These lakes include; Edward, George and Albert, in Uganda; Rukwa Tanganyika, Malawi, Eyasi, Manyara in Tanzania, Naivasha, Elementaita, Baringo and Hannington in Kenya. Formation of Grabens by compression forces:

Diagram

Diagram

Diagram

Tilted block Lakes e.g. on the tilted blocks in Kenya i.e. the western corner of the Aberdare mountains e.g. L. Olbolossat form when rain water collects along the tilted angle of tilted blocks on top. Such tilt blocks form when the uplifted blocks after faulting are followed by tilting.

Diagram

Warping; Warping, which is the large-scale deformation of the surface of the earth, has led to formation of Lakes. The formation of Lakes Victoria and Kyoga involved a combination of down warping and drainage reversed. The effects of tectonic movements in western Uganda reversed rivers formerly flowing west wards. River Kafu was reversed by uplifting of the eastern shoulders of the west rift valley and its water flowed back thus filling the valleys of its tributaries (back pounding) to form Lake Kyoga. This explains the numerous fingers like projections which are in fact the flooded parts of the former river valleys.

Lake Victoria was formed in the same way, with rivers Katonga and Kagera getting reversed and filling up the down warped basin. Other lakes formed by back-ponding are Kijanebalola, Kachira, Nakivale and Mburo. The reversal of rivers, Lake Rwizi resulted into back-ponding and formation of these Lakes.

Diagram

Vulcanicity; When magma flows, numerous landforms are produced after its cooling down. Among these are Lakes. Lakes formed under vulcanicity, include;

i)crater/caldera Lakes; When a volcano is formed, a depression is often left on the top. This is due to violent eruption, which blows off the top of a volcano leaving behind a depression called a crater. When it is filled by water, it forms a crater lake. E.g. on Mt Longonot, Muhavura.

Cauldron subsidence may cause the whole top of a newly formed volcano to sink, producing an extensive crater called a **caldera**, which after being filled with water forms a caldera Lake e.g. Ngorongoro and Embagai Lakes.

Diagram

ii)Explosion crater Lakes; Over a hundred Lakes of this kind were formed in the western rift valley. They appear as circular depressions usually small by size rarely exceeding 2 miles by diameter. They form when violent eruption blew the top of the earth surface leaving behind a circular depression. Fragments from the broken surface, pyroclasts and ash fall back surrounding the hole/depression to form a low rim of deposits. Water from the rain fills the depression to form an explosion crater. Examples are L. Katwe, Nyamunuka, Munyanyange, Rutooto.

Diagram

iii)Lava dammed Lake; When lava flows from a volcano that neighbours a river, the magma may flow down the foothills and finally blocks a river and therefore dams it. The damming will make the water levels to rise behind the lava and to extend backwards in the direction of a river flow. This finally will produce a Lake. Such Lakes include; L. Muhehe, Mutanda, Bunyonyi, Chahafi and Kayumbu in Kisoro/Kigezi, Bunyaruguru in South western Uganda.

Diagram

Non-Tectonic cause of Lake formation.

Erosion; Erosion by water, ice and wind may create a good number of Lakes which include;

a) Glacially eroded Lakes;

i)Cirque or tan Lakes; These Lakes are formed on the mountain side when flowing ice tends to erode the mountain sides by plucking and freeze thaw action circular depressions called **cirques**. When ice melts, water collects in these depressions to form cirque Lakes. Examples of cirque Lakes include; Lac du Speke, Lac Catherine, Lac Vart and Lac Noir o mount Rwenzori. As well as Teleki tan, Hangington tan and Gallery tan on mt Kenya.

Diagram

ii)Ribbon or trough Lakes; These are Lakes that occupy elongated hollows excavated by the ice on the floor of a u-shaped valley due to glacial plucking, abrasion and freeze thaw processes. Examples include Lake Michealson in the Georges valley on Mount Kenya.

Diagram

b) Wind eroded Lakes; Wind as it moves can erode off some rocks especially in and areas until a depression is excavated deep below the water table by eddy wind currents, which scoop out loose sand and drain it away depositing it as dunes. When this happens, a Lake will in the long run be formed. These are often found in arid areas and semi-arid regions. Such Lakes are always muddy swamps. If an acquifer is exposed and **oasis** is formed. For example, the Qattara depression in Egypt.

Diagram

Deposition;

i)Ox-bow Lakes; In the old stage of a river, meandering across a flood plain often produces cut offs which become side stepped by the river and hence abandoned as oxbow lakes. Oxbow lakes were originally meanders, which are finally cut off as a result of erosion on the concave banks and deposition on the convex banks. Such lakes are found on rivers Tana, Athi, Ngaila, Ntando, Rwizi, Malaba and Ruvu.

Diagram

ii) Lagoons; Wave deposition leads to the development of sand bars and spits which may finally engulf and cut off parts of the former seas that fringes the coast. The separated waters from a Lagoon lake. For example, L. Nabugabo along the shores of L. Victoria and Ikimba in North West Tanzania was also cut off from L. Victoria, Tonya point Lagoon on Lake Albert that is about 1km square. These are also called **Haffs** Lakes.

Diagram

iii)Delta Lakes; Deposition of sediment on a river mouth during the formation of a delta may result into sediment colonizing off part of the sea and therefore separating it from the main sea. Consequently, the separate part becomes a Lake. An example can be traced on R. Rufigi with Lake Mchengu.

Diagram

iv)Moraine Dammed Lakes; These are formed when terminal moraine is deposited across a river valley and dams the waters of the valley. The water first fills the valley to form a Lake before overflowing to continue with its movement. On Mount Kenya, Tyndal tarn at the head of Teleki valley is a moraine dammed Lake. Others include Lake Horhnel on Mount Kenya and L. Alice.

Diagram

v)Kettle Lake; These are formed when part of ice is separated from the main ice and is later covered by deposits. When this block of ice finally melts away, it will leave behind a depression which is filled by water to form a kettle Lake. An example is Lake Machoma on mount Rwenzori and Lake Ellies on mt Kenya.

vi)Lakes due to deposition of glacial drift; These are formed in lowland glaciated highlands which are characterized by drumlin landscape. In drumlin lowlands where drainage is poor, there are depressions intermittently produced by drift deposition. These depressions are waterlogged forming small lakes.

Human Activities:
Man made lakes in East Africa have come into existence through man's activities e.g. man has dammed rivers which has resulted into the rising of the water level up stream to produce a lake e.g. the damming of river Pangani in Tanzania to create water for irrigation created a Lake. Man has also dug valley dams to store water for irrigation, watering their animal, for fishing purposes and culture purposes. Such lakes include Lake Kibimba, Lake Kiyanja near Lake view Hotel in Mbarara and Kabaka's Lake in Kampala. The depressions left behind in abandoned mining sites have been filled by water to become small lakes e.g. some Lakes (ponds) in Kajansi valley. Lake Nasser in Egypt, on Aswan high dam, Akasombo dam created Lake volta in Ghana.

Solution Lakes; Some rocks are easily dissolved by rain water percolating through them and therefore transported way in solution. Such rocks include chalk and limestone whose dissolution creates underground caverns which are buried under the surface. with time the roof of these carverns will collapse and these lakes will be exposed to the surface. such Lakes are usually Long and narrow e.g. some small Lakes in Nyakasura around Kalyango hills in Uganda. These are also called **Karst Lakes.**

Flood plain Lakes; These are lakes that result from deposition along the course of the river valley. They are shallow and vary greatly in size. They are formed when levees prevent the flood waters from returning to the river thus making the waters to accumulate into a lake. Examples can be seen west of Dar-es-salaam in the lower valley of river sinza and river Luhanga for instance Lake Magomenu and Lake Mwananyamara.

Mass wasting; Lakes formed by the damming of river valleys due to mass wasting and landslides. In Tanzania a Lake was formed in Mbaka valley in 1955 when landslides blocked the course river Mutale in the south to form Lake Funduzi which was $1^{1/}{}_{4}$km long. In south west Uganda, Lake Nyabihoko was formed by deposition of alluvial fans. It is located between Lake George and Lake Victoria.

Extra-terrestrial causation; Such lakes are the result of effects of meteorites. A meteorite is a meteor that strikes the surface of the earth. A meteor itself is a rock fragment from space that passes through the earth's atmosphere, heated to incandescence by friction. This is sometimes referred to, through incorrectly, as a 'shooting' or 'falling' star. Meteors travel at tremendous speed but, fortunately, most burn out before reaching the surface of the earth. However, if a meteorite reaches the surface of the earth, it strikes it with such tremendous force that a deep crater is generated. Such a crater can be occupied by water to forma Lake. The Lake is contained in a crater, approximately 10km in diameter.

ECONOMIC SIGNIFICANCE OF LAKES:

Positive aspects of Lakes:

ELEMENTS OF PHYSICAL GEOGRAPHY

1.water supply; Lakes provide water for domestic and industrial use. For example, water is pumped from Lake Victoria, at Ggaba, to several factories and thousands of homes in Kampala city.

Lakes provide water for irrigation purposes for example Lake Kyoga supports the Olweny scheme, L. Kibimba on River Kitumbezi supports Kibimba rice scheme, L. Kanyaboli in western Kenya supported rice plantations.

2.Fishing. Lakes are sources of fish and, therefore, contribute to the protein content in people's diet. Small and large-scale fishing is carried out on major East African Lakes. Some fish processing factories have been established to develop the fish potential in the region. Tilapia and Nile perch are the major fish caught in Lakes Victoria, Kyoga and Tanganyika.

3.Transport; Water offers the cheapest mode of transport. Canoes, boats and bigger vessels are often used for navigation on Lakes in Uganda and indeed in East Africa as a whole. Uganda railways corporation, for example, operates marine vessels between Jinja and Port Bell, with Mwanza and Kisumu as the destination in Tanzania and Kenya respectively.

4.Mining; Some Lakes contain minerals and therefore, promote the mining industry. For example, salt is mined from Lake Katwe while soda ash is extracted from Lake Magadi. Soda ash is used to make soap, glass and salt. Sand is obtained from the sand beaches such as Kasenyi and Lutembe along the shores of Lake Victoria and is used in the construction industry. Its also potential raw material for the glass industry.

5.Hand crafts; Lakes have promoted the development of art and craft industry in the country. Lake Kyoga for example has dense cover of swamp vegetation like papyrus and reeds that are used to make mats, baskets, huts and other products for sale.

6.Lakes have modified the climate of Uganda/East Africa and this has promoted settlement. They tend to recharge the atmosphere with water vapour through evaporation process-thus promoting the formation of convectional rainfall and regulating the temperature condition. Therefore, areas with wide water bodies like Victoria basin and Lake Kyoga receive heavy rainfall and have moderate temperatures which have promoted dense settlement in the region.

7.Lakes have promoted agricultural development in East Africa. For example, Lake Victoria and Kyoga basin are associated with fertile alluvial soils which favour the growing o banana and coffee. Besides, Lake Victoria provides farming Like Kakira and Lugazi sugar estates as well as Kibimba rice scheme.

8.Lakes have promoted tourism development that brings in foreign exchange to the country, Lake Mburo and Lake Edward harbor crocodiles, bushbucks, hippopotamus, snakes among other animals that has made the government to gazette them as national parks for example queen Elizabeth national park on Kazinga channel and Lake Mburo national park in Mbarara district. Lake Nakuru in Kenya has a sanctuary of flamingos.

9.Lakes have promoted energy sector for example the papyrus plants on Lake shores have high potential for the development of energy resources because it is believed to contain Methane gas. This can be harnessed to produce bio-gas which is a much-needed energy resources for domestic and even for industrial purposes.

10.Lakes are water reservoirs which regulate the flow of rivers. Rivers passing through such lakes are assured of constant supply of water and can be dammed to provide hydroelectric power. Lake Victoria, for instance, acts as a reservoir to the Nile river which has been dammed at Jinja. In addition, Lakes are also reservoirs for irrigation water.

11.Lakes are important damping zones e.g. sewage from Kampala is directly to Lake Victoria swamps and industrial wastes are always damped there.

12.Help to control floods.

13.Promote forestry like Ssesse island forests.

14.Promote culture for example Kabaka's Lake.

15.Promote research for example Entebbe Fisheries Research institute on Lake Victoria.

16.Act as international boundary for example Lake Victoria and Lake Albert.

Negative aspects of Lakes;

1.Lakes harbor disease vectors such as water snails transmitting bilharzia, tsetse flies that cause sleeping sickness and Nagana to animals as well as mosquitoes that cause malaria. This has led to high death rates in the region especially southern Bukedi and Busoga region around Lake Victoria.

2.Lakes are associated with floods during wet seasons that displace homesteads and destroy people's property. Fore example the 1997-1998 Errino rains made Lake Victoria and Kyoga to over flood that displaced thousands of villages.

3.Lake occupy too much space which would have been used for other economic activities like Agriculture and settlement. For example, Lake Victoria occupies 18800square kilometers that could have been used for other activities.

4.Lakes have promoted interstate conflicts due to territorial claims. For example, Uganda and Kenya are always conflicting over the ownership of Migingo island in Lake Victoria. In the year 2007, army officers from Democratic Republic of Congo attacked and killed Ugandan Oil experts in Lake Albert region claiming that the oil reach island in the Lake was part of the territory.

5.Lakes have promoted high levels of profit repatriation by the various foreign investors in the fisheries sector.

6.Lakes have promoted insecurity due to the high levels of piracy especially at the shores of Lake Victoria and Lake Albert.

7.Hinderance to road development

8.Low-lying areas around Lakes are very susceptible to flooding e.g. 1960-1961 around Lake Victoria.

A SKETCH MAP OF EAST AFRICA SHOWING THE MAJOR LAKES:

Guiding Questions.

- To what extent has tectonism been responsible for the formation of Lakes in East Africa
- Assess the relative importance of Lakes to the economies of East Africa
- To what extent are the processes of erosion and deposition responsible for the formation of Lakes in East Africa?
- To what extent has the vulcanicity been responsible for the formation of Lakes in East Africa.

COASTAL GEOMORPHOLOGY:

One of the most unstable and everchanging features of any regional map is the coastline. The edge of the seas is in a state of modification, however stable the hinterland may be sea cliffs erode, deltas build up, sand bars and beaches shift. Around the world's coasts, conditions have not net stabilized after the changes in the sea level that accompanied the last ice Age.

The term **coast** refers to the zone of contact and interaction between land and sea either presently or in the past periods. The coast is another area of concern to a geomorphologist since a good number of Landforms are produced there.

In numerous areas, the land (valleys) and turn coastal hills into islands. In other areas the land is rising because of reduced pressure from the melted ice which melted thousands of years ago. Former beaches and cliffs are now found inland above sea level. It may still take thousands of years more for the coast to become fixed and stable.

The type of coastline and the landforms produced there will depend on weather the coast is submerging or emerging and whether the sea is eroding the land or building it up by deposition coastal landforms are a result of three process. Namely;

i)Wave Action
ii)Sea Level Changes
iii)Coral reefs.

WAVE ACTION ON THE COAST.

Waves are the most potential agents of erosion and deposition on the coastline. Wave are the **undulations** usually seen on water bodies whenever the water is disturbed. These waves transport energy from the point of disturbance to the coast. Waves when seen seem to be moving forward but they actually don't move. What moves is the shapes of ripples. The oscillations are only observed which reflect the magnitude of disturbance. Objects on water are seen just moving up and down without making any significant forward or backward motions.

HOW WAVES ARE GENERATED?

Waves on the water bodies can be generated into two broad ways:

i)By Wind

ii)By catastrophic objects.

1.Wind generated waves; Whenever winds move on top of a water body, some resistance is created at the point of contact between the wind and water. The resistance creates a fractional drag that heaps the water and hence forcing it to move forward in the direction of the wind.

Alternatively, the winds that are in direct contact with the water are exposed to frictional resistance, which therefore reduces their speed when actually the speed of the wind above the water is not affected. This will steepen the winds on top forcing it to dive into water surface. this will create circular motions or eddy motions in the water that will exert a lot of pressure in the water. This will result into the displacement of surface water that will automatically generate waves.

Wind generated Waves.

Diagram

2.Catastrophic generated waves; Earth quakes, landslides, cyclones, submarine volcanic eruptions and other moving objects e.g. ships generated waves. Such waves are usually rare but very strong and destructive e.g. in 1998, an earth quake generated waves that pushed the water on the mainland Papua New Guinea which covered about 6miles inland and killed many people.

The structure of a wave.

Diagram

i)Wave crest: This is the highest point of a wave.
ii)Wave trough: This is the lowest point of a wave.
iii)Wave height: This is the distance between a crest and trough (usually between 5-6 meters)
iv)Wave length: This is the distance from one wave crest/trough to another.
v)Wave amplitude: This is half height of a wave.
vi)Wave velocity: This is the speed of movement of a wave crest in a given period of time or a distance covered by a particular wave crest in a given time.
vii)Wave frequency: Is the number of wave crests that pass a particular observation point per minute.

Breaking of wave:

Before waves break, there will never be any impact they will create on the coastline. When they break however, the energy that carry is released which pushes water forward towards the cliff to create erosion or deposition.

Water in waves moves in circular orbits.it rises up to the apex of a wave crest and down to the wave trough and the system continues comfortably. When the depth reduces however, these waves come into contact with the bottom of the sea. This contact automatically generates friction which vetards the velocity of waves at the bottom. The velocity of water particles at the crest remains normal and this frictional interference at the base will steepen the crest as it moves ahead and, in the process, it will be thrown forward hence breaking the waves.

These breaking pushes the water to the cliff and this pushes water is called a **swash** or a **send.** The water that comes back after a swash is called a **backwash**. Waves which do more of erosion than deposition are called **destructive waves** while waves that do more of depositions than erosions are called **constructive** waves. Constructive waves are usually gentle while destructive waves are usually steep.

WAVE EROSION:

Waves do not work the same way rivers do. They erode the coast when they break and push the water to the shore. Waves, which are steeper, are more erosive and the reverse is true. Waves like rivers erode in four ways:

1.Solution; Also called **corrosion** is common on coasts composed of soluble rocks e.g. Limestone and rock salt. The solvent action of water dissolves these rocks and are transported and eroded away in solution.

2.Corrasion; Also called **abrasion** is a type of wave erosion in which the load already weathered down and hence being transported drag itself on the bed of the coast and hence wears away some rock particles. This is the most effective method of wave erosion especially on beaches that are attacked by storn waves,

3.Attrition; This is a process of wave erosion which involves the reduction in size (erosion) of eroded particles by themselves. As these particles are being transported, they usually knock one another and hence reduce one another in size. Particles erode themselves.

4.Hydraulic action; This is the direct action of breaking waves that push water on a cliff. Breaking waves especially those which are steep generate a force equivalent to 30tones per square meter. As this water is punched on a face of a cliff, it will be compressed causing a lot of pressure within the joints. As water retreats during a back was, pressure is suddenly released and this generates shock waves that weaken rock particles and make them easily eroded by a backwash.

Factor affecting Wave erosion:

1.The power of waves; This is by far the most important factors that determines wave erosion. Energy from wind is transformed into waves which after breaking push water on a cliff and erodes the particles there. Therefore, the stronger the waves, the more erosive they are and the weaker the waves, the lesser erosive they will be.

2.Nature of rocks at the coast; Wave erosion is more pronounced on areas that are weak and soluble e.g. jointed and unconsolidated erode. The hard and resistant rocks stand as headlands while easily eroded rocks become bays.

3.Openess of the shore to wave attack; Coasts which are totally exposed to wave attack are easily undermined by wave attack while those which are sheltered by coastal reefs and islands eroded rocks become bays.

4.Abundance and size of load which is used as an abrasive tool; When materials e.g. boulders, sands etc. are in abundance, the coastline will be easily eroded through corrosion. In the absence of such materials, were erosion becomes meagre.

5.Stability of the sea (frequency of wave creating events); Coasts which are characterized by strong winds and other catastrophic events e.g. earth quakes are highly attacked by waves while calm coasts generate weak waves which are less destructive.

6.Relative movements of sea (sea level changes); When there is a drop in the level of the sea, the coast emerges and is hence exposed much more to wave attack while a rise in a sea level, the coast becomes submerged which reduces on wave attack.

7.Work of man; Man, dredges estuaries, builds drainage canals and beaches which all interfere with the waves energy to erode. **Groynes** erect to prevent sand from being wasted from the beach and **break water** built all hamper wave ability to erode.

8.Slope of the coast; Coasts which have gentle slopes are not heavily eroded by waves. Waves break and water is just thrown on a beach and simply comes back. Coasts which are steep however, act as a barrier to water thrown by the breaking waves and hence are terribly eroded.

LAND FORMS OF WAVE EROSION:

a) **Cliff;** This is a high and steep rock face that fringes the seas. Cliffs are majorly caused by waves although some other forces e.g. faulting can cause cliffs. As waves break, water is thrown on a beach. At a point of high tide (High tidal level) **a notch** is created by the back wearing of water. The notch gradually widens and develops a steep face, which becomes a cliff Good examples of coasts with cliffs occur at watamu coast and fort Jesus in Mombasa, Fort Gereza in Kilwa, at Dar-es-salaam and on Lake Victoria e.g. at Lutembe beach, Botanical garden and above Entebbe pier.

Diagram

b) **Cave;** This is one of the minor features produced by wave action (erosion) during the process of cliff formation. A cave develops along a line of weakness at a base of a cliff that has been exposed to prolonged wave atlach. A cave is a cylindrical tunnel that eats and extends into a cliff following extensive erosion exerted by breaking waves along lines of weakness within a cliff.

Its diameter is broad at the entrance and it decreases as the distance from the entrance increases. Several caves occur along the coast of Lake Victoria e.g. at Lutembe beach, Nsamizi and Botanical gardens. Other exist at Tiwi beach and Kilifi in Kenya and Oyster bay in Tanzania.

c) **Blow hole;** This is just an extended cave that is produced when waves breaking at the back of a cave splash water upwards to the cave roof. This splashing weakens the rocks at the roof of a cave and they continue collapsing and progressively removed slowly by slowly until a hole on the top of a cliff. This hole is what is referred to as a blow hole. Blow holes can be seen on Botanical gardens on Entebbe Peninsular, Mamangina drive in Mombasa.

d) **Headlands;** A headland is another feature formed by wave erosion in the opposite style of a bay. As waves erode away weak rocks on the coast quickly to produce a bay, the resistant rocks will be left protruding into the water as headlands. Examples of headlands are found at Kibanga on Entebbe Peninsular on the Lake Victoria shores, and at Watamu on the Kenya coast. Others include; Walukuba peninsular, Tiwi beach, kilifi at Mombasa etc.

e) **A bay;** This is a wide indentation into the sea or Lake. In other words, a bay is an extension of sea or Lake water into the land. A bay is formed as result of differences in resistance to erosion. Hence those rocks on the coast that are easily eroded become quickly retrograded to produce bays. Bays can be seen on Kavirondo gulf (bay) in Kenya, Speke and Emin pasha gulf in Tanzania, Napoleon, Sango, Kibanga and Murchison bays in Uganda, all on Lake Victoria. On the East Africa coast, these are Manda bay, Malindi bay, Mombasa, Watamu, Tanga bay and Kombeni bay on Zanzibar.

Diagram

f) **Geo;** This is formed when the roof of a cave collapses due to prolonged erosion through solution. When this roof collapses, a narrow gorge like features called a geo is formed.

Diagram

g) **Arch;** An arch is a bridge-like landform found raised above water. It can be formed when a cave is driven into the side of a headland and ultimately opens out on the other. Alternatively, it can also form when two caves develop from both sides of a headland and then ultimately meet, creating a water passage through the headland. This leaves a raised bridge-like roof above the passage. The whole natural structure is known as an arch

Diagram

h) Stacks; A stack is an isolated rock landform in the sea or Lake completely surrounded by water. It is effectively detached from the mainland. It is therefore, occasionally referred to as an island rock. A stack forms when an arch is gradually eroded until it collapses resulting into the detachment of a rock from the headland. The two are separated by part of the sea water. Once a stack is formed, it is also gradually attacked by waves and agents of weathering and ultimately reduced to a residual rock known as a stump. Examples include the islands of Pemba, Zanzibar and Mafia.

Diagram

i) Stamp; This is formed when the stack is eroded to sea level. It is believed that some Ssese islands especially those almost being submerged were stacks that formed stamps when eroded to the water level.

Diagram

j) Wave cut platform

WAVE DEPOSITION LANDFORMS.

While some parts of a coast are being eroded by constant pounding of waves, the sea is carrying material removed to other areas where it is deposited. Wave deposition is a result of constructive waves.

The two main mechanisms by which eroded materials is transported along coastlines i.e. by **long shore drift** in which the debris is carried along by waves moving parallel to the shore and by **beach drifting** on which the debris is moved by the action of waves on shore line itself. Beach drifting usually occurs where wakes strike the shore obliquely. The up rush (swash) carries material diagonally; up the beach and back wash drags the coast material fragments back down at right angles to the shoreline. As this process continues, the coastal materials e.g. sand and pebbles are gradually moved and finally deported to produce across-section of landforms.

1. **A beach;** This is a gentle slope at the coast where there is accumulation of sand and pebbles on the shores. Beaches are usually formed between low and high ide levels but storm waves along some coasts tend to throw pebbles and sand well beyond the normal level reached by waves at high tides thus producing storm beach. Examples of sand beaches include Nyali at the Mombasa, Lido and Kasenyi on Victoria. Others include Lutembe and Munyonyo beach.

Diagram

2. **Barrier beach;** This I along beach of sand deposits which is approximately parallel to the coast. It is separated from the coast by a Lagoon. It is formed on gently slopping area by along shore drift and waves breaking off shore materials deposited. Examples can be seen at the coast of Benin.

Diagram

3. **Split;** This is a narrow of pebbles or sand joined to the land at one end with the other end projecting into the sea. It is formed when there is deposition of materials by long shore drift. Spits can be classified as hooked spit and tombolo.

   A hooked spit is formed when strong wave forces the sea ward edge to curve towards the land. An example can be seen at Butiaba on Lake Albert.

Diagram

4. **Tombolo;** This is a depositional feature that joins an island to the main land. When materials are carried by the long shore drift, they may be deposited and starts developing as a spit but with time, these materials may join the mainland to the island. A good example can be seen on the north Eastern Somali coast. On Lake Victoria, there is a tombolo joining Bukakata mainland to Lumbu and also Bukaana mainland to sigulu island in Bugiri district.

Diagram

5. **Sandbar;** A sand bar is a ridge of material, usually sand, which lies parallel, or almost parallel to the coast. There is a variety of sand bars. Those which extend across bays are known as bay bars. Off shore bars develop on gently sloping sea beds away from the shore. They develop where sand is thrown up by waves which break before they reach the coast. An off shore bar is separated from the coast by a Lagoon. Off shore bars are found on the Kenyan coast at Lamu.

Diagram

6. **Mudflat;** A mudflat is a platform built of mud, silt and other types of alluvium. It develops when rivers and waves deposit materials along gentle coasts, especially in bays and estuaries between high and low tides. Mudflats are well developed in the Niger delta and on the coasts of Kenya and Tanzania for example near Tanga and the mouth of River Rufiji, Near Luzira in Murchison bay on Lake Victoria shores.

   A cuspate spit is formed when two spits grow from the coast towards the sea by long shore drift deposition and converge towards each other in the water. Eventually the two spits meet to form a cuspate spit.

Diagram

A cuspate foreland; This is a triangular deposit of sand and single projecting seawards. It is formed from a cuspate spit when the enclosed water of a cuspate is filled with deposits and soon colonized by the vegetation. The area colonized by the vegetation is called a cuspate foreland.

This can be seen at Tonya point on Lake Albert.

Diagram

7. **Coastal sand dunes;** Many beaches are backed by sand dunes formed as coastal winds blow sand from the beaches further inland. These winds must be dominantly on shore. This sand may be trapped and stabilized by grass and vegetation to form sand dunes. They are common along arid coasts.

8. **Salt marshes;** As a result of deposition of fine and fertile rich silts during the formation of mud flats, some salt tolerant plants may begin to appear and later on colonise mud flat zones. These in the long run form coastal swamps and are called salt marshes. In the tropics, salt marshes are of mangrove swamps.

9. **A Lagoon** is a body of comparatively shallow salt water separated from the deeper sea by a shallow or exposed sandbank, coral reef, or similar feature. Thus, the enclosed body of water behind a barrier reef or barrier islands or enclosed by an a toll reef is called a **Lagoon**. It can also be defined as a body of calm water which is enclosed by a spit or sand bar. Examples can be seen in Mombasa, near Nabugabo on Lake Victoria and on Lake Albert especially behind Toya and Kabira spits north of port Butiaba.

Diagram

10. **A Berm;** This is the accumulation of heavier stones and boulders at the upper beach limit. This accumulation is due to a swash being stronger than a backwash.

END