7 CHAPTER RIVERS AND LANDFORM FEATURE DEVELOPMENT

Introduction

A river is a mass of liquid water flowing in a distinct channel incised over the surface of the earth. Over many years streams become rivers by eroding their bed. Rivers flow from areas of higher altitude to areas of low altitude. Where a river begins (a glacier or mountain) is called a **source** and where it ends (lake, sea, or ocean) is called a **mouth**. Rivers move down slope due to force of gravity; as it flows down slope it receives branches known as tributaries; and therefore gradually develops into a drainage system. The land area drained by a river and all its tributaries is known as a **drainage basin** (catchment area). The surrounding highland which separates one catchment area from another is called a **watershed (a divide).**The highland which separates adjacent tributaries of a river is called an **interfluve.**

The work of rivers

In the process of their (river) movement from source to mouth, rivers perform three functions i.e. **erosion**, **transportation** and **deposition**. Therefore through their work, rivers are able to wear down highlands and build up lowlands. This implies that they are able to produce landforms.

The ability of a river to perform its functions depends on the energy of the river. For example, a powerful river is likely to carry out erosion on a high scale while a weak one is likely to cause extensive deposition.

The energy of a river is determined by volume of water and the gradient over which water is flowing. A river with a large volume of water is a much stronger river compared to that with a smaller volume, therefore the higher the volume the greater the energy. Gradient is also positively correlated with the energy of the river. The steeper the gradient the greater the river energy. When a river flows on a steep gradient, the speed is increased and therefore the energy is enhanced. In contrast, when a river flows over a gentle or flat surface, the energy increasingly gets reduced owing to its low speed. Therefore rivers flowing in the old stage tend to be weak rivers compared to those flowing in the youthful stage.

River regimes

This refers to the seasonal variation of water volumes carried by a river. There are periods when a river carries great volumes of water i.e. during floods and when a river carries less volumes of water i.e. during the dry season. These variations are due to climatic variations (rainfall seasonability), differences in rock permeability, character of vegetation cover and man's interference through activities like irrigation.

In the developed world, there are few rivers that flow wholly under natural conditions. Many rivers are managed and regulated by human beings. However, those not managed by human beings fall in three major categories of regimes i.e. simple, double and complex regimes.

Simple regimes

This means that a river has only one period or season of high water volume and one season of low water volume in a year. Such a regime is common in tropical regions which experience one wet and one dry season. For example the Blue Nile that originates from the Ethiopian highlands in an area with savannah climate has a simple regime. Rivers Mbako, Mwalesi and Ruvuma in Southern Tanzania experience simple regimes.

Double regime

This means a river experiences two seasons of high water volumes and two seasons of low water volumes in a year.

The two periods of high rainfall normally coincide with the two equinoxes in equatorial locations. Rivers Kagera, Kafu and Katonga in Uganda experience a double regime.

Complex regime

This means a river experiences more than two periods of high water volume and low water volume in a year. This regime is experienced by rivers which flow in many climatic regions. For example rivers that flow from Mt. Ruwenzori (glaciated) have high waters for more than two seasons due to high rainfall and melting of snow.

River erosion

This is the wearing away of rock particles by a river or the process through which rivers detach and remove rocks from the surface of the earth.

Processes of river erosion

These are mechanisms or ways through which rivers detach and remove rocks from the surface of the earth. Rivers carry out erosion in four main ways;

Corassion

This process is also referred to as **abrasion**. It involves the wearing down of rocks on the river bed (floor) and river bank (side) using the transported material for erosion. The transported material is collectively referred to as "load". These particles are used as "grinding tools" to crush and remove the surface rock outcrops on the channel. This process is enhanced by the existence of turbulent (fast, rough water) stream. Corassion leads to formation of a smoothened, polished and sometimes scratched channel.

Hydraulic activity

This is the eroding force of water on rocks of the river channel as a result of its physical power. Water pressure produces shock waves against the river bank. Each powerful force removes the unconsolidated particles. This happens for example when a river moves in channels characterized by cracks and loosely attached rocks. Sometimes running water moves against a river channel and traps air within cracks forcing it to get compressed, when the water gradually withdraws from the channel side, the trapped compressed air expands with an impact which breaks the rocks around the cracks. This is also referred to as **cavitation.**

Corrosion

It is at times referred to as **solution**. It is the wearing down of rocks of a river channel by chemical processes. This therefore affects those rocks which can dissolve in water. For instance, as rain water seeps through rocks like limestone, rock salt, dolomite (readily soluble in water), they are eroded away in solution. The process of corrosion also results in the removal of the cementing power that binds particles together. Once this power is removed the rock gradually crambles.

Attrition

This is a process in which the transported particles themselves gradually break down. It is therefore a process where the transported "load" is eroded. During the transportation, particles of all sizes are hurled against each other leading to break down. This collision leads to gradual breakdown of large rock particles into progressively smaller ones.

Therefore when attrition occurs for a long time, particles which were originally big get reduced in size or get in shape. Attrition is more likely to occur when a river is characterized by turbulent flow rather than lamina flow (smooth even flow of water).

Types of erosion

1. Vertical erosion: This is the deepening of river channel by gradual cutting particularly by abrasion. It leads to deepening of the river bed and formation of a V-shaped valley.

2. Lateral erosion: This is the wearing of the channel sides. It leads to river widening and formation of a U-shaped valley.
3. Headward erosion: This is the lengthening of a valley in an uphill direction above its original source by gulleying, mass wasting and sheet erosion. The source of a stream gradually recedes hence lengthening the river

River transportation

A river also does the work of transporting eroded materials. The rock particles transported by a river vary in size and type. They may range from fine, tiny particles such as sand, clay and silt to large materials namely boulders. All these particles are capable of being transported by a river depending on the energy and competence of that river. A weak river may transport light materials and therefore is likely to be incapable of carrying large sized heavy rock particles. However, when a river's energy is increased, then a river is rejuvenated. It is capable of carrying even larger particles.

Processes of river transportation

A river's load is transported in a number of ways namely;

(i) Solution:

Rock materials which are capable of dissolving in water are transported in a dissolved state. Such materials include common salt, limestone and dolomite. These are therefore transported in solution with river water until they are precipitated to form a rock again. The speed at which these materials travel is the speed at which the river is flowing.

(ii) **Suspension:**

This is the movement of insoluble light rock particles. Such particles include sand, clay and silt materials. These are the materials which occasionally give river water a muddy appearance. The holding of small particles in suspension depends on the size of the particles and competence of the river. If the particles are small and light enough, they are likely to be transported in suspension, but if the weight increases without the river energy proportionally increasing, some of the particles inevitably will be moved along the river channel. This therefore ceases to be suspension.

(iii) ~~Saltation:~~ Traction

This is the movement of particles through rolling, dragging or pushing of material directly on the channel floor by moving water. The particles are therefore in direct contact with the channel floor. This is different from saltation to a small extent and from suspension completely. This is because particles moved through traction are; often the largest and these are too heavy to be transported by the other three processes.

River deposition

This occurs when stream energy is insufficient to carry on the load. When the river's competence reduces, that is, its ability to carry the load declines, the load it was carrying is eventually dropped on the bed; this is what is termed as river deposition. Deposition often occurs in the old stage of a river where:-

- A river flows in an arid or semi arid area where there are high temperatures causing excessive evaporation of river waters hence reducing volume of river water.
- The gradient of a river channel has reduced.
- The velocity becomes low due to slope changes, roughness within channels and decreases in the volume of the water.
- A river enters a sea or lake and therefore velocity falls.
- Particle size becomes too heavy relative to velocity and volume of water discharge i.e. for a certain velocity and volume there is maximum particle size that can be carried.
- A river channel is rough due to presence of many boulders and potholes. The rough surfaces increase friction and enable some of the transported load to

be trapped and laid to rest.

- A mass of flowing water (river) reaches a flooded area; calm waters consequently reduce its speed and deposit its load.
- There's increase in channel width, this reduces the river energy and carried particles will be deposited.

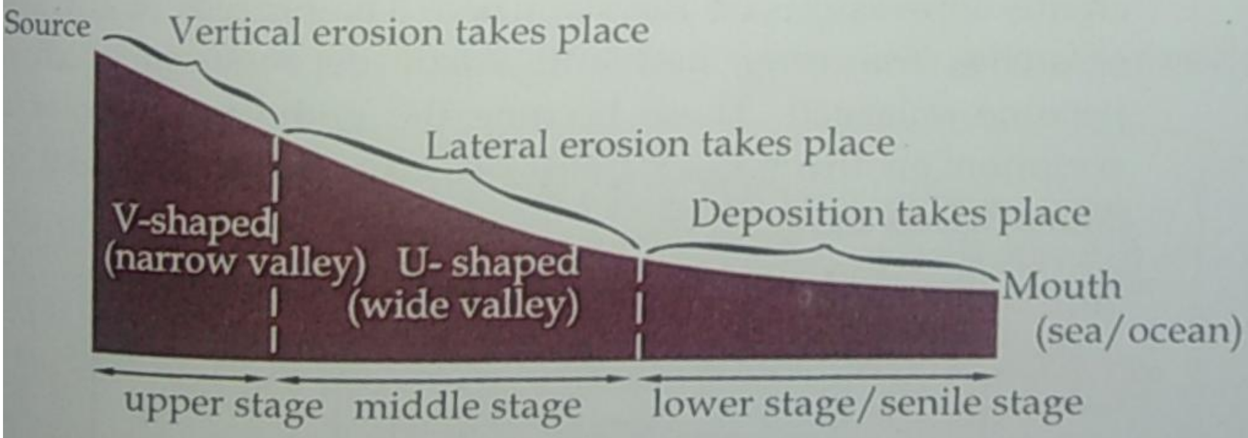
Long profile of a river

This refers to the longitudinal section of a river from the source area down to the mouth. The source area is the starting region of a river and inevitably this has to be a highland area. The mouth of a river is inevitably located in a lowland area. Almost universally rivers end in the sea or ocean. There are however, exceptions where some rivers end in lakes, such rivers are termed rivers of **inland drainage.**

The long profile of a river can be sub-divided into three divisions namely.

(i) Upper-section (Youthful or torrent section)
(ii) Middle section (Mature section)
(iii) Lower section(Old or senile stage)

Illustration: long profile of a river



Upper section (youthful stage)

This stage is sometimes referred to as the **torrent stage**. A river in its youthful stage flows against a very steep gradient. Because of this, the river is very fast with a turbulent flow, a lot of swirling currents and producing potholes. Erosion here is mainly directed to the bed and so valley deepening by vertical erosion is dominant. The upper section of a river valley is generally characterized by the following:-

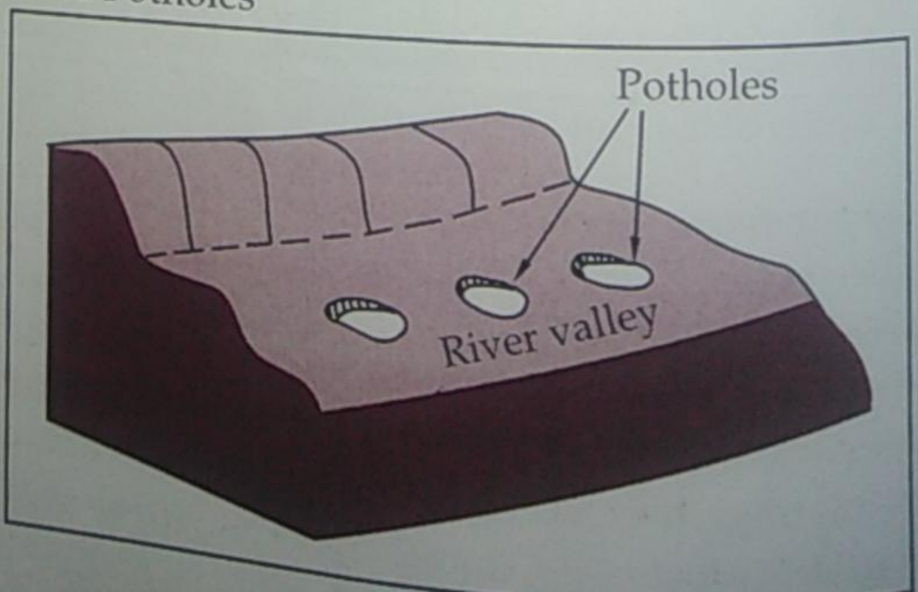
- Water flowing at a high speed with swift flowing currents.
- River carries out vertical erosion.
- River flows in a steep sided valley characterized by a V-shaped cross profile. This is because of greater vertical erosion compared to lateral erosion.
- The river takes a winding course between spurs (hills) called interlocking spurs. This implies that a river flows around interlocking spurs because it has not had enough time to erode away the hard rocks.
- The load carried by a river consists of large angular particles.
- Features like waterfalls and rapids are evident in this stage of a river profile.

Main features associated with a youthful stage of a river

1. Potholes:

These are depressions on the floor of a river channel. They are caused by the effect of fast flowing turbulent water. These depressions particularly develop when the fast flowing river uses the rock particles it transports as grinding tools to create depressions on the river bed. The process of corrasion scratches the river bed and small depressions gradually become enlarged. These become the potholes. Potholes are common on the bed of rivers Athi in Kenya, Mobuku and Manafwa in Uganda.

Illustration: Potholes



2. Waterfalls:

A waterfall is a fast flowing and often turbulent section of a river. It is found on a steep slope of a river channel. Waterfalls exist due to a number of factors and ways which include: -

(i) Where a hard rock overlies softer rocks in a river bed. This means that the hard and soft rocks are juxtaposed and there's differential erosion in which the softer materials are eroded faster than the hard ones. This leads to a steep slope over which the river plunges (falls) down slope to form a waterfall. At the bottom of the steep slope there's usually a large volume of water commonly referred to as a **plunge pool**. Sezibwa falls in Buikwe district, Uganda was formed in this way. Examples of rivers with plunge pools include Sezibwa River at the falls and at Sipi falls.

Illustration: River channel before differential erosion

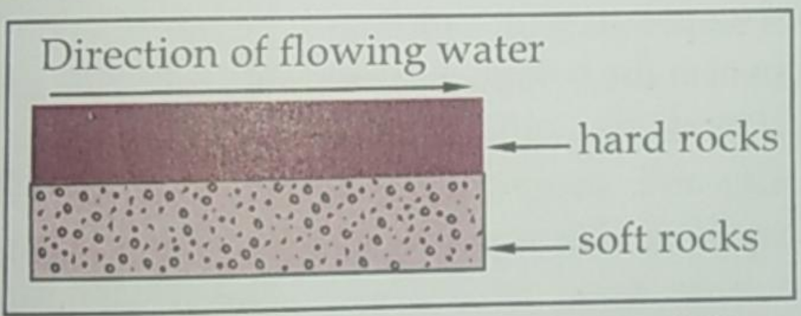
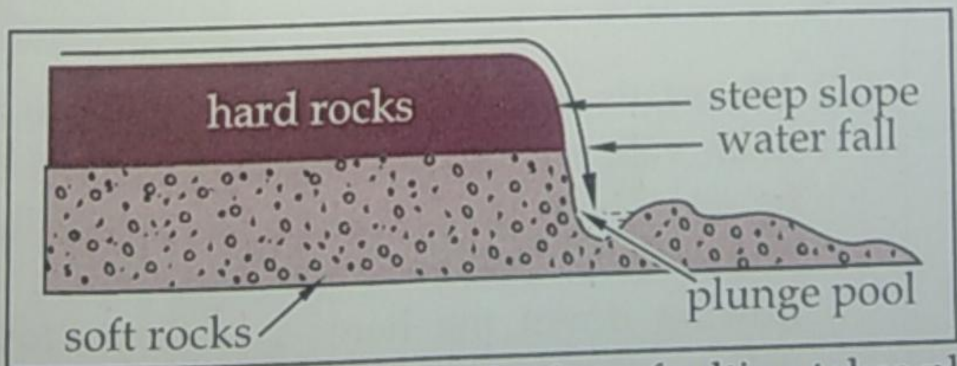


Illustration: River channel forms a waterfall after differential erosion



(ii) Waterfalls may also be formed where faulting takes place across a river bed. Displacement along a fault line causes an escarpment cutting across a river valley. Eventually water will fall steeply across the escarpment. This is what is referred to as a waterfall. Karambo falls on river Zambezi, Murchison falls and Karuma falls on river Nile were formed in this way.

Illustration (i):
Landscape before faulting

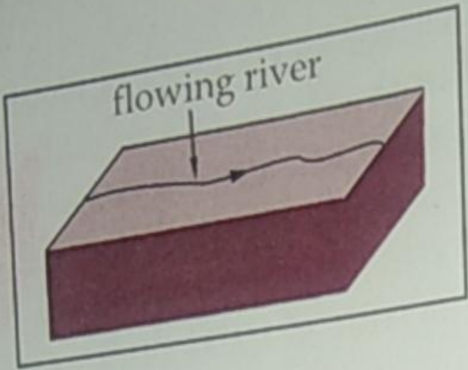
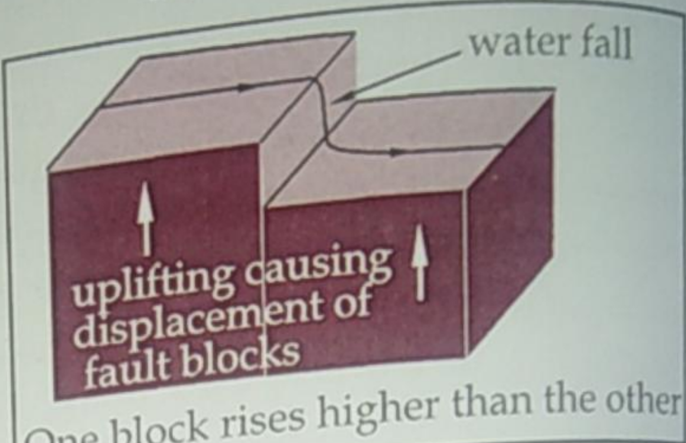


Illustration (ii):
Water falls formed where faulting takes place across a river bed



One block rises higher than the other

One of the most prominent examples of a waterfall is the Victoria Falls on the River Zambezi.

Figure 8: Sippi falls with a plunge pool at the bottom, Eastern Uganda

(iii) Waterfalls are also formed in glaciated areas where a main valley is deepened more than its tributary valleys by ice. These tributary or hanging valleys are left at a higher level. When ice retreats from the area, rivers flowing down the hanging valley drop into the main valley as a waterfall. For example in the Ruwenzori mountains melt water from the Speke glacier falls into the main Bujuku valley forming Bujuku falls. Refer to chapter 8: Page 219 for illustration.

(iv) A waterfall may also be formed where a river falls over a plateau edge especially where if flows from a higher level plain to a lower one. It does with a lot of force along a steep gradient forming a waterfall.

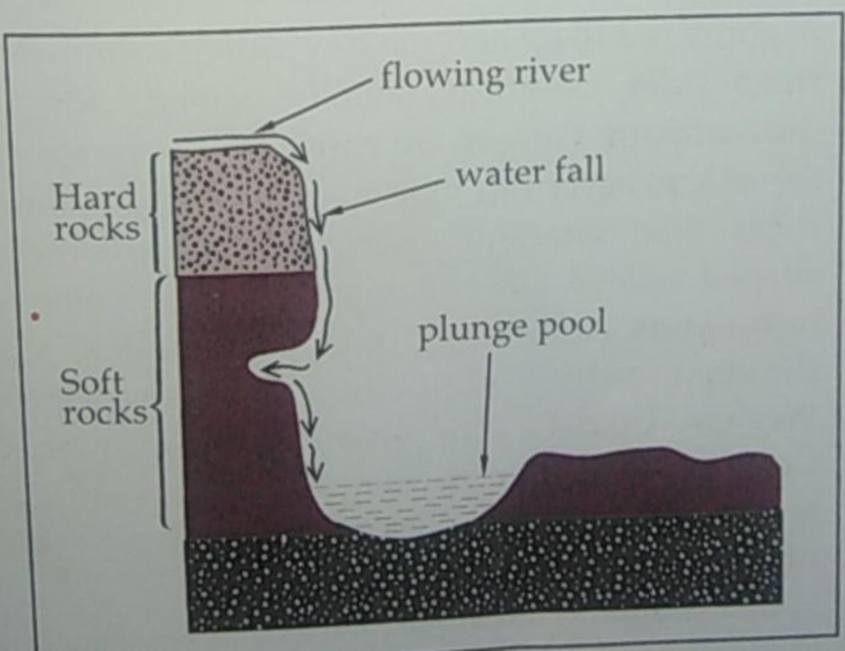
(v) River rejuvenation also leads to formation of a waterfall. When a river rejuvenates (regains more energy to carry out erosion), it incises its valley and flows in a much deeper channel compared to its victim eventually causing a break in slope near the point of capture. This break in slope is at a knick point, where a river plunges steeply forming a waterfall. Refer to page 189 for the illustration.

(vi) When a river flows over exposed resistant dykes in an area forms a waterfall. The Sippi falls in Kapchorwa, Eastern Uganda were formed in this way.

3. Plunge pool:

This is a hollow or a broad depression with a mass of water at the base of a waterfall. It is formed by river erosion where soft rocks underlie hard rocks in a river channel. River erosion through hydraulic action and corrasion of falling water around rocks, wears off the soft rocks forming a wide depression known as a plunge pool. For example a plunge pool exists at the bottom of Sippi falls in Kapchorwa, eastern Uganda.

Illustration: a waterfall and a plunge pool.



4. Rapids:

The term rapids refer to a section of a river where the flow of water is irregular or uneven over a fairly long distance. Rapids are therefore a section of fairly disturbed water but the speed is not as high compared to waterfalls. This is partly because the slope over which rapids form is not as steep as that over which waterfalls develop.

In the upper stage of a river, the channel bed is rocky and steeply slopes downstream for a long distance over which the water flows at a fairly fast speed. The rock channel bed causes the irregular flow of water. Rapids are common in the upper stage of a river but they can also be found in the middle or lower sections depending on local situations. Examples of rivers with rapids include R. Ngaila in Western Kenya.

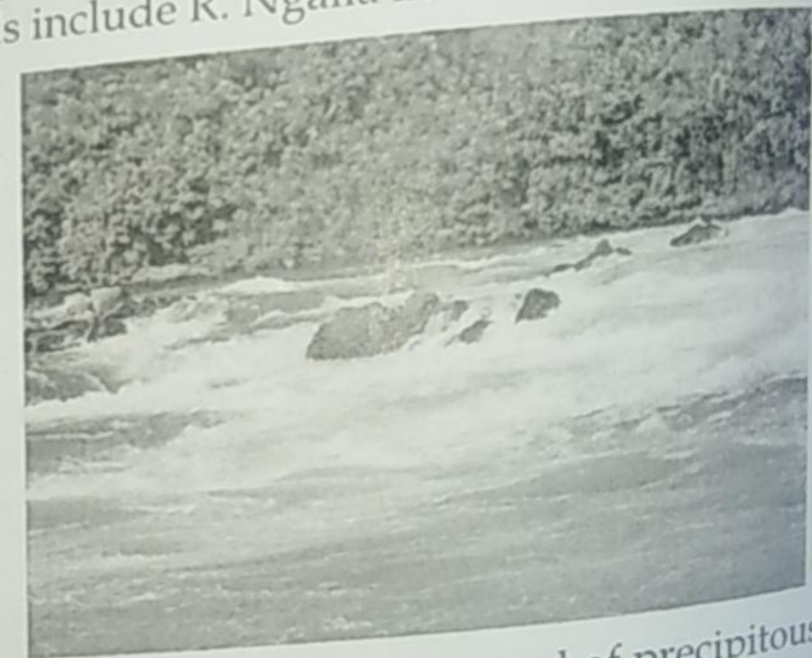
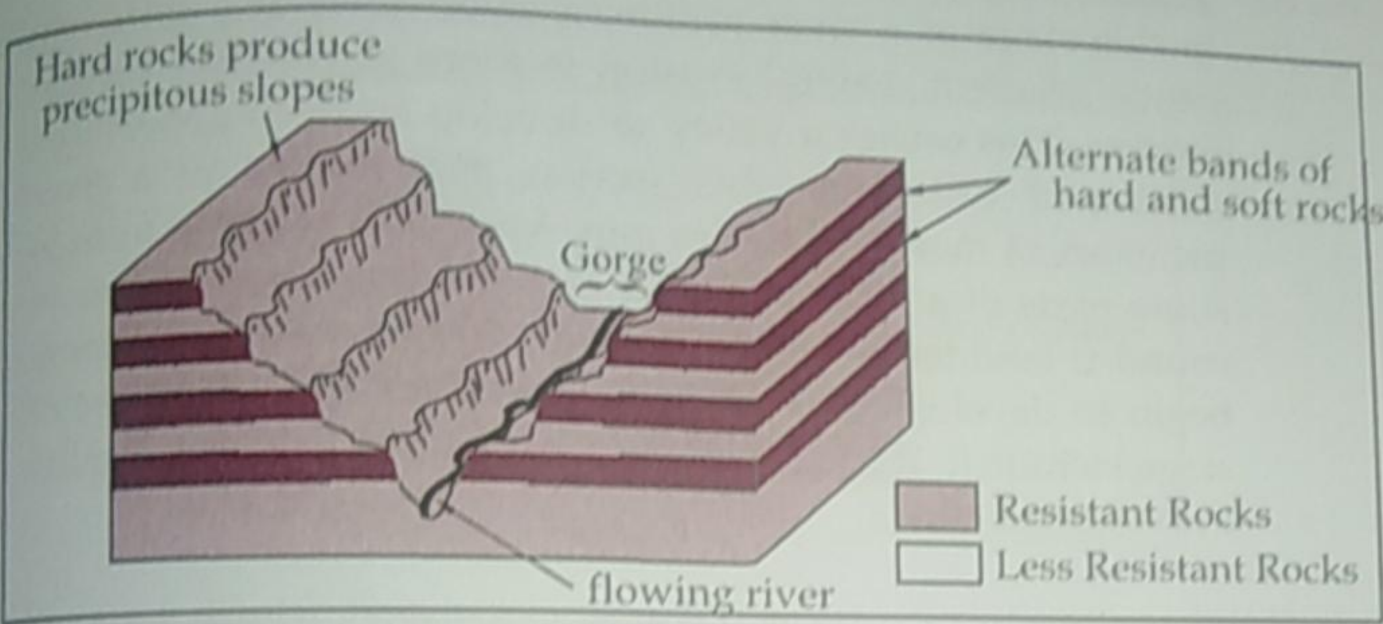


Figure 9: Bujagali rapids along River Nile

5. Gorge:

A gorge is a deep and narrow valley composed of precipitous steep sides. A gorge usually extends for a long distance downstream. Gorges are caused by very strong rivers which are able to carry out more vertical erosion along bands of soft rocks than lateral erosion. Gorges are therefore deep V-shaped valleys. Gorges are alternatively referred to as **ravines** or **canyons**. An example of a gorge is the Kyambura gorge off the main road in Queen Elizabeth National Park Kasese South Western Uganda. The Grand Canyon 1.6m deep of River Colorado is a striking example of a canyon. Another example is the antecedent gorge of the Great Ruaha River North east of Iringa in Tanzania.

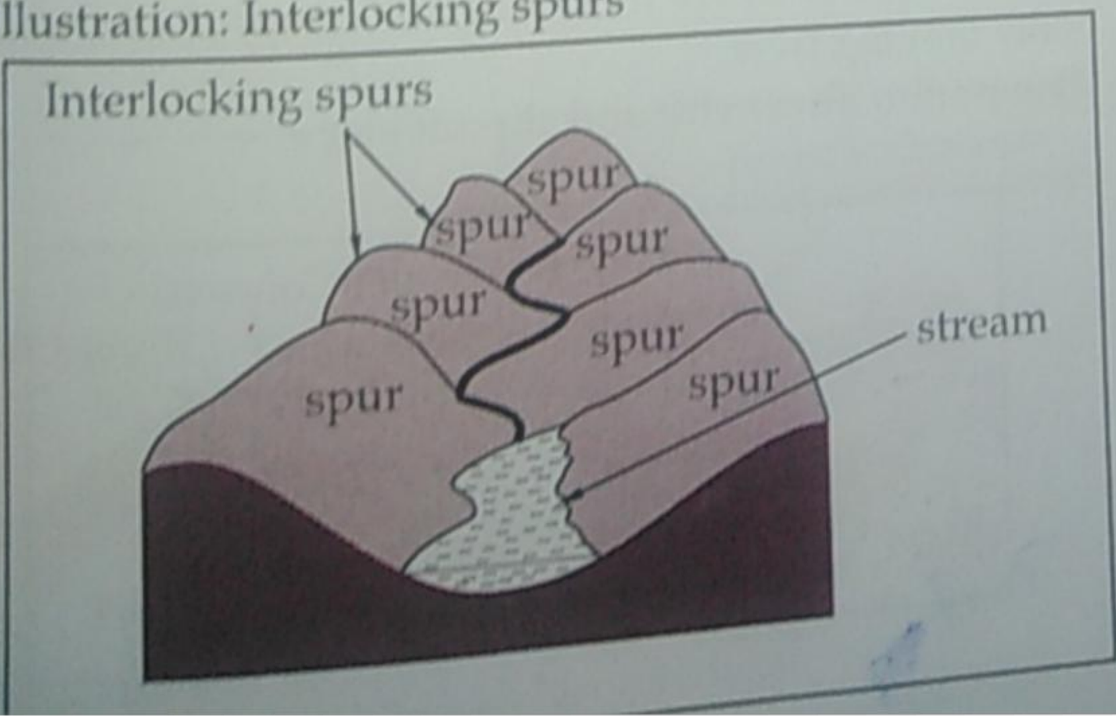
Illustration: Gorge



6. Interlocking Spurs:

These are adjacent hills which slope gently down to the valley, when several spurs or hills occur alternately on opposite sides of a valley. They are referred to as interlocking spurs. A river flows in the narrow valley and often winds around the steep sided hills. A river winds because it attempts to avoid obstacles (rounded hills) which are resistant to erosion. In fact, the spurs seem like fingers of land and the two spurs which seem to interlock are on the opposite sides of the river from each other. For example there are interlocking spurs around River Kamulikwizi along mountain Ruwenzori in Kasese, western Uganda.

Illustration: Interlocking spurs



Middle Stage (Mature Stage)
In this stage of a river profile, a river flows at a relatively gentle gradient. Lateral erosion is more active than vertical erosion. This causes a valley to develop an open appearance (U-shaped valley). In this section, the volume of a river increases as more tributaries join. Meanders begin to form in some parts of a river; the load of a flowing river consists of rounded boulders and small stones. Bluffs or truncated spurs begin to develop. Examples of rivers that show this type of stage include R. Rufigi, R. Pangani in Tanzania and R. Semliki in Western Uganda.

Features associated with the mature stage of a river profile

1. River Cliff:
It is a steep slope formed by lateral erosion on the river bank. It develops on the concave bank, which is the outside bank of a channel. Along this bank, the speed of water is high and greater lateral erosion takes place.

2. Slip-off slope:
This is a gently sloping landform composed of deposited rock particles on the convex bank. This landform develops out of the laying down of rock particles derived from the Concave river bank. The slip off slope develops on the convex bank because this is where it is likely to be a zone of slack water or slow moving river.
Illustration: River cliff and slip off slope

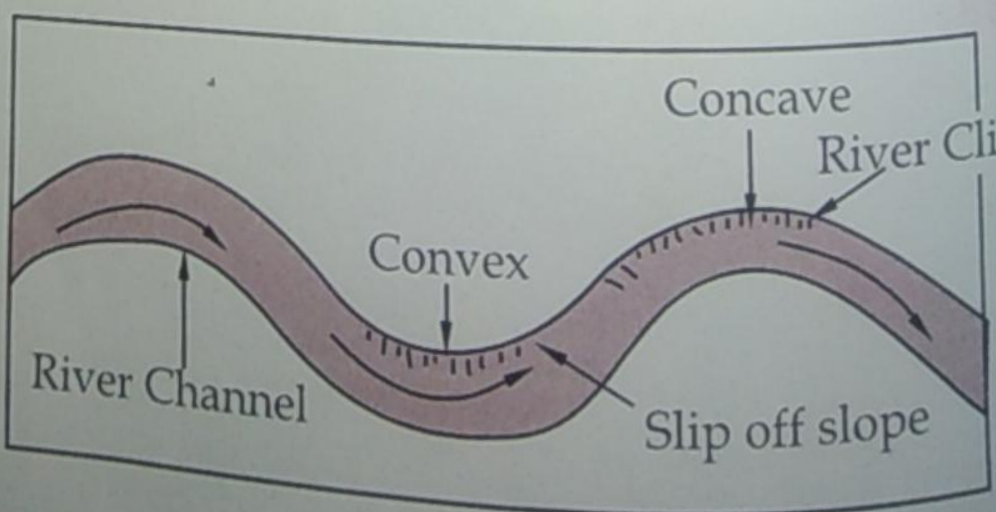
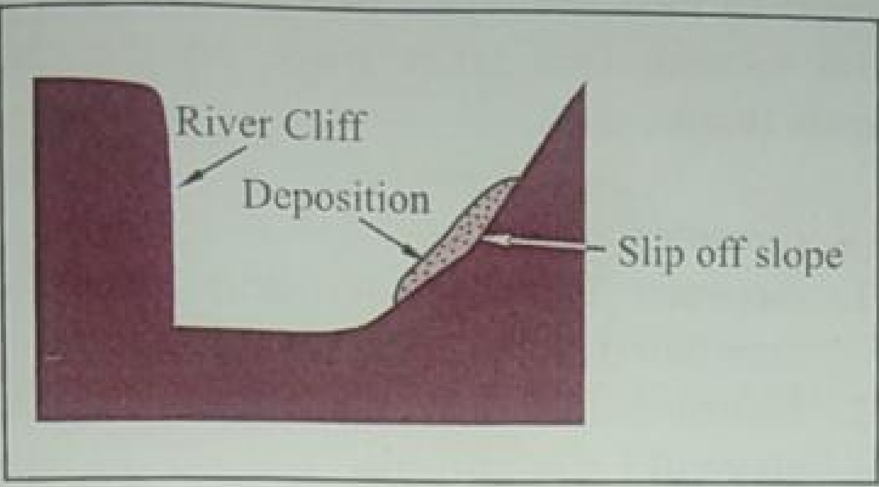
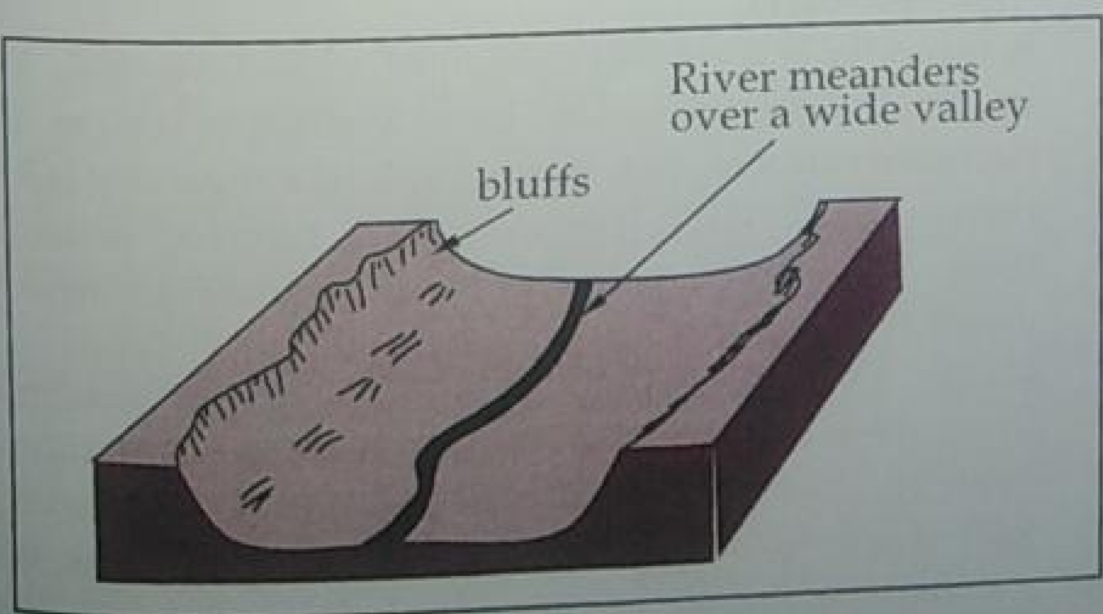


Illustration: Cross-sectional view of a river cliff and a slip off slope



3. Bluff: This is a cut off end of an interlocking spur. It is also referred to as a **truncated spur**. A spur is an area of high land that jilts out into an area of lower land. We saw earlier that rivers found it very difficult to erode spurs quickly and so flowed around them. But a deep, powerful river can be so strong that it can move straight on and cuts straight through these spurs. The strong river cuts off the lower ends of the spurs. This means they have truncated them. The truncated spurs are usually very steep. The erosion (wearing down) of interlocking spurs therefore leads to the development of river bluffs. This leads to the development of a fairly wide river valley. Examples of river cliffs, slip off slopes and bluffs exist along rivers Rufigi and Pangani in Tanzania.

Illustration: Bluffs



The mature section of a river's long profile is characterized by an open U-shaped cross profile and is therefore commonly referred to as a U-shaped profile. This is because of greater lateral erosion that takes place on the channel sides and extends them.

Reference Questions

1. Account for river erosion and the formation of associated features in Africa.
2. Examine the formation of features in the youthful stage of a river profile.
3. Explain the characteristics and the formation of associated features in the mature section of a river profile.
4. (a) Distinguish between waterfalls and rapids.
   (b) Account for the formation of waterfalls in E.Africa.

Lower section (old stage or senile stage)

This is the last stage of a river profile and it is characterized by the following: A river has a very gentle gradient and this means the river's speed is greatly reduced and flows sluggishly. This section of a river valley is dominated by transportation and deposition. There's very little erosion if any, the river flows in a wide area (channel), and it has well developed meanders and ox-bow lakes.

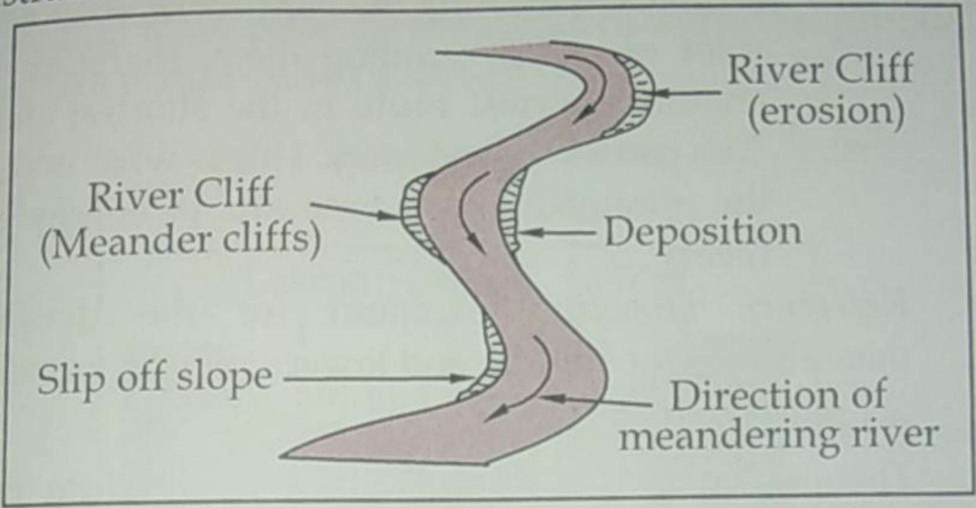
Characteristic features in the lower section

(a) Meanders:

A meander is a curved section of a river channel. It is a bend in which water ceases to have a straight course but takes a circuitous course. The inside bank of a meander is known as a **convex bank** while the outside is referred to as a **concave bank.** The greatest erosion is on the outside bank while the inside bank is largely associated with deposition.
Meanders develop in a river's course on condition that it flows over a reduced gradient which consequently affects its velocity (low speed) and its competence (reduced), a river will begin flowing sluggishly. The land across which it is meandering is called a **meander belt**.

Examples of rivers with meanders include rivers Kilombero, Rufiji and Mkomazi in Tanzania, rivers Nzoia and Nyando in Western Kenya and river Ruizi near Mbarara University in W.Uganda.

Illustration: Structure of a meander



Reasons for the development of meanders can be summarized as follows:

- The reduced gradient over which a river flows encourages deposition of load leading to accumulation of material, hence meandering begins.

- The reduced river competence as a consequence of low velocity by a stream. This implies that the river's capacity to carry materials will be insufficient hence deposition that leads to meandering.

- Siltation along a river channel reduces the gradient. As a result the river wanders or meanders looking for an alternative steeper gradient, hence development of bends causing meanders.

- Existence of hollow (pools) and shallows (riffles) sections on the river floor. This makes the river avoid riffles (where there are hard rocks) and flows through pools (soft rocks), in the process the river swings from one side to another hence meandering. This is called the Pools and Riffles theory. For example there are pools and riffles along River Naro moru.

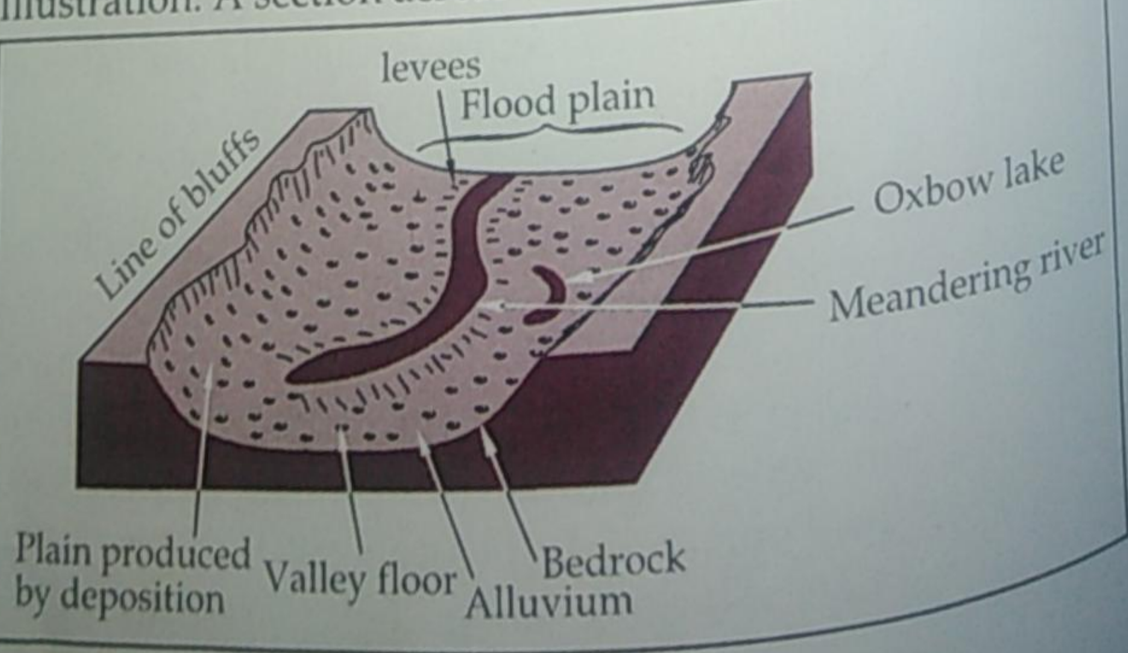
- When a river meets a band of hard rocks, it is forced to wander looking for alternative routes. This is termed as the Obstruction theory.
- A river will always follow the easiest route to its source. On meeting the hard rocks, it avoids spending a lot of energy eroding them, therefore will follow another shortest route in the shortest time possible. This causes meandering. This is what is referred to as the minimization of time rate of energy expenditure theory.

Reference Question: Account for the development of meanders in the middle and lower stages of a river valley.

(b) Flood plain:

This is the gently sloping plain of alluvium covering the valley floor down which the river flows in a meandering or braided channel. In other wards flood plains are the depositional surface of features formed by a mature river. A flood plain develops through the meandering of the river. As a river swings back and flows across the valley, it widens the valley floors. The valley sides and spurs are slowly worn back and with time a line of low bluffs is formed. Flood plains are not very common in West Africa but the lower course of the River Benue has a well developed flood plain. One of the best examples of floodplains is that of river Nile. Other examples of flood plains are Hwang-Ho in China and the Mississippi river in the U.S.A.

Illustration: A section across a valley containing flood plain.

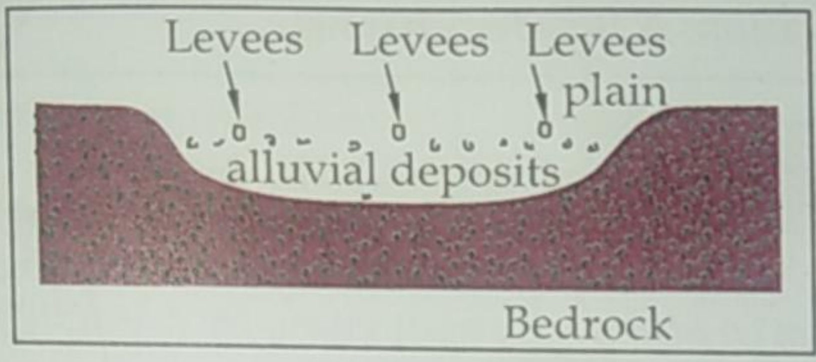


(c) Levees:

When a river over flows its channel, deposition takes place on the banks of the channel and this produces a ridge like feature known as a levee. A levee is an embarkment built by a meandering river alongside its channel. During flooding deposition takes place on the banks of a channel producing a ridge like feature called a levee.

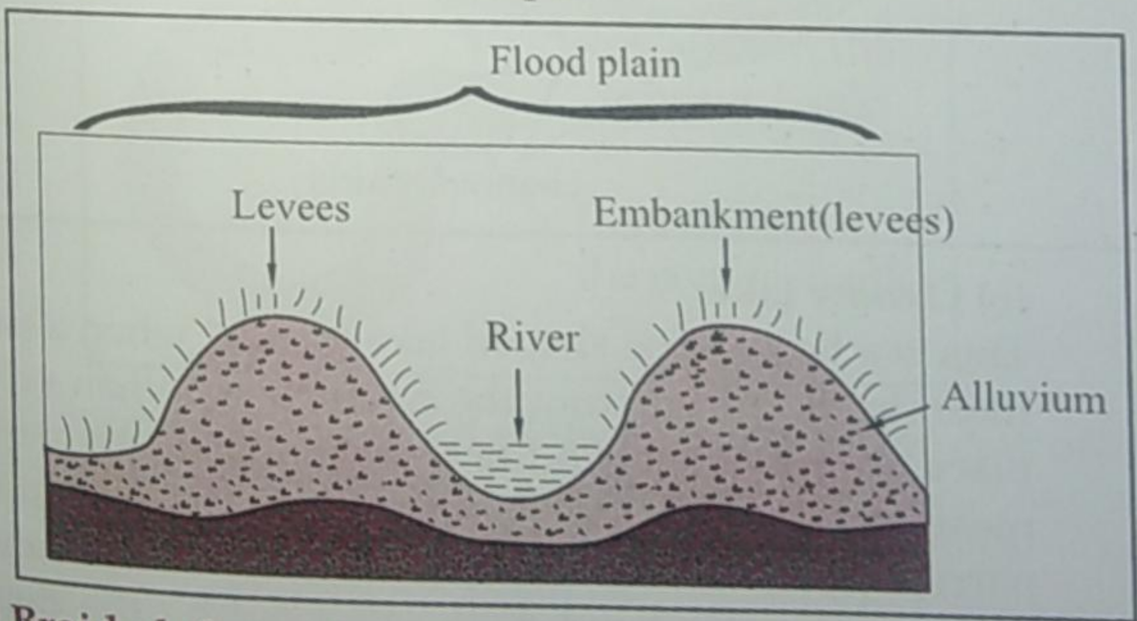
Illustration: Cross section of a flood plain with levees

Bluffs



Levees can be found on river Malaba (Eastern Uganda), Ngaila, Yala and Nyando on Kano plains of Kenya.

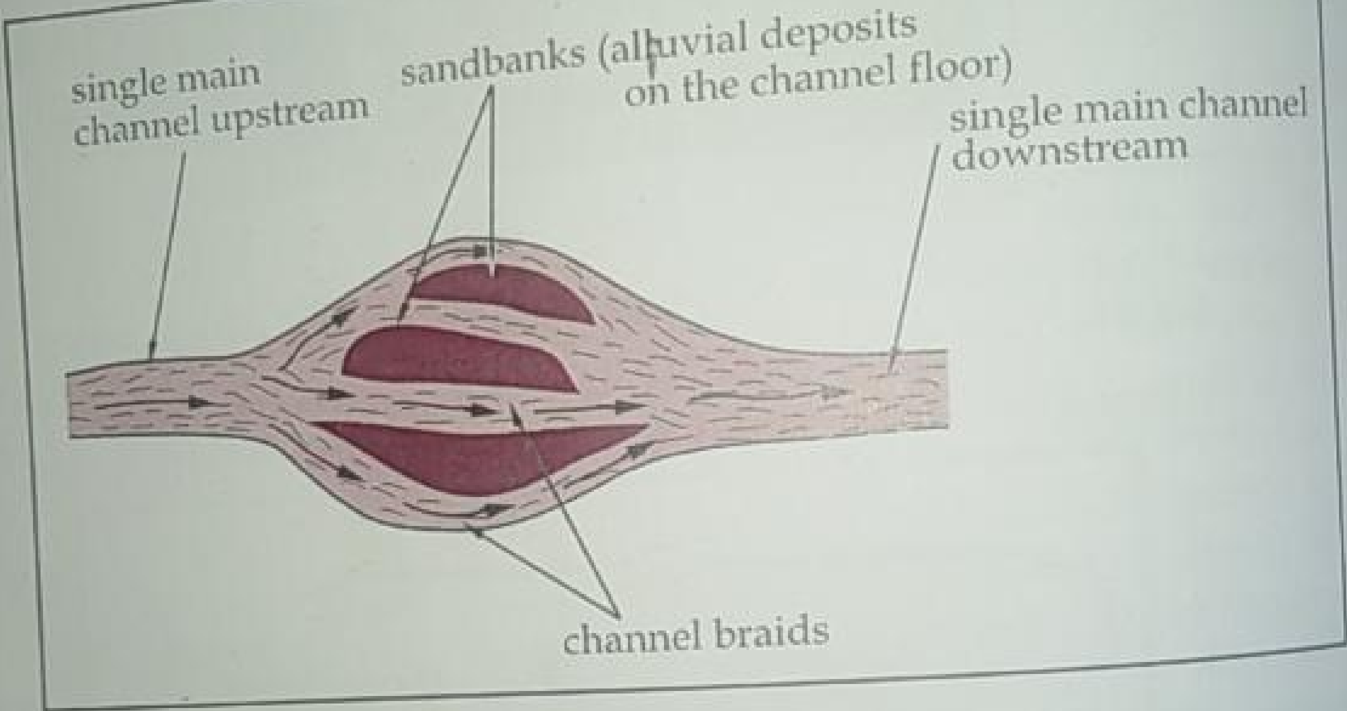
Illustration: Levees in a flood plain



(d) Braided channels:

A braided channel is an extremely wide shallow channel in which a river divides and subdivides in a series of inter-connecting minor channels separated by sandbars and islands of alluvium (deposits). A river with a very heavy load becomes overloaded in the dry season when the amount of water in the river falls, and deposition takes place in form of sandbanks and islands of alluvium, this causes the channel to braid. Therefore it is basically deposition on the valley floor that causes the river split into several channels. For example Congo River has a braided channel; other examples include the wide braided channel of the Magoky River East of Morombe south of Madagascar. R.Tana, R. Nile, R. Nzoia, R. Kilombero, R. Athi, R. Galana in E .Africa also posses braided channels.

Illustration: A Braided channel



(e) **Oxbow lake:**

This is a horse-shoe shaped lake formed when a pronounced meander is cut off from the main river. When erosion takes place on the outer bend of a meander, it cuts deep into the meander causing the adjacent bend to be closed and a narrow neck of land remains between two meander loops. Erosion on outer bend is also assisted by the deposition in the inside bank (convex). Further erosion leads to joining up of the meander loops, and during flood times the river breaks off through a narrow neck, cuts off the meander to form an ox bow lake and seals it off by alluvial deposits. In circumstances where water that has been trapped in dries up, a **meander scar** is formed. Examples of rivers with oxbow lakes and meander scars include R. Semliki, R. Ruizi in S. W

Uganda, (R. Nzoia, R. Tana and R. Nyando) in Kenya, Mkomazi and Kilombero in Tanzania.

Illustration: Formation of an Ox-bow lake

Illustration (i): A meandering river

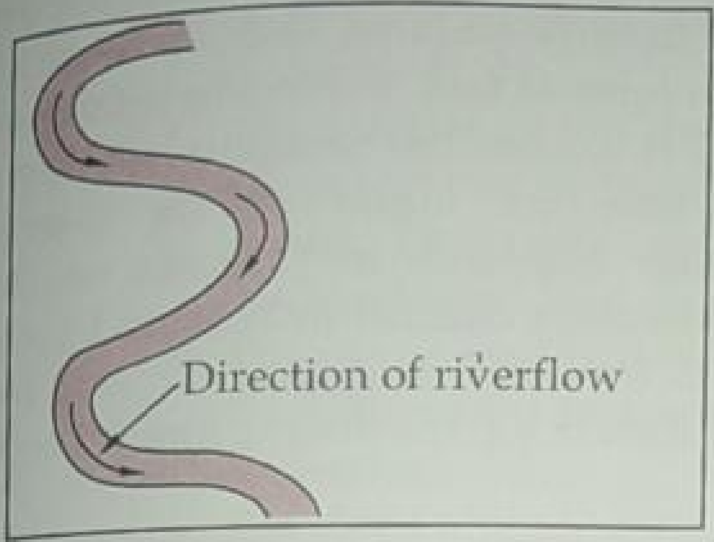


Illustration (ii): A meander loop develops

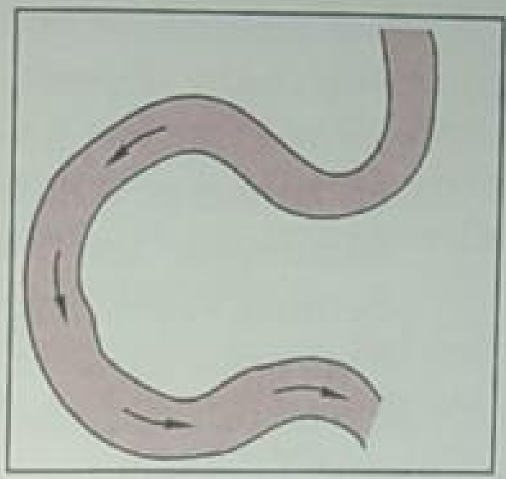


Illustration (iii): A meander loop closes due to erosion and deposition along river banks

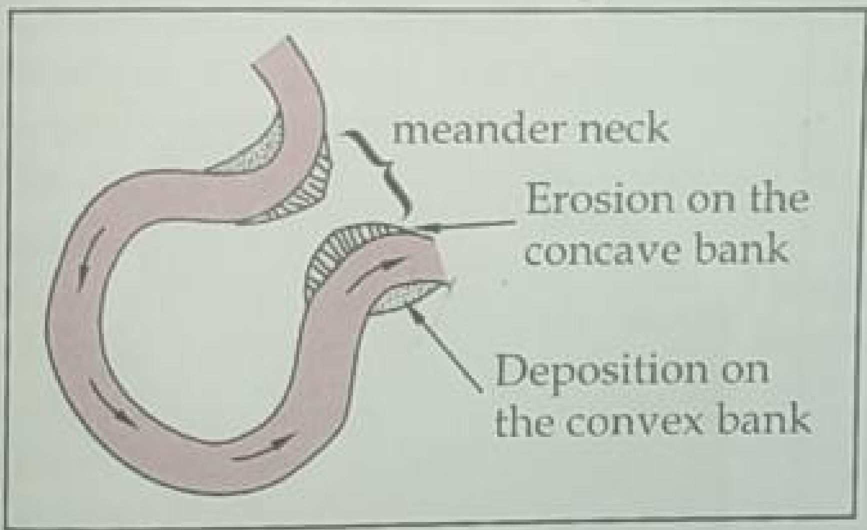
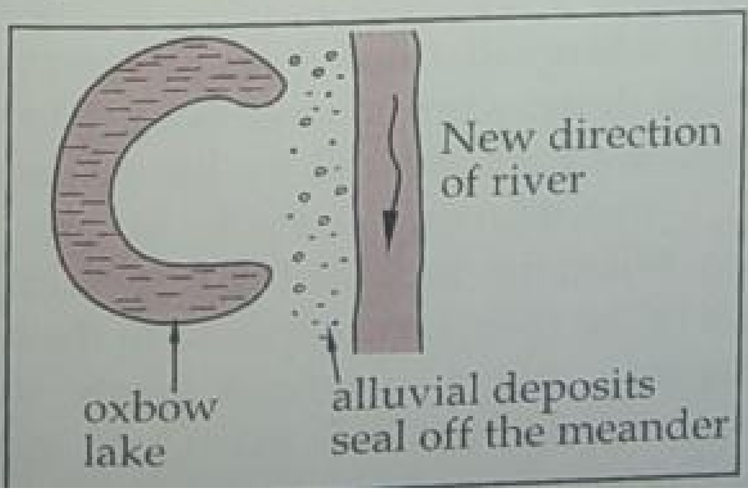


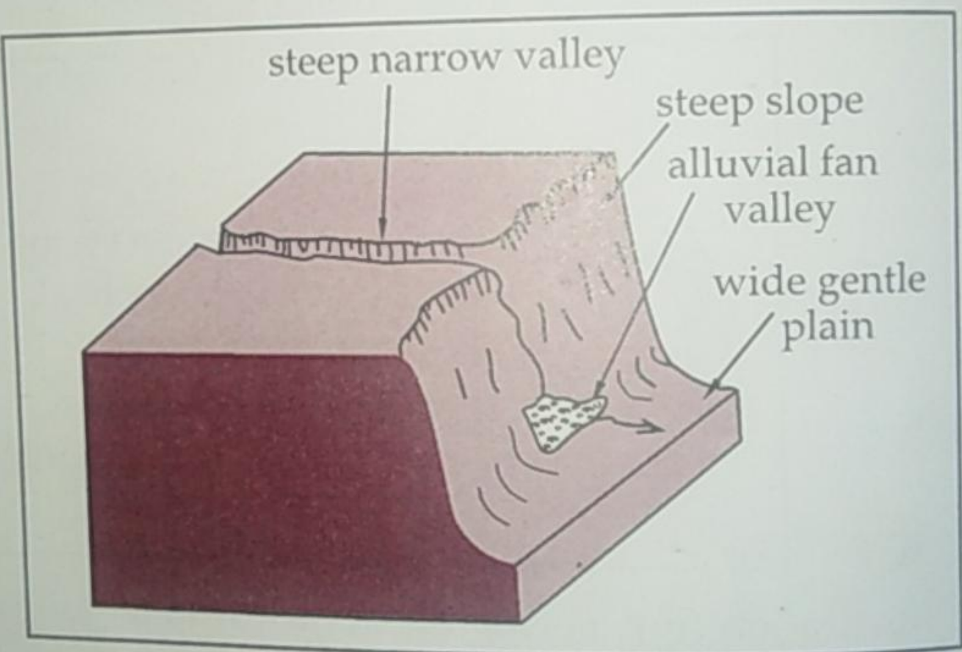
Illustration (iv): closing off of the meander loops cuts off the meandering river to form an oxbow lake.



(f) Alluvial fans:

These are fan shaped deposits of coarse material especially sand and gravel deposited by the stream with large load as it emerges from a steep narrow valley into a wide gentle plain. Alluvial fans are basically caused by deposition as the river has insufficient energy to carry on large load. Therefore it is eventually deposited in form of fans. For example Lume fan formed by R. Lume as it reaches the Semliki plain west of Ruwenzori. Alluvial fans are found on the floor of Uchungwe and Mahenge highlands in Tanzania, on river Semliki valley and on Kazinga channel in Western Uganda. There are more than 15 fans built largely of clay and sand between Utengule and Ifakara e.g. the Rondo, Rufiri, Lumero and Luvi fans.

Illustration: Alluvial fans



(g) Deltas:

A delta is a large flat low-lying swampy plain of river deposits laid down where a river flows into an ocean, sea or lake. Deltas are characterized by the presence of deposited materials, distributaries, small lakes, lagoons, and vegetation. When the deposited load is carried far away from the mouth of the river, before it sinks to the bottom a layer of sediments may collect to form a gently sloping platform. With time, the platform may extend up to the surface and above. It is now called a Delta.

The swampy plain gradually becomes colonized by various types of plants (vegetation).

For the formation of a delta, the following conditions are necessary;

- A river must have a heavy load to allow massive deposition.
- The velocity of the river must be sufficiently low to allow most of its load to be deposited in the river's mouth. That's why rivers like Congo though with a large sediment load cannot produce deltas.
- The river's load (sediments) must be deposited faster than the rate at which tides and currents carry away sediments.
- The slope altitude should be so low to allow enough deposition of sediments (usually at the mouth).
- The river should be entering the sea at a reduced gradient to allow thorough deposition at the mouth.
- The sea should be relatively shallow at the point where the river enters the sea.
- There should be no large lakes in river course to filter off the sediments.
- The river should have a long plain or lower course so that its current would be slackened before it reaches the sea.
- There should be no artificial barriers like walls and dykes to prevent deposition at the mouth.
- Presence of saline lake or sea in which a river flows. The salty content makes the deposited particles stick together (flocculation). As a result particles become large and heavy, hence deposition of a river to form a delta. A delta's size and shape depends on the type and amount of deposited sediments, and also on the power of waves and currents.

Process for Delta formation.

Stages in the formation of a delta in an ocean or a sea.

Stage 1;

Deposition at the river mouth takes place and divides the river into a number of distributaries. Lagoons are developed bordered by spits and bars, which are built by accumulation of levees. These levees extend into the sea through the distributaries.

Stage 2;

More deposition of sediment occurs and the lagoons begin to be filled with sediment. They become swampy and marshy. Now the delta begins to assume a more solid form and shape.

Stage 3;

The old part of the delta stabilizes more and is colonized by vegetation which rises in height, swamps and marshes disappear and the delta assumes a dry appearance and becomes part of the Flood plain.

Types of deltas

There are basically three types of deltas;

(1) Arcuate Delta:

This is the commonest type of delta. It is triangular in shape and consists of both coarse (large) and fine sediments e.g. gravel and sand. It is produced by a river that has got many distributaries and where offshore currents are strong enough to round off the delta's sea ward edge to produce a round convex shape. E.g. the Nile delta, the Niger delta, the Rufigi delta and the Semliki delta on L. Albert. These have a shape of an inverted cone.

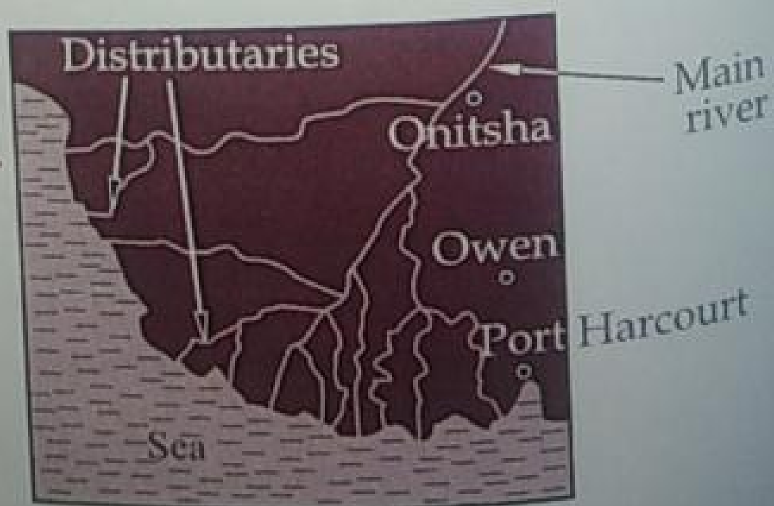
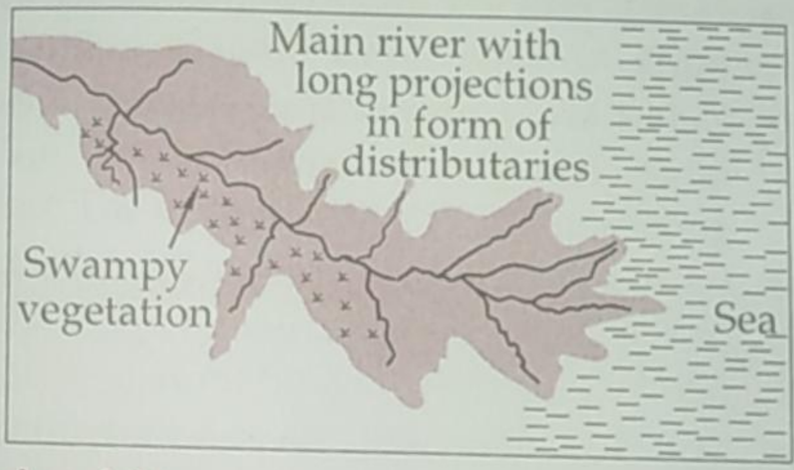


Illustration: The Niger delta and some distributaries

(2) Bird's foot Delta:

This delta consists of very fine materials called silt bordered by levees that jilt out from the shore. This type of delta is formed when the power of waves and currents is too low. Because of carrying fine and less dense materials of silt, the river tends to deposit far deep into the sea, hence producing a delta with long projections. It resembles a bird's foot. The Mississippi delta and the delta of Omo River in Ethiopia are good examples. Such a delta has formed on the mouth of the Victoria Nile where it enters L. Albert.

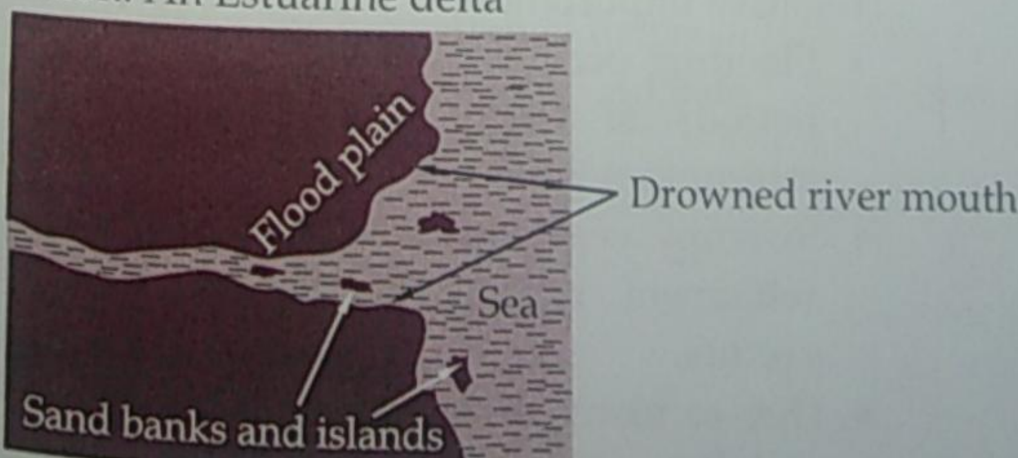
Illustration: A Bird's foot delta



(3) Estuarine delta:

This is a delta formed from materials deposited in the submerged mouth of a river. It takes the shape of an estuary. These deltas do not extend into the sea but extend up to streams due to deposition within the submerged mouth of a river. Sand banks and islands are formed with several distributaries winding around them. R. Rufigi was an estuarine delta as it had a submerged river mouth. Other examples include; Rivers Vistula (Poland) and the Ob delta (Russia).

Illustration: An Estuarine delta



Importance of deltas

Deltas both have positive and negative significances which are as follows:

Positive importance

- They contain fertile soils due to massive deposition at the river mouths. This implies that fertile soils favour agricultural activities to be practiced in delta regions.
- Deltas attract settlement due to fertile soils. The delta of river Nile has for long time been a home for a large population.
- Deltas provide good conditions for the formation of ports.
- Deltas are a tourist attraction e.g. the Nile delta is a large foreign exchange earner to the Egyptian government.
- Fishing activities take place in delta lagoons. The silt that is brought in by rivers is good for the growth of planktons which are food for fish.
- Deltas facilitate research and study purposes.
- Mining activity is carried out in delta regions. For example pottery and petroleum deposits exist in delta areas. Rufigi and Semliki deltas are mineral prospecting areas.
- In deltas where mangrove forests are found e.g. the Rufigi tree are harvested for poles used as good building materials.
- In deltas where papyrus swamps exist like the Omo delta, they (papyrus trees) are exploited for crafts and art industry.

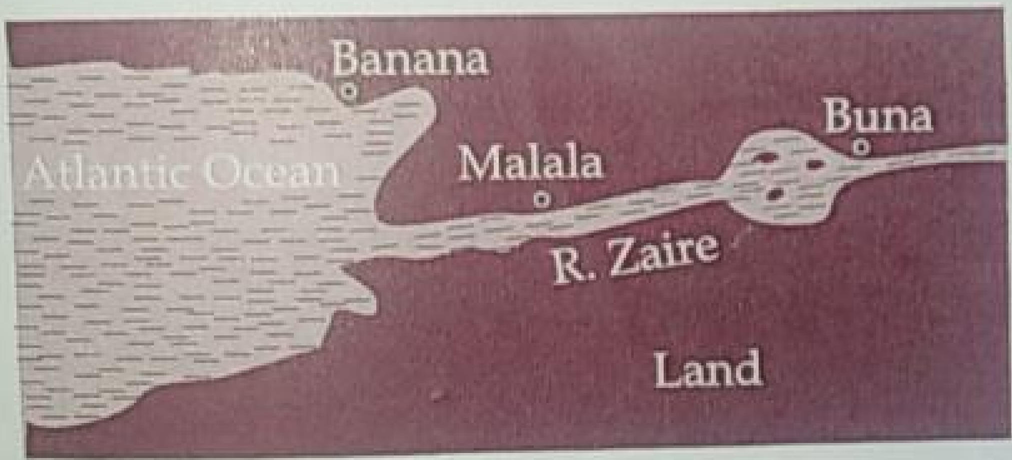
Negative importances

- Flooding occurs especially in estuarine deltas during periods of heavy rains. This breeds insects and mosquitoes which carry diseases to human beings.
- Swampy vegetated areas in deltas tend to discourage settlement because they harbour disease carrying vectors.
- Due to many distributaries the delta forms, transport and communication is hampered.

- Salinity of sea or lake waters consumes much soap; this affects domestic activities like washing.

Estuary:
An estuary is a wide deep single channel around a river mouth as it enters the ocean, sea or lake. They tend to be funnel (U-shaped) in appearance. Most estuaries result from submergence of the coast due to a rise in the sea level. An estuary is relatively clear of sediments because they are soon removed by tidal currents and allows easy mixing of channel and sea or lake water. Examples of estuaries exist on rivers Congo, Gambia, Gabon, Cross river in Nigeria, R. Sierra Leone and R. Senegal in Africa.

Illustration: The Congo Estuary



Reference Questions

1. Account for river deposition and the formation of associated features.
2. Examine the formation of features in the senile stage of a river profile.
3. (a) Differentiate between a delta and an estuary.
   (b) Account for the formation of deltas in East Africa.
4. (a) Distinguish between an Arcuate delta and an Estuarine delta.
   (b) Explain the importances of deltas to the people of East Africa.

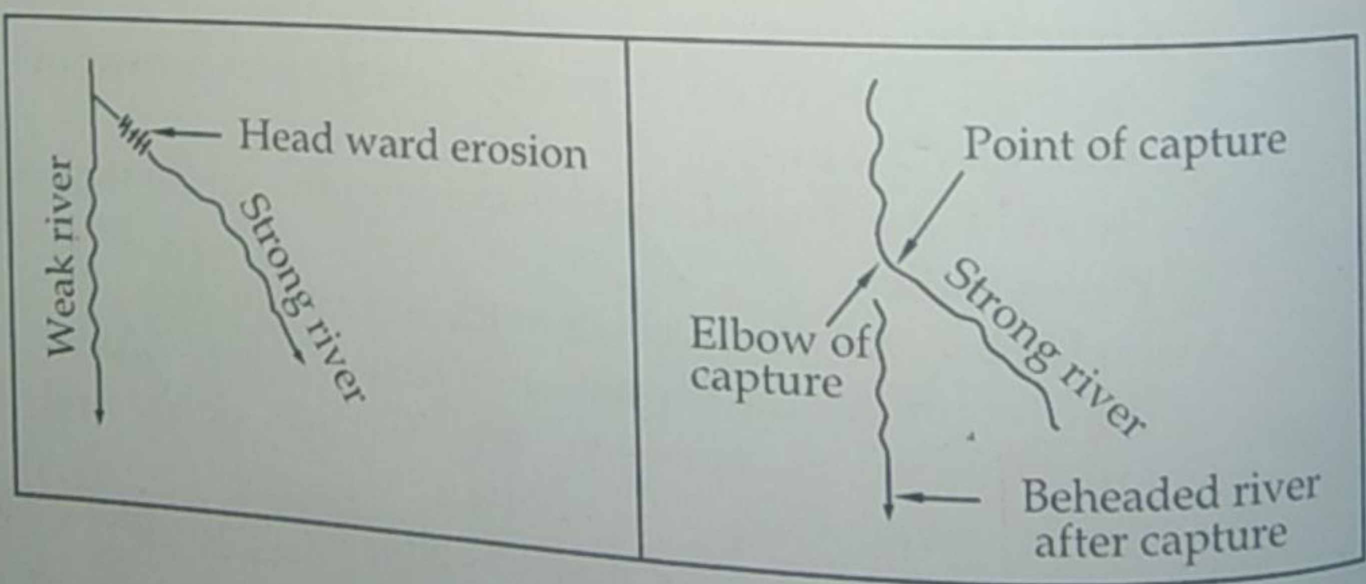
River Capture

It's also referred to as **stream piracy**. This is a process through which part of the river course is diverted into the system of an adjacent powerful river able to erode its valley more rapidly than its weak neighbours. It includes both small scale capture of single streams and capture of the entire river basin.

The capturing stream is called a **pirate stream**; it flows in a deeper valley than the captured stream (beheaded steam). For capture to be successful, the capturing stream will be flowing at a lower level than its victim and has greater energy for vertical and headward erosion. This may be due to either; (i) The pirate river flowing over easily eroded rocks such as weak rocks or rocks that have been broken by faulting.

(ii) The pirate river flowing down a much steeper gradient than its victim e.g. a Scarp or a cuesta or plateau. A stream flowing down a gentle backslope may be captured by a powerful scarp stream cutting back across the watershed. This process is called **divide migration** or **watershed retreat.**

Illustrations: Before capture After capture



Effects of river capture (evidence of river capture).

These are features or evidences of river capture i.e. after it has taken place and these include the following:

(a) Wind gap

It is the valley of the beheaded stream below the point of capture. It may be left as a dry valley or a swampy area. The floor of this former valley may be lined with old river gravel and other alluvium. With time, rivers in the area will be flowing at a lower level and the dry valley will only appear as a gap or col in the adjacent hills.

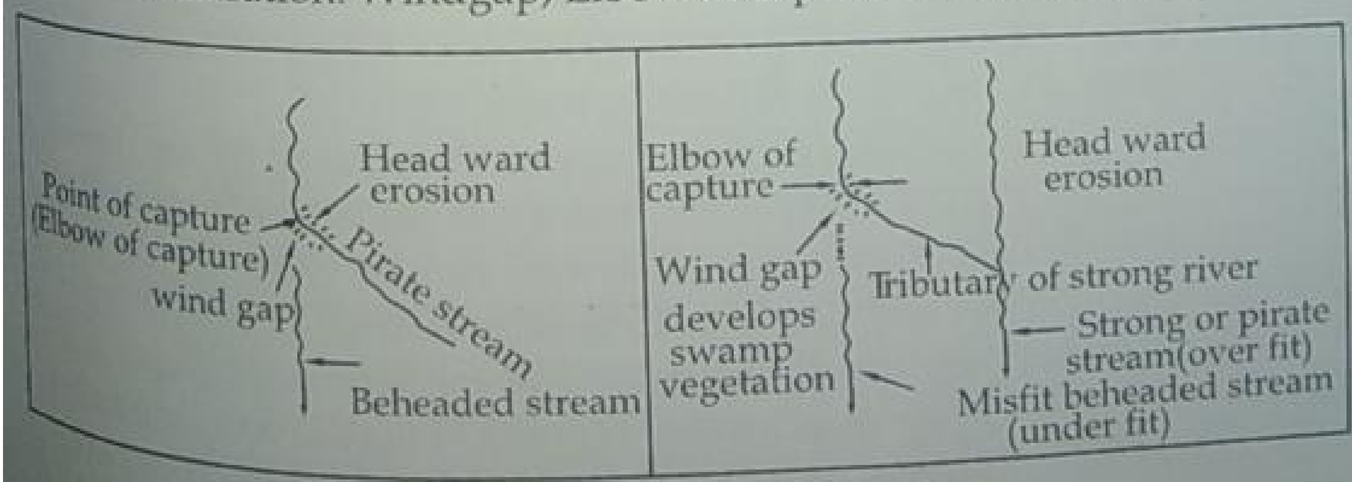
(b) Elbow of capture.

This is a bend or sharp change in the direction of a river course at the point of capture. But not all right angled bends in rivers are due to capture; many are a result of structural control. It is marked by a knick point and waterfalls.

(c) Misfit stream;

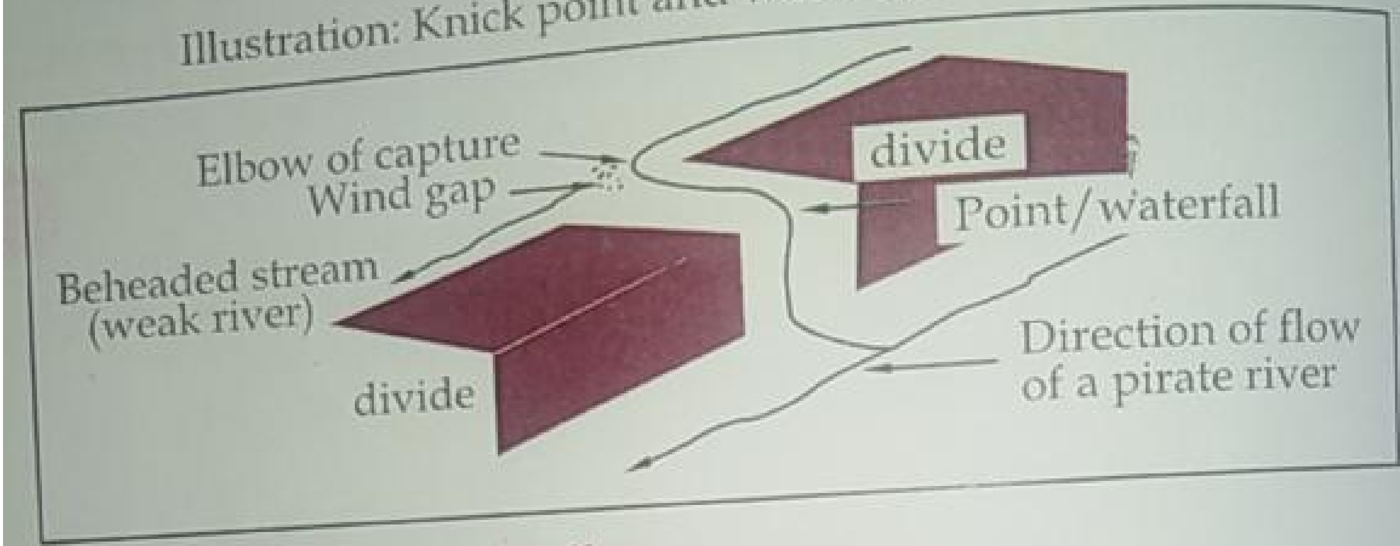
The beheaded stream having lost its head waters may be reduced in volume causing it to appear too small for its valley. It is therefore described as a **misfit** or **underfit stream**. In contrast, the pirate stream is enlarged because of addition of more water from the beheaded stream and thus the volume of the water becomes too much for the original valley. In this case it is specifically referred to as an *overfit*.

Illustration: Windgap, Elbow of capture and Misfit stream.



(d) Knick point and water fall
This is a break of slope in the long profile of a river valley. When the pirate stream (strong river) rejuvenates, it incises its valley and flows in a much deeper channel compared to its victim eventually causing a break in slope near the point of capture. When water from the stream flows down steeply, it results into a waterfall e.g. Ruachana falls on R.Cunene (Angola) being a good example of a waterfall.

Illustration: Knick point and water fall



(e) Rejuvenated valley
Near the point of capture, the valley is incised because of increased power from the enlarged headwaters. The increased volume increases the water speed. The river is therefore rejuvenated. It incises its valley below the point of capture and this results into a rejuvenated valley.
River capture has had a profound impact on the drainage system of East Africa.
Drainage system can be defined as the actual arrangement of the main river and its tributaries. East Africa's drainage has been affected in the following ways:

- The capture of the upper Tiva River, by the lower Tiva. Tiva was a tributary of R.Galana that used to flow southwards but the waters were diverted to flow eastwards i.e. in Eastern Kenya.
- The capture of R.Aswa at its tributaries Pager and Agago in northern Uganda. These rivers originally flowed south and westwards into Kyoga, Aswa and her tributaries captured those streams formerly flowing southwards into L. Kyoga.

- In Tanzania R.Ruaha cut through Ngerengere gorge by headward erosion and captured the drainage system of Pawaga and Usangu plains.
- The capture of R.Kafu and its tributaries; Tochi, Koli, Aracha by Albert Nile. This is evidenced by the rejuvenated valley of Albert Nile (pirate stream).
- River Mizmui in N.E Tanzania captured the waters of R.Mwine's tributaries in the Usambara mountainous region.

Other examples outside East Africa include the Cunene river capture in Angola where the upper Cunene used to flow south from the Bihe plateau to a large inland drainage basin, similar to Okavango delta, but it was captured by vigorous coastal streams and now turns west to the Atlantic Ocean. The Msaki river capture in Ghana (in the Akwapin hills) west of Aburi, the Nsaki a tributary of the Densu River has captured the Bisasi river.

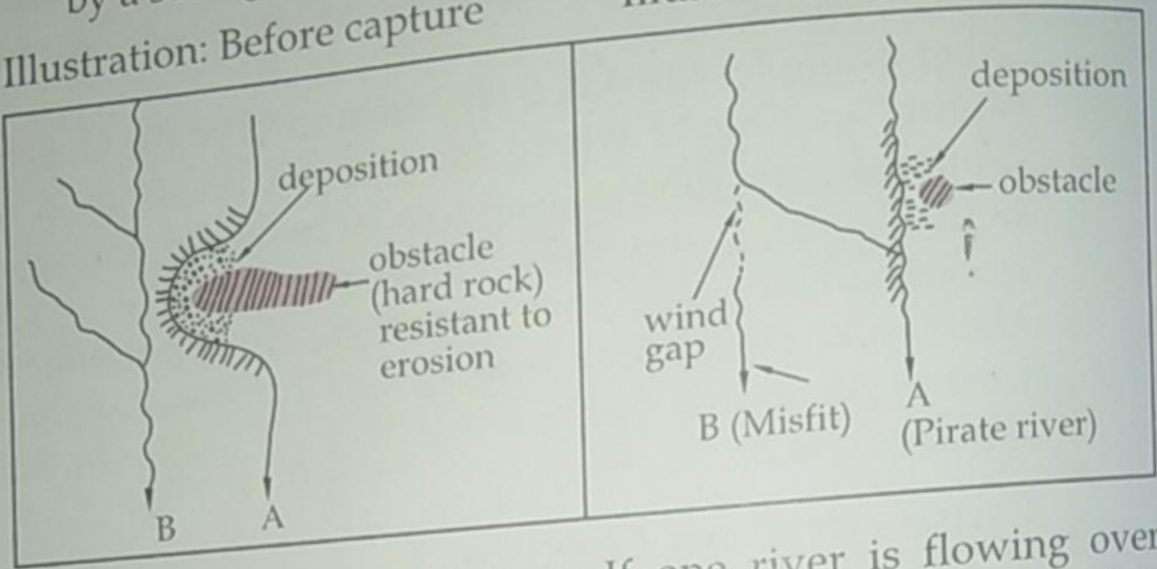
Causes of River Capture

1. Earth movements, involving warping and faulting may cause river capture. If two rivers are flowing side by side under similar conditions, down warping along the course of one river makes it bend at a lower level than the other river. Therefore, when there is a fault across the divide, the powerful river will divert the waters of the weak river into its channel. Formerly before the Pleistocene period, rivers like Kagera, Katonga and Ruizi were flowing west wards towards the Congo basin. But due to earth movements, these rivers were forced to change direction and R.Birira in W. Uganda captured the tributary of R. Rwizi .
2. River rejuvenation may cause river capture. River rejuvenation is the renewed erosive ability of a river due to increase in its energy. When two rivers are flowing side by side, if one experiences rejuvenation its bed will be much lowered compared to another and such a stream can cut backwards diverting the waters of another stream in its channel.

3. Presence of an obstacle or hard resistant rock in the river course may cause river capture. If there's a resistant rock or outcrop in the course of the river, the stream will try to avoid the obstacle, and by so doing there is much erosion on the outer bend and deposition along the inner bend, the river eventually takes another route and may be captured by a strong river in the process.

Illustration: Before capture

Illustration: After capture



4. Differential rock structure: If one river is flowing over softer rocks which can easily be eroded or if the land is jointed, the river will have the capacity to cut a deeper valley compared to the one flowing over hard rocks. This implies that the waters of the river flowing over hard rocks will be diverted into the valley of the other powerful river flowing over soft rocks. For instance R.Wasa near Fort Portal captured the waters of R. Nyaboroga that flows from Mt Ruwenzori simply because R. Wasa flows on soft rock as compared to Nyaboroga.

5. The pirate stream (strong stream) must be more powerful than its victim (Beheaded stream) so that it can be able to carry out vertical or headward erosion, i.e. For example R.Aswa captured R.Pager in Kitgum, R.Kafu was able to capture the waters of R.Tocini and R.Okole because it was more powerful than them.

6. Erosion along a fault line may also cause river capture. A river flowing over a faulted landscape tends to down cut its valley more rapidly than its neighbour. This is the case

with R.Wasa at the north end of Ruwenzori Mountain as it was able to capture R.Nyaboroga.

7. Presence of a parallel river with rivers having differentiated erosive abilities. Where one powerful river and a weak river are flowing adjacent to each other on homogenous rocks, the more powerful river erodes its bed faster through headward erosion and captures waters of another river. For example river Nile captured the waters of Tochi, Arocha, and Okole rivers, river Aswa captured river Pager in Kitgum in the same manner.

8. The nature of gradient of the long profile of the two rivers. If a pirate stream is flowing over a fairly steeper gradient than its victim, then it will have greater erosive capacity and will certainly divert the waters of its neighbour into its channel.

Reference Questions;

1. With reference to specific examples and relevant diagrams, examine the effect of river capture on the drainage systems of East Africa.
2. Discuss the causes and effects of river capture in Africa.

River Rejuvenation

This is the process by which a river's erosive activity is renewed as a result of increasing energy. Such a river is said to have been made young again and starts behaving like a river in a youthful stage. If a river in the middle age or old age is rejuvenated, it flows faster and with greater energy. It incises its valley and carries out erosion such that pot holing on the river bed can start again.

Causes of River Rejuvenation.

Rejuvenation may be caused by a number of factors which are as follows:

1. The lowering of the base level. The base level is the lowest level at which a river can erode and the universal base level is the sea. The lowering of the base level itself can be caused by glaciation. When there is a major climatic

change involving drastic lowering of the global temperatures, water is removed from seas and locked up in form of ice sheets and this definitely causes a fall in sea level. This induces fast movement of rivers.

2. Diastrophic movements: For example, regional uplift of land in relation to the sea. When the land on which the river is flowing down the sea is uplifted, the river's long profile is steepened. This directly causes the fast movement of rivers flowing down this steepened gradient hence renewed erosive activity.

3. An increase in the amount of water (Discharge carried by the river). Due to high rainfall totals and deglaciation discharge in a river channel may increase leading to increased energy of a river to carry out erosion hence rejuvenation.

4. River rejuvenation may be a result of river capture. When a capturing stream captures the waters of a beheaded stream, this increases its discharge and its energy to carry out erosion hence rejuvenation.

5. A decrease in the load carried by the river may cause rejuvenation. In this case a river will begin to erode in order to restore the balance between the energy and the load.

6. Human activities, like deforestation can lead to the increased run off and in the process cause increased water volume which ultimately leads to an increase in the erosive power of the river.

7. Nature of basement rock: If a river flowing on hard rocks suddenly enters soft and easily erodible rocks, it will erode the soft rocks quickly and rejuvenation will suddenly set in at a point soft rock.

In general, river rejuvenation is a gradual but steady process which may be **dynamic** i.e. if it is caused by a fall in sea level and diastrophic movements and **static** if it is due to increase in rainfall and river capture.

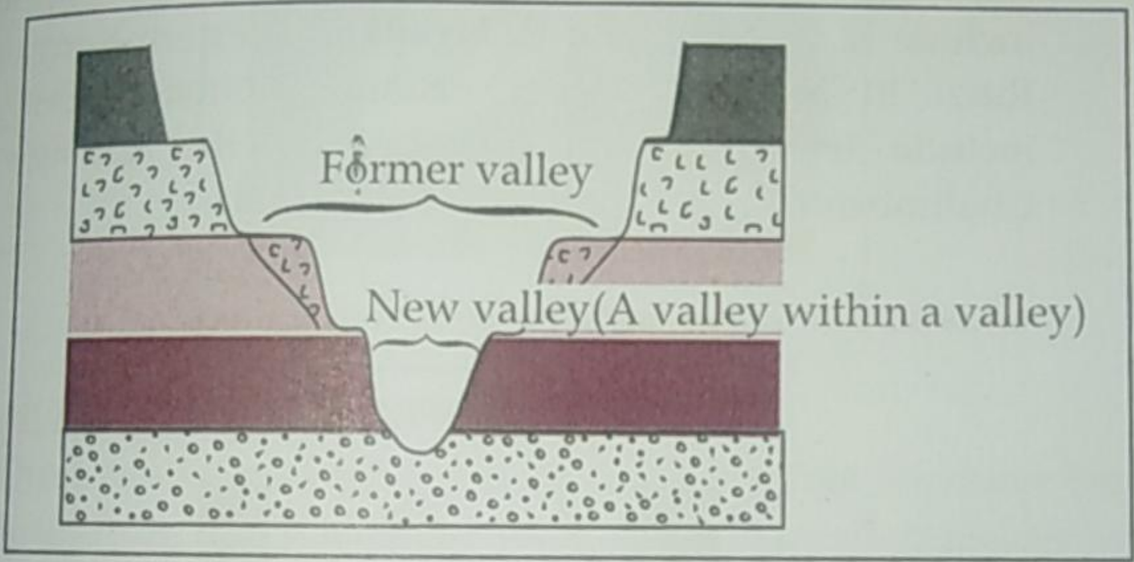
Effects of river rejuvenation on a landscape

(Landforms of river rejuvenation)

1. A valley in a valley:

Increased rejuvenation makes a river under cut its valley drilling a new valley within the old existing valley. Rivers like Ngaira, Ruizi and Nyando as it crosses the Kano plains, as well as Semliki and Kafu possess this feature.

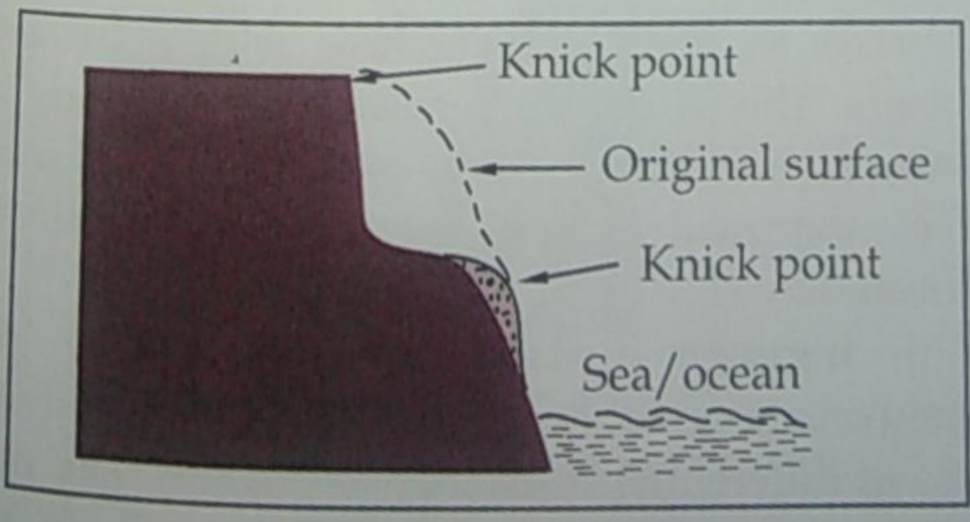
Illustration: A valley in a valley:



2. Knick point (rejuvenated head):

This refers to a break of slope in a long profile of a river valley where the new circle of erosion is created. A knick point is sometimes marked by a waterfall e.g. The Kabalega falls on R. Nile is at a knick point, R. Mkomazi in Tanzania and R. Mwachi in Kenya, are also at knick points.

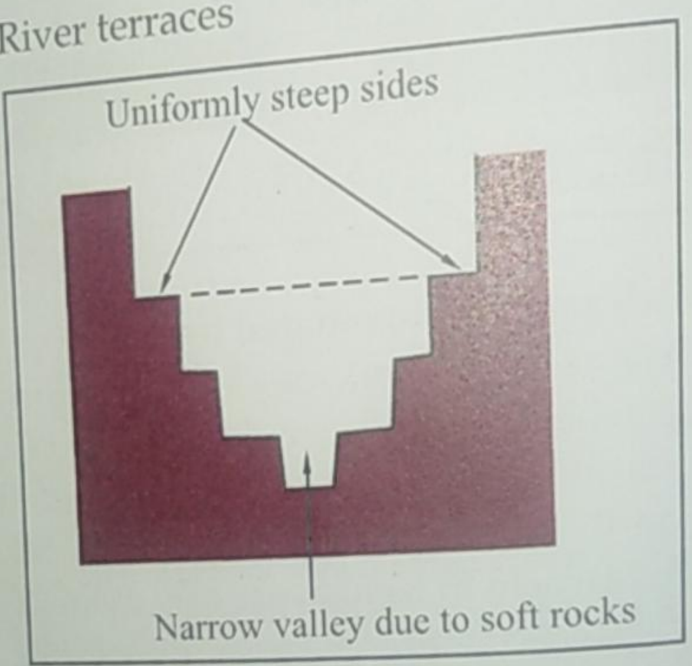
Illustration: Knick point



3. River terraces:

A river terrace is step or bench cut in the side of a river valley and covered by a layer of gravel and other alluvial deposits. River terraces are formed when a river renews the down cutting especially when there's a fall in the base level. If these terraces are found on equal height on either side of the valley, they are referred to as **paired terraces**. When a rejuvenated river undercuts downstream in a meandering form, **meander terraces** are formed. They seem to appear small in size and unpaired. Examples of rivers with terraces include R. Nyando, and R. Ngaila in Western Kenya and R. Ruizi in Mbarara. Other examples outside East Africa include terraces above the bed of the Chongwe and Chalimbana rivers East of Lusaka, Zambia.

Illustration: River terraces

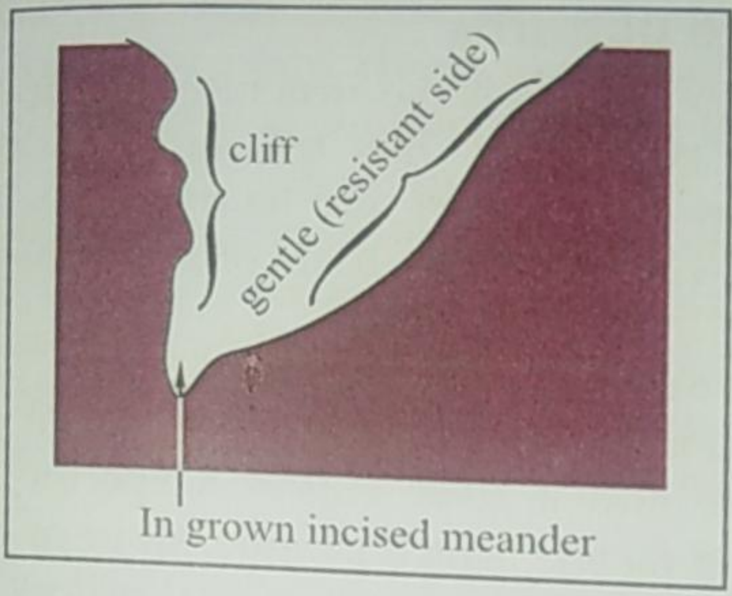


4. Incised Meander:

This is a curved bend of a river that has been incised in bed surface so that the river now winds between steep sided walls. This is due to renewed undercutting of the already meandering stream. There are two types of incised meanders i.e. ingrown incised meander and entrenched incised meander.

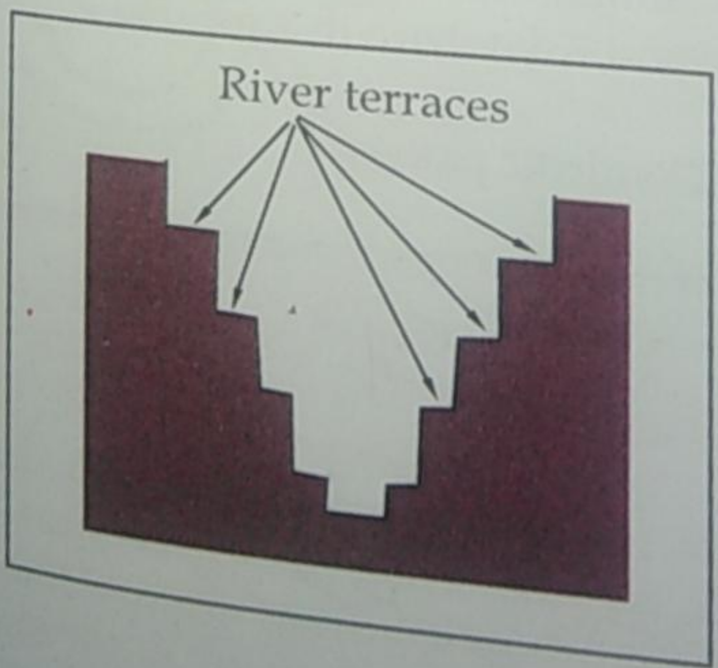
(i) **Ingrown incised meander**: These develop when rejuvenation makes a river incise its meanders, whose rocks have differential resistance to erosion. The resultant incised meanders will be asymmetrical in profile (not uniform) with deep under cutting on the easily eroded rocks to form a cliff while the slip off slope forms a resistant side. R. Mkomazi in Tanzania, Mwachi and Kyasimba in Kenya posses ingrown incised meanders.

Illustration: In grown incised meander



(ii) Entrenched incised meander:
These are formed when under cutting within meander bends is uniform on both sides forming an incised meander with symmetrical (uniform) side. For instance, all incised meanders on R.Mpanga, R.Mgeri, and R.Mutamuvara in Tanzania are of this type.

Illustration: Entrenched incised meander



Reference Questions:

1. Examine the causes and effects of River rejuvenation on East Africa's landscape.
2. With reference to specific examples and relevant diagrams, discuss the effect of river rejuvenation on Africa's landscape.

Drainage patterns

A drainage pattern is the structure, physical layout, or a plan made by rivers and their tributaries on the landscape. An area drained by a river and its tributaries is what is referred to as a drainage basin or a river basin.

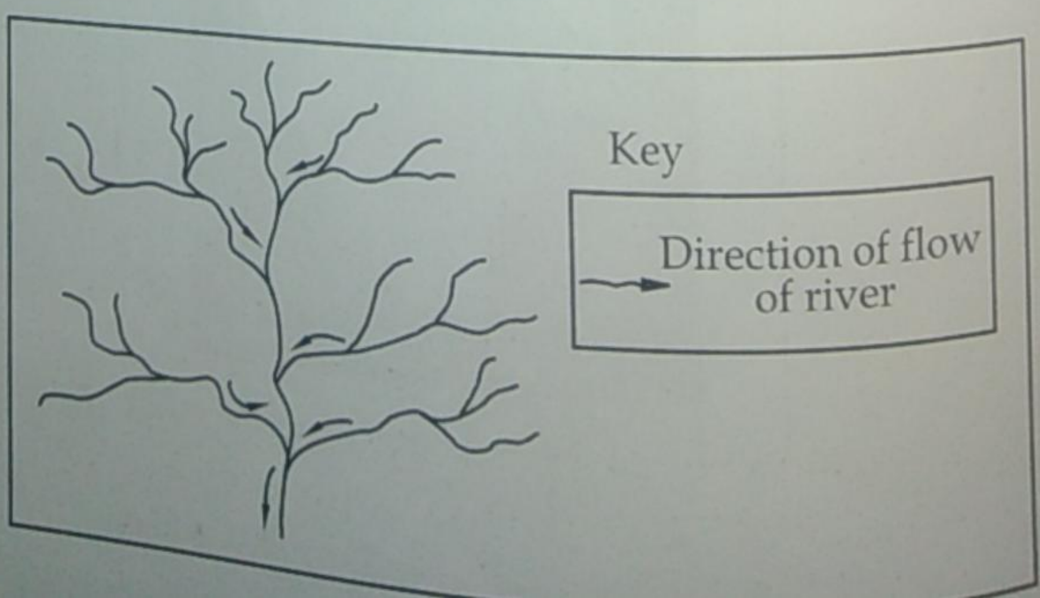
Types of drainage patterns

Under normal circumstances, drainage patterns develop with time and a river curves a specific pattern due to a number of factors which include: slope of the land, nature of rocks, earth movements, geological history of the area, actual surface network of streams and structure of the landscape.

(1) Dendritic Drainage Patterns.

This is a type of pattern where rivers and their tributaries converge at acute angles. Its structure resembles a structure of a tree and its branches. It is also likened to a sensory nerve. Such a pattern is displayed by rivers such as river Apwac in Kalongo area, river Athi and Tana in Kenya and rivers Rufigi and Kilombero in Tanzania.

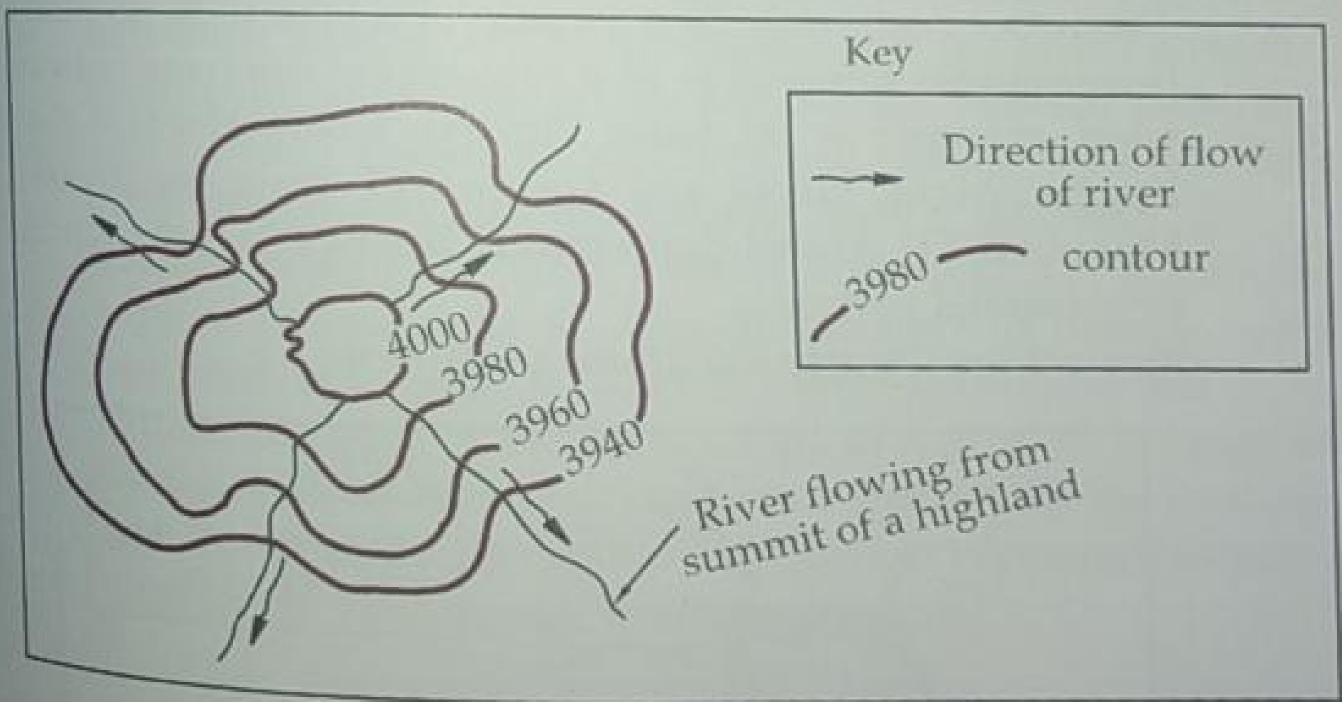
Illustration: Dendritic pattern



(2) Radial Drainage Pattern:

This is the type of pattern with rivers originating from a central point like dome shaped highlands and flow outwards to different directions like spokes of a bicycle wheel. They are long and swift, and on reaching a lowland they become tributaries of other main rivers. The major cause of this pattern is the nature of landscape or the gradient of land. Rivers having this pattern include R.Mobuku, R. Nyamwamba, R. Nyamugasani and R. Lume all flowing or radiating from Mt. Ruwenzori, R.Sironko, R.Sippi, R. Malaba, River Koitobus all radiating from Mt. Elgon, R. Himo, R. Ruguti, R. Mutonga, R. Sagana, R. Kathita, R. Isiolo and R. Tsavo flowing from Mt. Kilimanjaro, form a radial pattern.

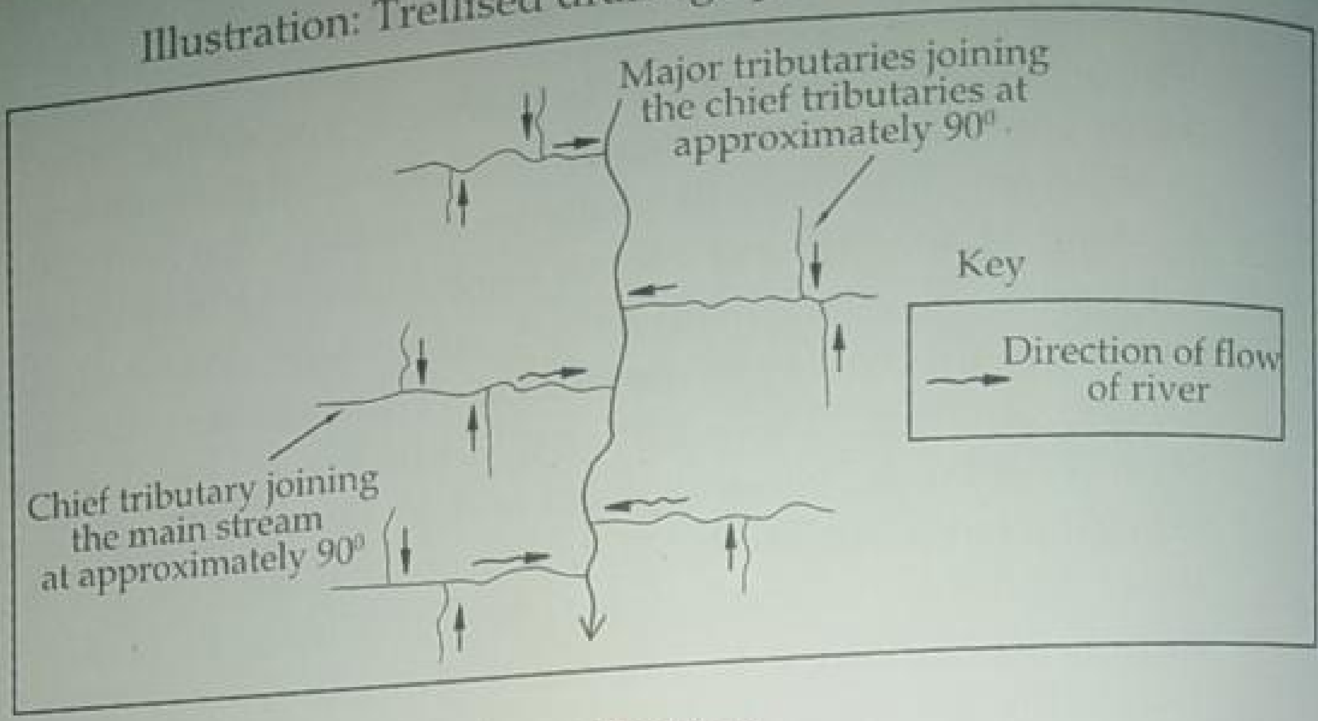
Illustration; Radial drainage pattern



(3) Trellised Drainage Pattern:

This is a pattern where the tributaries of the main river join the latter at approximately right angles. It is common in areas with heterogeneous rocks especially where differences in rock hardness exist, in elongated channels that were formed due to earth movements and glaciation. For example the tributaries of River Aworanga in Northern Uganda and River Mlovo in Tanzania display this pattern.

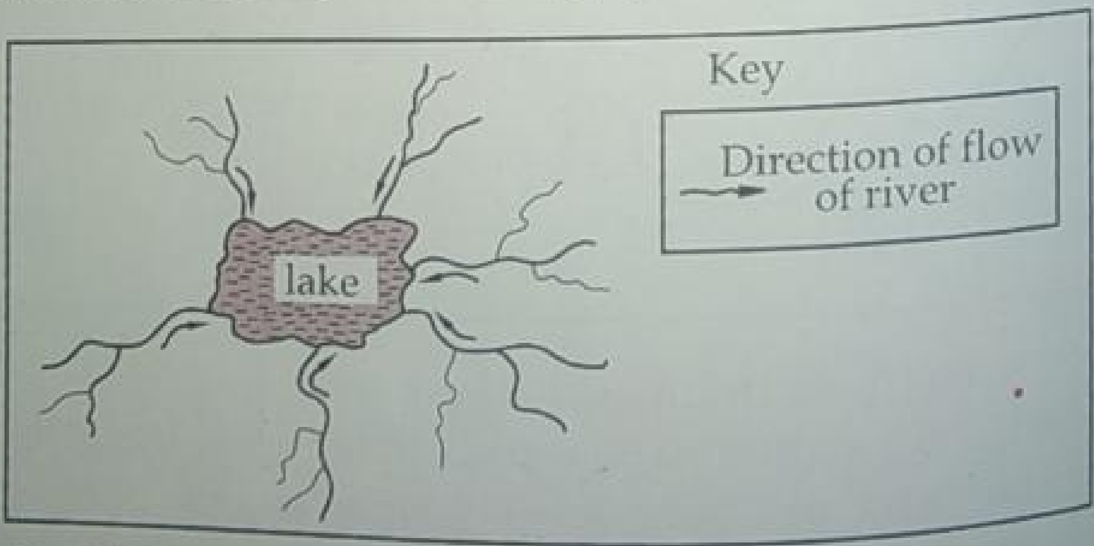
Illustration: Trellised drainage pattern



4. Centripetal Drainage Pattern:

This is the type of pattern where numerous rivers converge from different directions in a depression or a water body. The water body may be a swamp or a lake with no outlet. It is sometimes referred to as a convergent drainage pattern. A good example is on Lake Victoria where rivers Katonga, Kagera, Mara, Nzoia and Gurumenti drain in. Rivers O1 Mukutani, O1 Arabel drain into L. Baringo in Kenya forming a centripetal pattern.

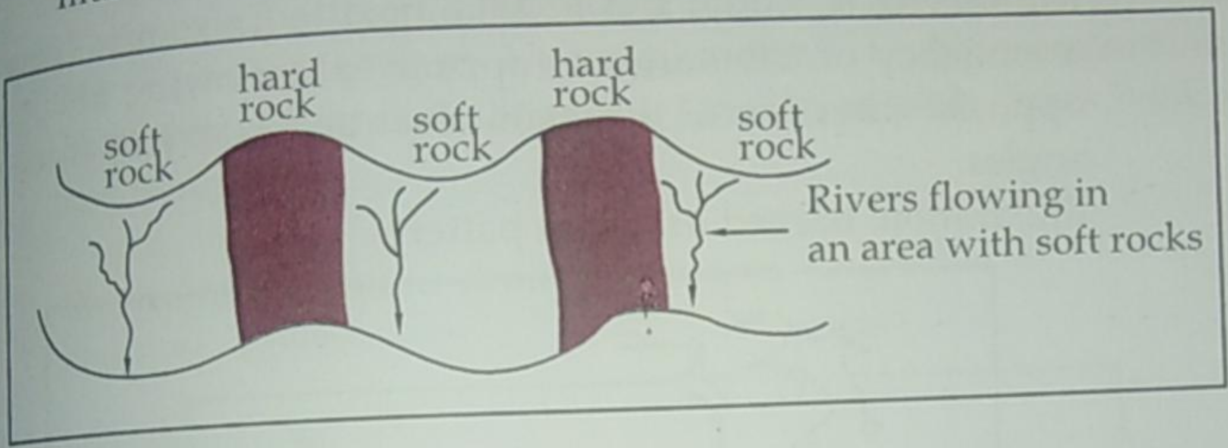
Illustration: Centripetal drainage pattern



5. Parallel Drainage Pattern:

This is the type of pattern that develops in areas with alternating hard and soft rocks, such that rivers create their own courses along soft rocks separated by hard rocks. Such rivers are said to be parallel to each other and normally flow in the same direction. This pattern is displayed in the eastern slopes of Aberdare ranges and west of Mau ranges (Kenya) where tributaries of river Athi, Nairobi, Rwiru, Thirika and Komu flow parallel to one another.

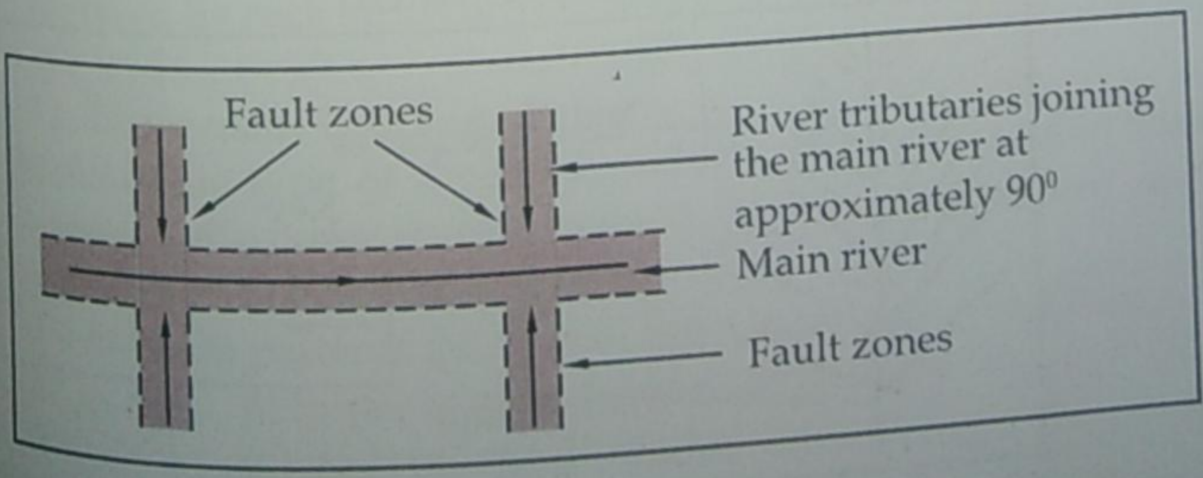
Illustration: Parallel drainage pattern



6. Rectangular Drainage Pattern:

This is the type of drainage pattern which displays a rectilinear shape, where tributaries join the main stream at approximately right angles just like the trellised pattern. This pattern normally develops in areas affected by earth movements and the streams have a tendency of flowing in joints or fault lines within rocks i.e. are fault guided. For example R. Athi drains into L. Baringo with this kind of pattern; R. Mara in Kenya also forms this pattern, R. Aswa in the Kerio valley of Kenya, R. Pangani at the foot hills of Pare and Usambara mountains in Tanzania and the upper Nile north of L. Albert in Western Uganda.

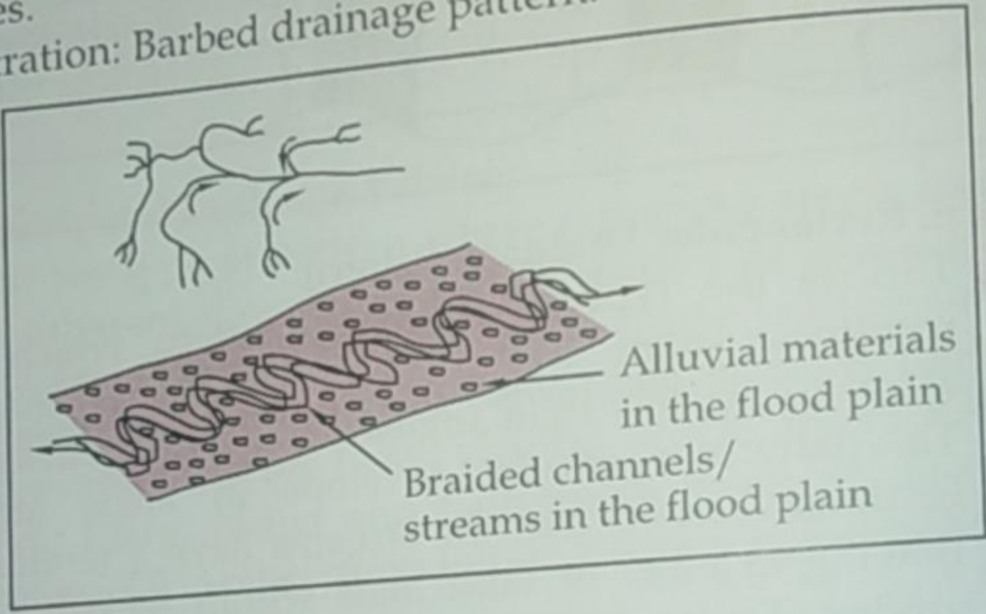
Illustration: Rectangular drainage pattern



7. Barbed or Braided Drainage Pattern:

This is the type of drainage pattern where a river splits up into many tributaries or distributaries due to accumulation of materials (levees) along their channel. This kind of pattern is normally displayed by rivers in the old stage; for example R. Birira that flows into L. Edward. Other examples are R. Kilombero, R. Rufigi and R. Mkomazi in Tanzania. There is a tendency of tributaries to appear to be flowing in opposite direction of the main river and later join at acute angles.

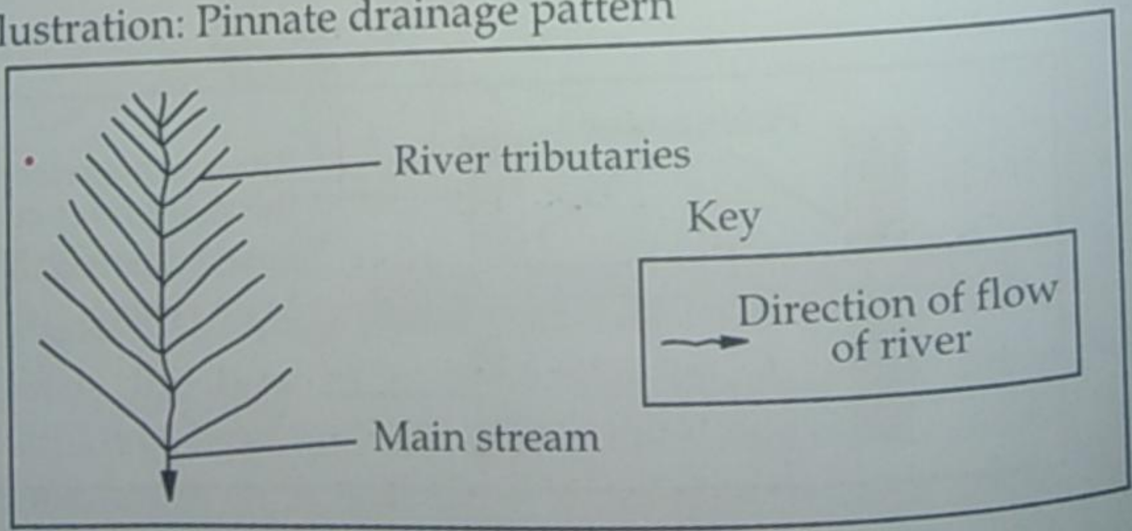
Illustration: Barbed drainage pattern.



8. Pinnate Drainage Pattern:

This is a type of drainage pattern where tributaries join the main river at extreme acute angles in form of a feather. For example, the parts of the Kerio valley in a secondary rift valley in western Kenya show this pattern.

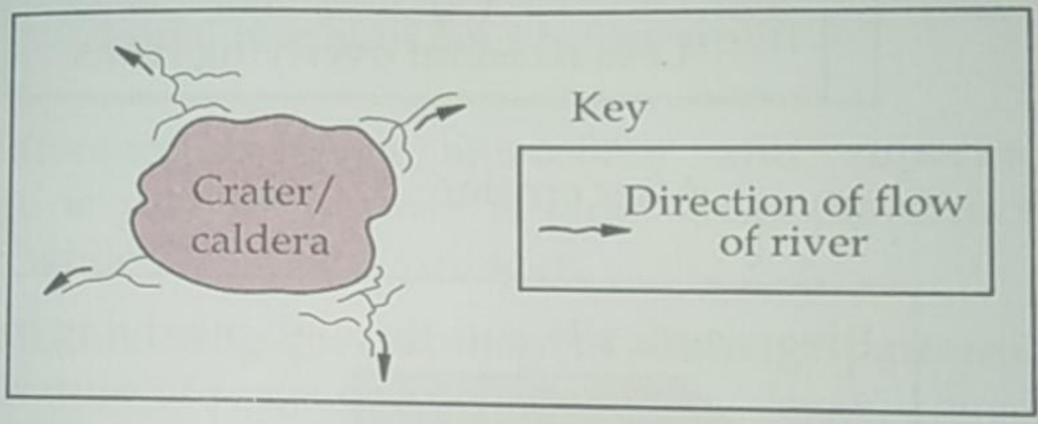
Illustration: Pinnate drainage pattern



This pattern normally develops in areas which experience high amounts rainfall, gently dipping slopes with uniform rocks resistant to erosion.

9. Annular Drainage Pattern:
This is a pattern where tributaries join the main stream at sharp angles but arranged in a series of curves around a crater or a basin or a dissected dome. For example around Mt. Elgon in eastern Uganda, around L. Ngorongoro in Northern Tanzania, L. Bosmutwi in Ghana with rivers Banko and Benin.

Illustration: Annular drainage pattern



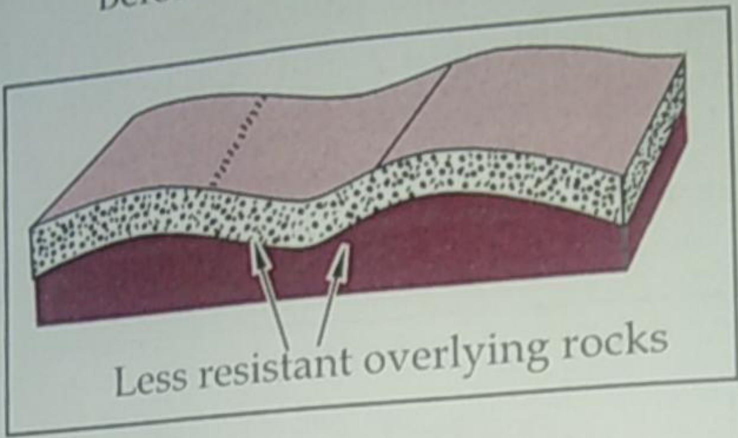
10. Accordant Drainage Pattern:
This is the type of the drainage pattern where rivers and their tributaries flow is determined by the underlying rock structure. In this pattern, streams naturally flow along easily eroded rocks avoiding resistant rocks. Many drainage patterns are accordant because their direction of flow is dictated by rock structure i.e. nature of rock.

11. Discordant Drainage Pattern:
This is the type of drainage pattern where rivers and their tributaries' flow is not related to the underlying rock structure.
Discordant patterns are of two types namely;

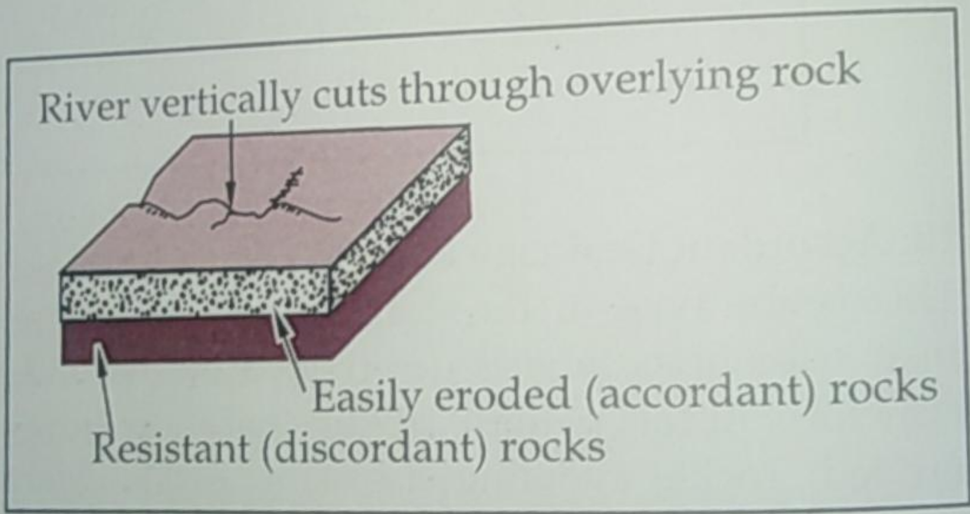
(i) Super imposed drainage pattern.
(ii) Antecedent drainage

The **super imposed drainage pattern** develops when a river initially flows on rocks which are accordant (related) and easily erodable, but with increased down cutting. The river finally flows over underneath buried rocks that are completely not related (discordant) to the flowing river. For example the Nile river at Sabaloka in Sudan forms this kind of pattern.

Before erosion

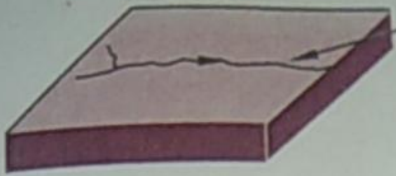


After erosion



Antecedent drainage pattern develops when a river flows on a landscape later uplifted by local earth movements, but as the uplift occurs, the river maintains its flow by vertically eroding the valley at a rate balanced with the rate of uplift.. This implies that the uplift should be so slow to enable the river maintain its course through vertical erosion. Finally, a river cuts a deep gorge within the uplifted landscape. Such a pattern exists on the great Ruaha river in Tanzania; River Birira is antecedent at Mitano gorge, Niger, Antecedent River above Jebba in Nigeria.

(i) Illustration: Landscape before uplift



(ii) Illustration: After uplift

The difference between antecedent and superimposed drainage is that the former is older than the structure it crosses, while the latter is younger.

Factors influencing development of drainage patterns

- **Nature of rocks or Rock structure**
  - The presence of massive homogenous rocks that offer uniform resistance to stream erosion leads to development a dendritic drainage pattern and a radial drainage pattern. This is because rivers are able to erode uniformly and develop a variety of river tributaries.
  - On the other hand, existence of heterogeneous rocks (alternate hard and soft rocks) in an area allows differential erosion to take place leading to development of a parallel pattern, annular pattern and a trellised drainage pattern. This nature of rocks partly explains why rivers can't meet at a specific point.
  - The presence of jointed or faulted rocks has encouraged development of a trellised and rectilinear drainage pattern. This is because streams take advantage of the joints or fault

lines to carry out erosion and flow to their destined areas. They are also easily erodeable rocks that at times lead to development of a centripetal drainage pattern.

- The presence of steeply dipping rocks encourages the development of a radial drainage pattern especially if it is on a dome shaped upland.This is evident on Mountain suswa in Kenya and mountain Ruwenzori in Uganda.
- The presence of impervious rock structure in a drainage basin or a catchment area encourages drainage, causing alot of runoff in form of streams.This leads to the development of a dendritic drainage pattern as indicated by River Apwac and its tributaries in the kalongo area of Northern Uganda.

❖ **Relief or nature of slope**

- Existence of highlands with steep slopes favours the development of radial and annular drainage patterns. This is because the highlands are water catchment areas for rivers since some highlands like Ruwenzori and Kilimanjaro have snow at the summit. The steep slopes accelerate the downward movement of rivers along rocks for their continuous flow.
- Gently sloping areas favour the development of dendritic drainage pattern. This is because gentle slopes enable flow of rivers by gravity and develop several tributaries.
- The basins or depressions encourage the development of the centripetal drainage pattern. This is because, basins being at a lower gradient, they allow several rivers to drain into them.
- Existence of hills separated by wide valleys leads to development of a trellised drainage

pattern. In an attempt by river tributaries to avoid the hilly areas that are resistant to erosion, they follow wide valleys that are easily erodible and in the process join the main stream at right angles, hence forming a trellised pattern.

❖ **Tectonic processes**

- Warping led to the development of a centripetal drainage pattern. Areas in East Africa that were affected by upwarping and downwarping, that is Western Uganda and central Uganda respectively led to the formation of down warped basins of Victoria and Kyoga. For instance, upwarp of the western and eastern rift valley shoulders led to the reversal and rejuvenation of rivers respectively. Rivers Katonga and Kagera reversed their direction while rivers Mara, Nzoia and Gurumenti rejuvenated and in the process poured their waters in the down warped basin of Victoria forming a centripetal drainage pattern.

- Faulting led to the development of fault lines or joints which influenced the flow of rivers and their tributaries. These fault lines encouraged the development of trellised and parallel drainage patterns.
- Faulting also led to the development of antecedent drainage pattern. Faulting caused the uplift of the landscape, but as uplift occurred, rivers maintained their flow by vertically eroding the valley at a rate balanced with the rate of uplift, hence cutting a gorge within the uplifted landscape. Such a pattern exists on the great Ruaha river in Tanzania.

- **Nature of climate**
  Areas with reliable rainfall equally account for the development of drainage patterns. This is because; ample rainfall is required to enable the development of the main streams and the continuous flow of their tributaries. This leads to the development of several drainage patterns. All drainage patterns develop as a result of reliable rainfall in a catchment area.

- **River capture**
  In circumstances where a strong river is able to erode its valley deeply and diverts the waters of a neighbouring weak stream, into its own channel, a number of drainage patterns such as trellised, dendritic and barbed may develop. For example, when the lower Tiva captured the upper Tiva, which was a former tributary of the Galana river in Kenya, a dendritic drainage pattern emerged.

Reference Questions

1. Account for the development of the following drainage patterns;
   (a) Dendritic
   (b) Annular
   (c) Rectangular
   (d) Parallel
2. To what extent has the nature of rocks influenced the development of drainage patterns in East Africa?
3. (a) Distinguish between a radial and dendritic drainage pattern.
   (b) Explain the influence of rock structure on the development of drainage patterns in East Africa.
4. To what extent has relief influenced the development of drainage patterns in EastAfrica?
5. Examine the factors influencing the development of drainage patterns in East Africa?

Economic importance of rivers

Positive importances

1. Rivers are sources of transport routes along their valleys especially where roads and railways follow the profile of a river and in the old stage.
2. They supply water used for irrigation by farmers e.g. River Mobuku is used for irrigation farming in the Mobuku valley of Mt. Ruwenzori.
3. Rivers are potential sources of hydro-electric power generation at Knick points and waterfalls. Notable examples are Owen falls hydro power project and Bujagali power project on the River Nile. Hydroelectric power is important for industrial development and domestic consumption.
4. Flood plains and deltas of river valleys contain alluvial fertile soils which favour agricultural activities. E.g. the River Nile flood plain in Egypt is agriculturally very productive.
5. Some river mouths contain deep sheltered water which enables port development. For example Alexandria Port on the distributary of the River Nile.
6. Due to fertile soils in mature river valleys and flood plains, settlement is suitable.
7. Rivers are sources of water for industrial use e.g. the Breweries industry and soft drinks use water as a raw material and for cooling machines (industrial equipment)
8. River and their associated features like waterfalls and gorges are a tourist attraction, hence are sources of foreign exchange. E.g. Karuma and Murchison falls on the R. Nile attract tourists in Uganda.
9. Papyrus swamps along river profiles are sources of raw material for the craft and paper industries.
10. Some rivers are valuable sources of fish which is economically important and a food (protein) for human consumption.

11. Some rivers are used to demarcate boundaries of different places internally and externally. E.g. River Semliki marking the Uganda – D.R. Congo border.
12. Rivers enhance the mining industry due to great deposition of sand, silt and clay along their flood plains.
13. Development of recreation facilities along river flood plains.

Negative importances

1. Swampy areas along river profiles harbour disease carrying vectors like mosquitoes which scare away human settlement.
2. River valleys are dumping sites for waste material; this causes river water pollution which destroys aquatic life. This retards fishing on rivers.
3. River features like waterfalls, rapids, gorges, knick points and terraces hinder transport development along their valleys.
4. Large rivers occupy vast areas that would be used for development through activities like industrialization and farming.
5. Changes in river volumes (river regimes) can destroy scenic beauty of certain areas, hindering tourism development and other activities like transportation.
6. Rivers breed conflict among nations and local people about ownership rights. For example there are quarrels amongst people in Western Uganda and the Congolese (D.R. Congo) about the ownership and utilization of River Semliki.

Reference Questions

1. Assess the economic significance of rivers to East Africa.
2. Discuss the importance of rivers to people in East Africa.
3. Examine the role of rivers to the economic resource base of African countries.

8 CHAPTER GLACIATION

Introduction

It is a process through which moving ice as an agent of erosion, transportation and deposition modifies the landscape and forms landform features. Glaciation therefore results from the work of *glaciers*.

A glacier is a mass of ice moving outward from an area of accumulation usually a mountain top (higher) to a lower ground. It is sometimes referred to as a mass of ice largely confined within a valley. Glaciers exist in the Atlas Mountains, the Cape Ranges, the Ethiopian Mountains, the Drakensburg Mountains, the Ruwenzori Mountains, Mount Kenya and Mount Kilimanjaro. However, it is only on the last three East African mountains that permanent glaciers exist.

Today ice sheets are confined to Antarctica (13 million Km^2), Greenland (1.872 million Km^2) and to the high mountains above the snow line. This lower limit of permanent snow is known as the *snow line*. However, much of these ice sheets are still retreating, i.e. melting due to climatic change (global warming) and their waters are raising the level of oceans by about 2 inches in a century.

Process of glacial ice formation

All glaciers are derived from snow, when snow falls; it accumulates on the land surface. More addition of snow adds to the weight of accumulation and the lower ice crystals are compressed, this is followed by melting of ice, water percolates down filling the air spaces before refreezing occurs. In the process air is squeezed out of minute crystals due to extreme compression. A solid impermeable layer called a glacier ice is formed. The study of the formation and behaviour of glacier ice is known as *glaciology*.

Types of glaciers

(i) Cirque glaciers:
When ice accumulates in a mountain-top depression and does not extend down the mountain side, it forms a cirque glacier. Sometimes it hangs over an edge of the depression to form a *hanging glacier*.

(ii) Valley glaciers:
If the ice flows out of a depression and extends down along a valley below the snow line it forms an *alpine* or *valley glacier*.

(iii) Predominant glaciers:
These form at a point where two or more valley glaciers join, where they emerge from their valleys onto plains.

(iv) Ice sheets or ice cap glaciers:
These are the largest type of glacier which largely submerge the pre-existing landscape and their movement is controlled by the thickness of ice rather than topography. The Arctic and Greenland ice sheets are the largest of this type.

Glaciation in East Africa

In East Africa permanent glaciers are confined to the summits of the three tallest mountains of Ruwenzori, Kenya and Kilimanjaro. The present glaciers found in these highlands are remnants of much bigger features that existed during the Pleistocene ice age (2 million years ago). During the ice age when glaciers covered a wide area in East Africa, they were only confined to the higher mountains above 2000m – 3000m above sea level.

Figure 10: Glaciers on Mt. Ruwenzori, Western Uganda

The extensive glaciers that once existed have now decayed and retreated to the smaller patches on the summits of three East Africa higher mountains. For example the Stanley glacier found on Stanley peak of Mt. Ruwenzori, Lewis glacier on Mt. Kenya, and the Penk glacier on Mt. Kilimanjaro. However, of the three glaciated mountains in East Africa, Ruwenzori is the most significant, with 37 glaciers mainly on Mount Speke, Stanley and Baker peaks.

Conditions responsible for occurence of glaciers in East Africa.

i) Altitude:

This refers to the height above sea level. In East Africa, areas above 4700m (16,000 feet) sea level have permanent snow cover. This therefore implies that 4700m above sea level is the permanent snow line in East Africa (a line above which snow cannot melt). It is only mountains Ruwenzori, Elgon and Kilimanjaro with such a snowline in East Africa.

ii) Relief:

This is the general appearance of the landscape. The gradient of slope determines the movement of ice, steep areas of highland areas accelerate movement of ice downwards at high rate, and gentle slopes encourage (ice) movement at a moderate speed. Valleys and depressions are accumulation areas for glaciers. This is evident in Kamusoso valley of Mt. Ruwenzori and Karanga valley of Mt. Kilimanjaro.

iii) Precipitation:
Glaciated mountains in East Africa receive much precipitation in form of snow from which glaciers originate. Mt. Ruwenzori although shorter than Kilimanjaro has much glacier coverage. This is because the former experiences high precipitation in form of snow than the latter.

Factors for the limited glacial coverage in East Africa
However, although glaciers exist in East Africa, in reality they cover a small area than before (i.e. during the Pleistocene ice age) because of a number of factors which are summarized as follows:

(i) Latitudinal location:
East Africa is located astride the equator where temperatures are constantly high due to the effect of the overhead sun. The high temperatures melt down the would be glaciers thus limiting wide glacial coverage.

(ii) Effect of Altitude:
Even during the Pleistocene period when the snow line was between 2000m 3000m above sea level only limited areas in East Africa (less than 5%) were glaciated. Currently the snow line is at 4700m above sea level and only three mountains, Ruwenzori, Kenya and Kilimanjaro attain this snow line.

(iii) Vulcanicity:
Most of the tall mountains in East Africa that would be glaciated are volcanic and therefore warm. Mt. Kilimanjaro is said to be getting warmer thus melting much of its glaciers. Mt. Kilimanjaro and Mt. Kenya are warm due to the hot interior, hence melting much of their glaciers. This is why of the three mountains that are glaciated in East Africa, have the least glaciers.

(iv) Global warming:
World temperatures are progressively rising due to several reasons like depletion of the ozone layer by green house gases. For instance many glaciers on Mt. Ruwenzori have melted due to the persistence rise in temperatures (global warming). It is estimated that glaciers on top of Mt. Ruwenzori disappear by 10 metres annually. If the current temperature rise persists, Mt. Kilimanjaro glaciers will be gone by the year 2027.

(v) Rain shadow effect:
Normally leeward sides of highlands are warm (hot) due to the effect of dry descending winds and adiabatic compression. This melts the glaciers on the leeward side. For example Mt. Ruwenzori though the shortest of all the three mountains, it has a number of glaciers because of heavy precipitation due to moisturized ascending westerly winds on its windward slopes.

(vi) Limited precipitation:
There are very few mountains in East Africa which experience sufficient precipitation in form of snow. For example Mountain Ruwenzori has more glaciers than Mountain Kilimanjaro as it experiences more precipitation despite being shorter.

(vii) Absence of winter season:
There are absolutely no winter seasons in East Africa, this would have contributed to high rate of glacier formation.

(viii) Pollution:
Most regions in East Africa are highly industrialized; this contributes to pollution hence increasing atmospheric temperatures which melt glaciers that would have existed.

Work of glaciers

Like Rivers, waves and wind, glaciers carry out erosion, transportation and deposition of eroded materials to low-lying areas.

Glacier erosion

This is a process through which moving ice, wears out the landscape on which it moves to form landform features. Stationary ice or ice with little debris has limited erosive power, while moving ice carrying with it debris can drastically change the landscape. Although ice lacks the turbulence and velocity of water in a river, it has advantages of being able to melt and re-freeze in order to overcome obstacles as the climate is too cold for chemical weathering to operate. Glacial erosion takes place beneath glaciers at the sides of valley glacier. It is therefore very difficult to observe glacial erosion in action. However there are mechanisms through which glacial erosion takes place.

Glacial erosion processes

(i) Plucking:

This process is also called **exeration**. It is a process where a glacier removes pieces of rock embedded in the base of a glacier. It occurs when the ice at the base of a glacier freezes into the crevices or cracks within the rock. As more ice accumulates, the pressure increases, layers of rocks are torn and moved away by the moving ice. This process causes more stress in the rock making the joints to enlarge and creating new ones. Freeze and thaw activity is increased. This process is very effective on well jointed rocks where melt water can refreeze in cracks.

(ii) Abrasion:

This is also called **Corassion**. It is a process through which rock particles such as pebbles and boulders are used by glaciers as grinding tools to wear out the channel. It occurs when the materials or boulders frozen into ice are dragged over the rock floor, polishing, scouring and scratching the surface forming deep grooves and striations. The magnitude at which the rock floor is scratched depends on the hardness of materials carried by ice and that of the rock floor. In this process ice uses materials it is carrying as an abrasive tool to erode the rock surfaces.

(iii) Bassal sapping:
It is also called *rotational slip* or *nivation*. This is frost shattering that occurs on the margins of a hollow or basin on a mountain side. This occurs when alternate freezing and thawing of ice and weathering shatters the rock along lines of weakness (back wall of a cirque). When melt water enters the cracks of a rock, it later freezes into ice which (ice) enlarges the joints due to increased pressure on crack walls. This ultimately shatters the rock, making the rock particles fall off to form moraines at the base of the rock. Plucking and abrasion only help to make the hollow formed by basal sapping appear bigger and deeper.

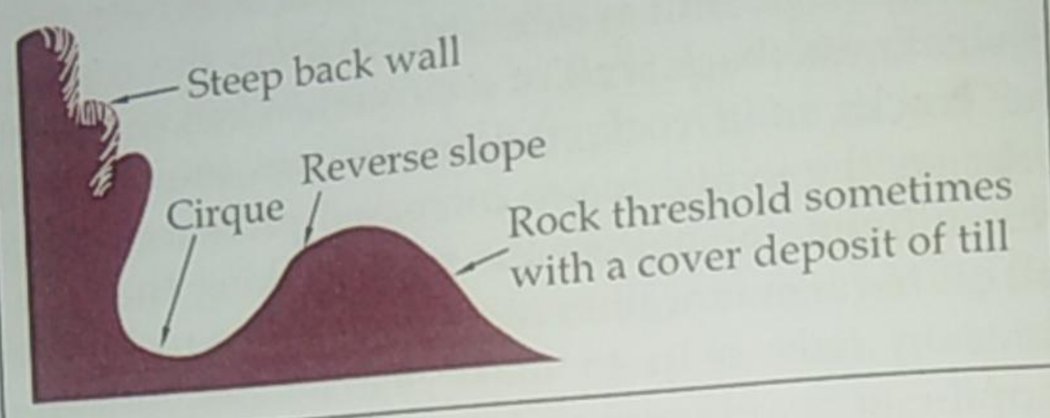
Effect of *Glacial Erosion* on landform feature development

A. Erosional upland features

1. Cirque/corries/cwm
A cirque is a steep sided rock basin, semi-circular in plan, cut into a valley head and mountain side. It is also called a **corrie** in England and **cwm** in Wales. Cirques usually develop from nivation hollows. Through the process of **nivation**, intense shattering of highland slopes tends to produce pre-glacial hollows where ice accumulates. Water freezes in the hollows and thaws or melts. This process causes expansion and contraction of crack walls, which ultimately breaks down the rocks through the process of **plucking**. As the rocks break, the hollow is enlarged. A combination of erosion and weathering on the sides of the hollow extends the sides of the depression. This is known as **basal sapping** or **back wall recession**. Plucking and abrasion helps to make the hollow deeper. With time, a big rock basin is formed. Debris from the hollow is removed by solifluction creating a semi-circular basin known as a cirque. However, when ice melts, water accumulates in it to form a lake known as **tarn**. Cirques in E

Africa include Lac du Speke, Lac du Catherine, Lac Noir along Mt. Ruwenzori, Emerald, Nanyuki and Tyndal tarn on Mt. Kenya and the North cirque and Mawenzi tarn along Mt. Kilimanjaro.

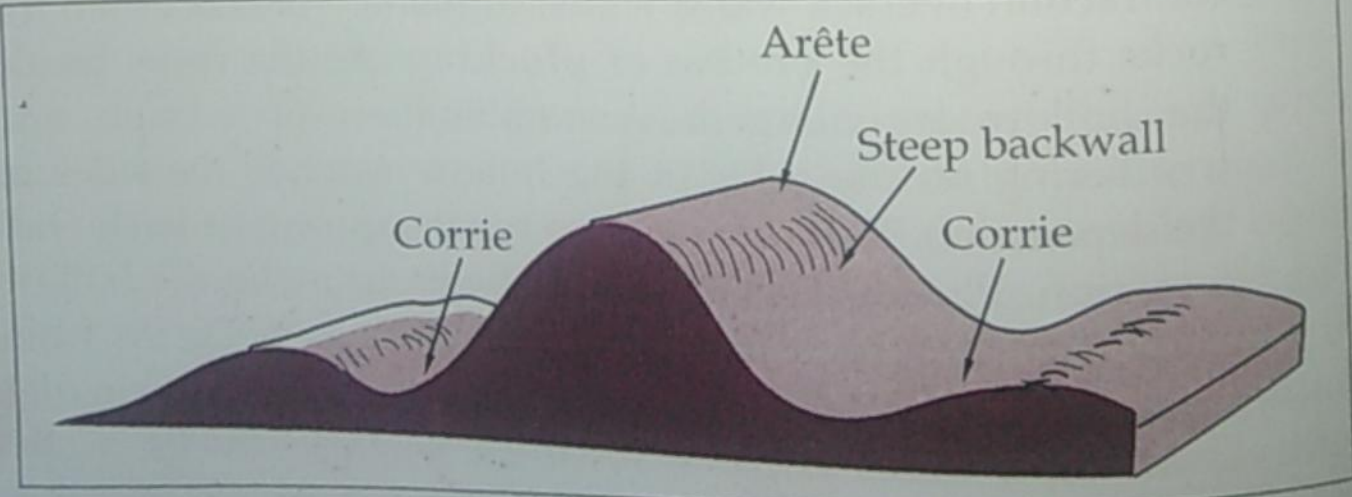
Illustration: formation of a cirque



2. Arêtes:

An arête is a narrow steep sided rocky ridge separating two adjacent cirques. It's formed when moving ice receeds two adjacent cirques backwards on a mountain side (back wall recession) through **abrasion.** Parts of a rock on the sides of a corrie are loosened and ultimately detached and removed. When this occurs over time, the corrie enlarges and its back wall retreats into the mountain. An adjacent corrie may be at the same time developing in a similar way and its back wall retreating. This process reduces the area separating the two corries to only a narrow "knife sharp ridge." Arêtes can be traced on mountains, Kilimanjaro, Ruwenzori and Kenya in East Africa.

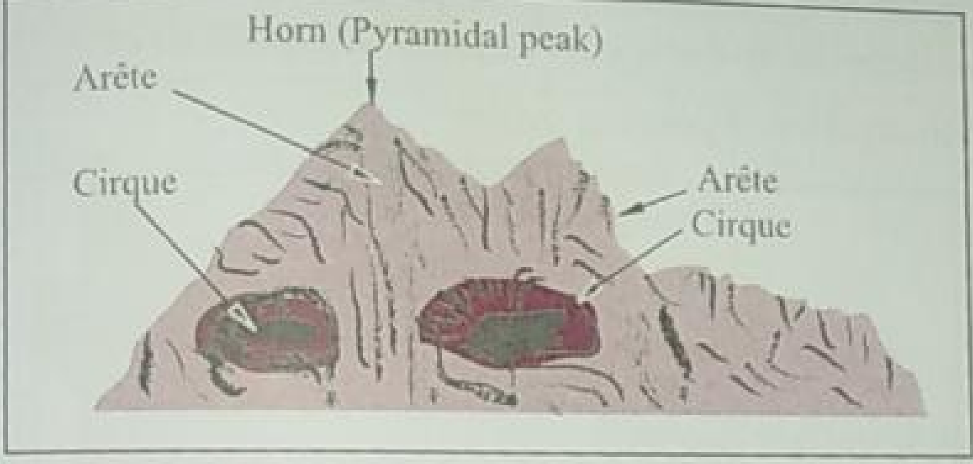
Illustration: formation of an arête



3. Pyramidal Peak.

This is a steep sided horn surrounded by cirques and a radiating system of ice. It is the surviving top mountain mass that has resisted glacial erosion, relative to neighbouring rocks. It is formed at the junction of arêtes as a result of back wall recession of two or more corries developing on all sides of the mountain. Pyramidal peaks include Margherita peak on Mt. Stanley, Mt. Baker, and Mt. Sovia all on Mt. Ruwenzori, Nelion, Bation and Midget peaks on Mt. Kenya.

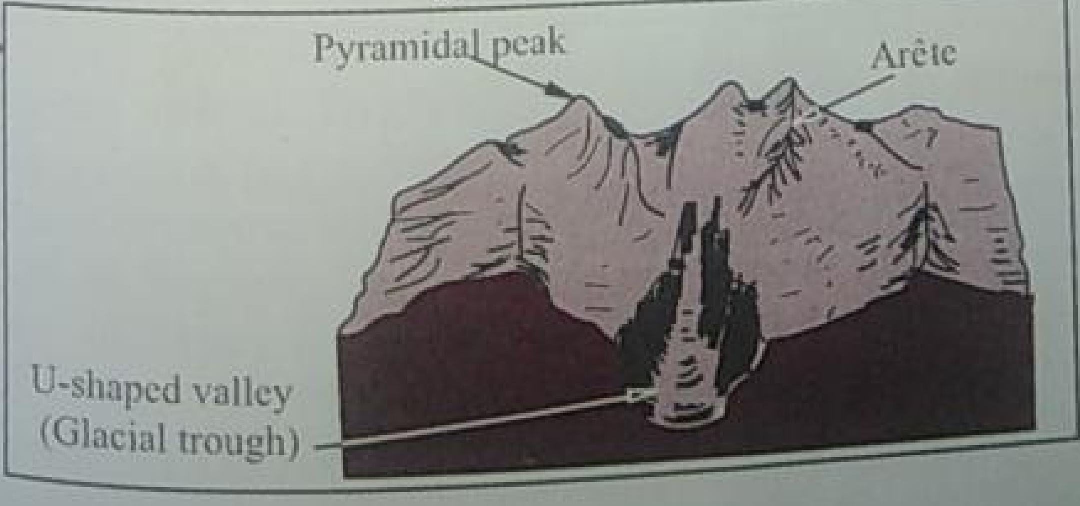
Illustration: Pyramidal peak



4. Glacial trough:

It is sometimes called a U-shaped valley. This is a wide relatively flat and steep sided valley. The plucking and **abrasive** nature of main glaciers with debris, deepens, scratches, polishes and widens a former narrow river valley gradually turning it into a wide valley called a glacial trough. Most glacial troughs are former river valleys that have been modified by ice erosion. Examples include; Bujuku, Mubuku, Kamusoso and Luziluble glacial troughs in Mt. Ruwenzori Teleki valley in Mt. Kenya and Karanga valley in Mt. Kilimanjaro.

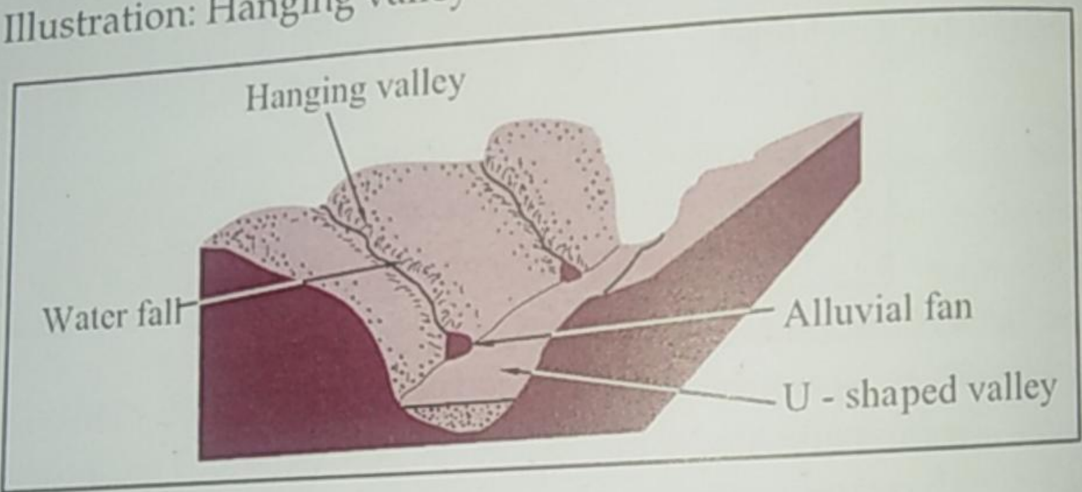
Illustration: Glacial trough



5. Hanging Valley:

This is a tributary valley of a glacial through which ends abruptly high above its floor. As a result of differential erosion between the glaciers of the main valley and tributary valleys, glaciers cut the floor of the main valley at a higher rate compared to the tributary valley. When glaciers in the tributary valley ultimately melt, it is left hanging above the main valley, hence the name "hanging valley". When a river flows in this hanging valley it plunges a waterfall. When the ice has disappeared with alluvial fans at the base i.e. with more accumulation of alluvial materials like sand at the point where the tributary river joins the main river.

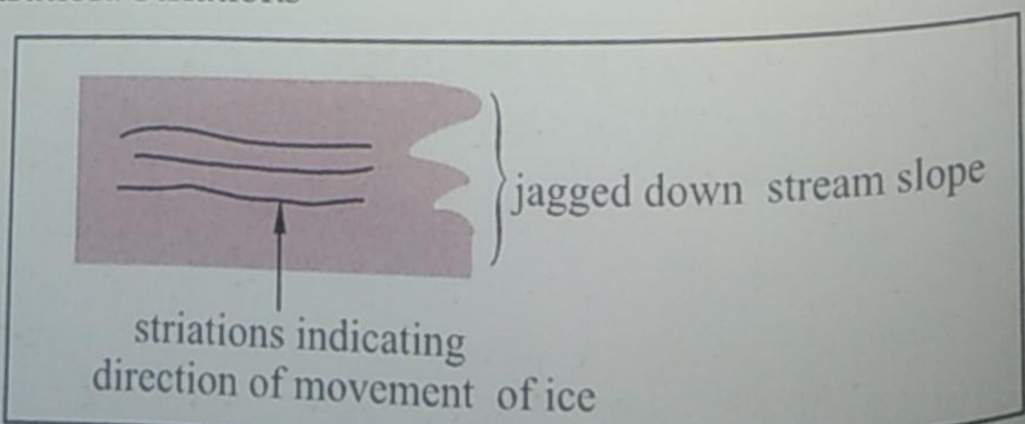
Illustration: Hanging valley



6. Striations:

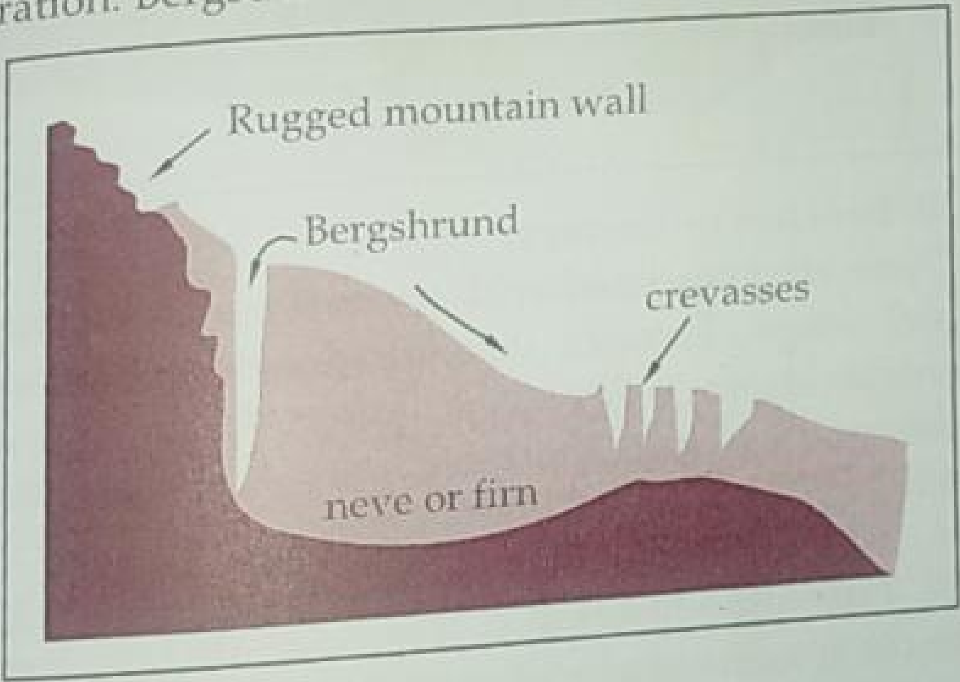
They are often parallel scratches made by rock materials embedded in glaciers along rock surface. The **plucking**, and **abrasive** role of glaciers with trapped debris, smoothens and scratches the surface of rocks forming scratches called striations. The direction of the striations indicates the movement of ice. Ice scratched rocks can be seen on the long profile of the Mobuku valley on Mt. Ruwenzori.

Illustration: Striations



7. Bergschrund:
At the head of a glacier, where it begins to leave the snow field of a corrie, a deep vertical crack opens up called a bergschrund (German) or rimaye (French). This happens in summer, when ice continues to move out of the corrie, there is no new snow to replace it. In some cases, not one but several cracks occur. Further down where the glacier negotiates a bend or a precipitous slope, more crevasses or cracks are formed.

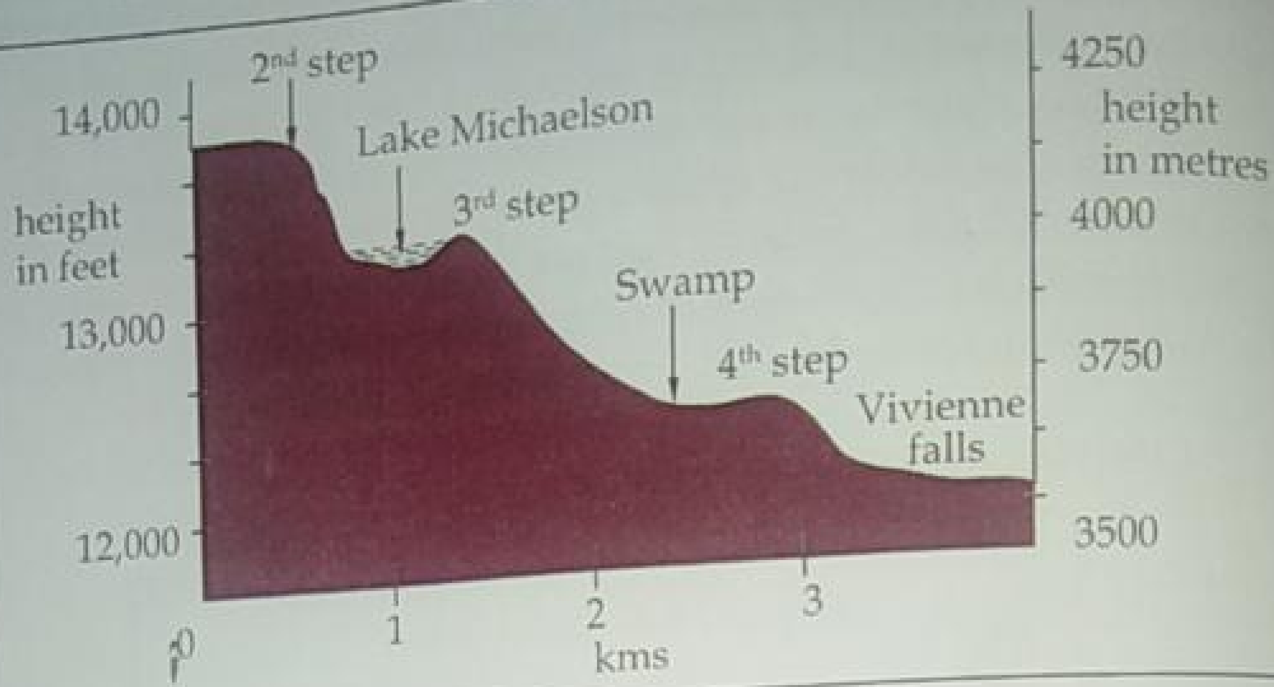
Illustration: Bergschrund



8. A trough end:
This is a steep wall formed when a series of cirque glaciers develop and their ice joins at one point to form a main valley. As time elapses, the thickness of ice, its weight and power suddenly increases, when it melts, an abrupt valley with steep walls called a trough end is formed.

9. Rock steps:
These are pronounced irregularities in the long profile of a glaciated upland. They are formed when there is differential erosive power of glaciers beneath valleys. Main glaciers carry out erosion more than tributary glaciers creating steep ends called rock steps. For example the upper point of Gorges valley in Kenya is divided into sections by rock steps. The wall of Mobuku valley on Mt. Ruwenzori is also interrupted by rock steps in the upper part.

Illustrations: Rock steps in the Gorges valley, Mt Kenya

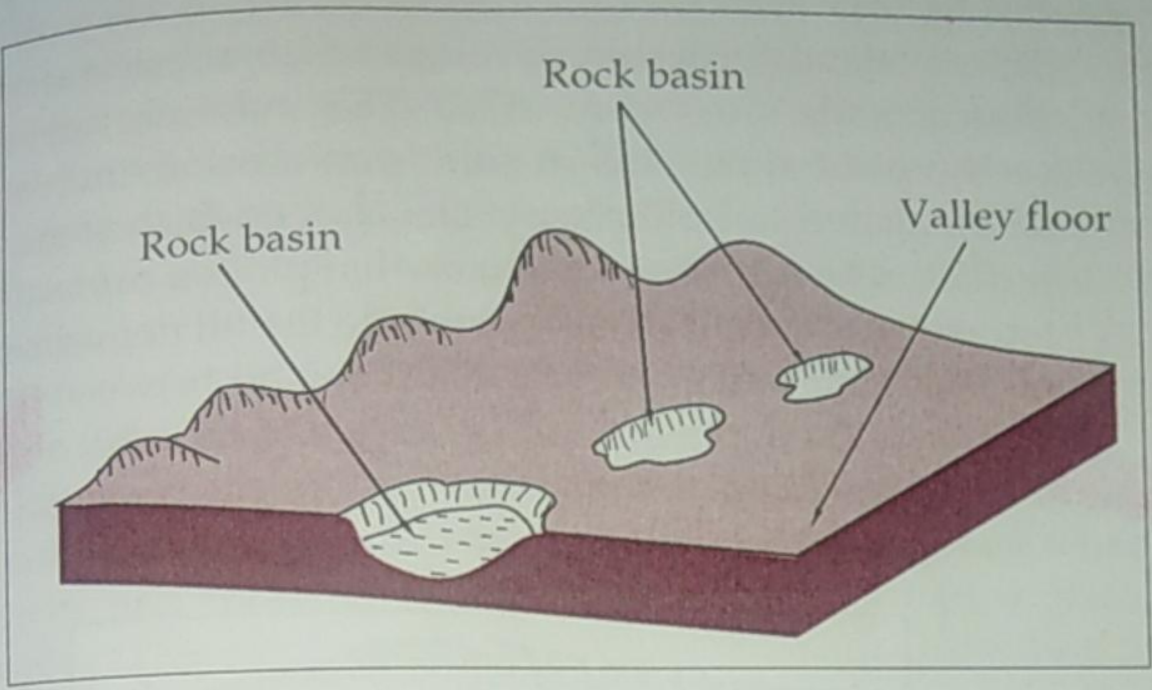


10. Benches or terraces:
These are associated with rock steps. They form the floor of rock steps. Terraces develop due to differences in glacial erosion over a landscape (upland) causing a prominent change of slope. The steep ends (wall) are the rock steps while the floors are the terraces.

11. Truncated Spurs:
In the process of glacial trough formation, moving ice deeply cuts former river valleys and also cuts down the lower end of former interlocking spurs. The resultant feature formed is a truncated spur.

12. Rock basin:
This is a shallow depression on the floor of a glaciated valley. The plucking and abrasive role of main glaciers usually scours and excavates depressions along the rock bed. Such depressions are called rock basins. They are, later filled by water to form rock basin lakes. For example on the second step of the Gorges valley, the Nithi River is interrupted by a small waterfall. Below this fall, the valley has been over deepened to form a rock basin now occupied by Lake Michaelson. Lake Hohnel on the floor of Teleki cirque is a good example of a rock basin lake.

Illustration: Rock basin

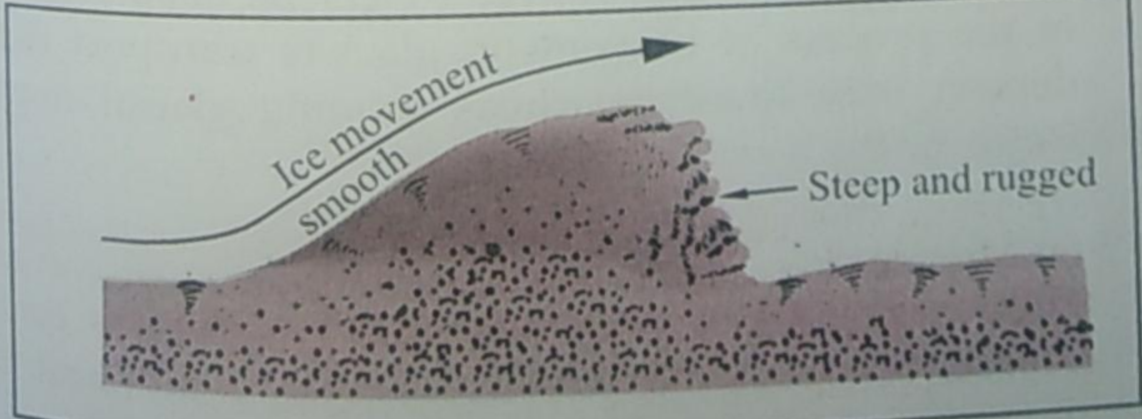


B. Glacial erosional features in lowlands.

1. A Roche mountonee:

This is mass of a resistant rock which rises above the general level of a glaciated floor. It is the rock embedded within the base of the ice that smooth down the rock outcrop sometimes cutting deep groves into the surface. It consists both the upstream and downstream side, so the abrasive nature of glaciers polish and smoothen the former then pluck the latter to form a steep rugged landscape. A large Roche mountonee is found on the floor of Mobuku valley in Mt. Ruwenzori and on the Gorges valleys in Mt. Kenya. Roche mountonees also give indication of the direction of ice movement.

Illustration: Roche mountonee:

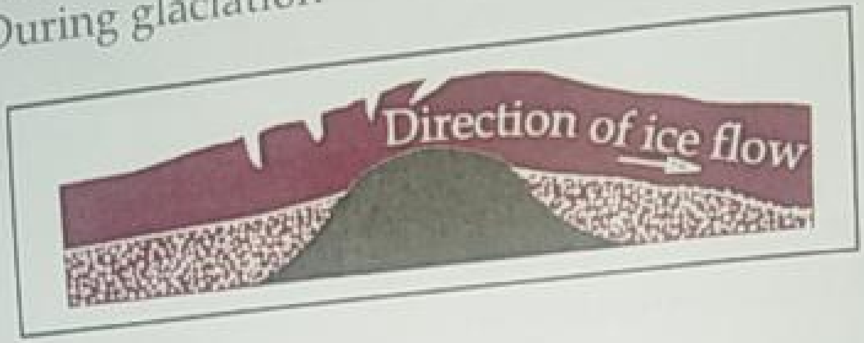


2. Crag and tail:

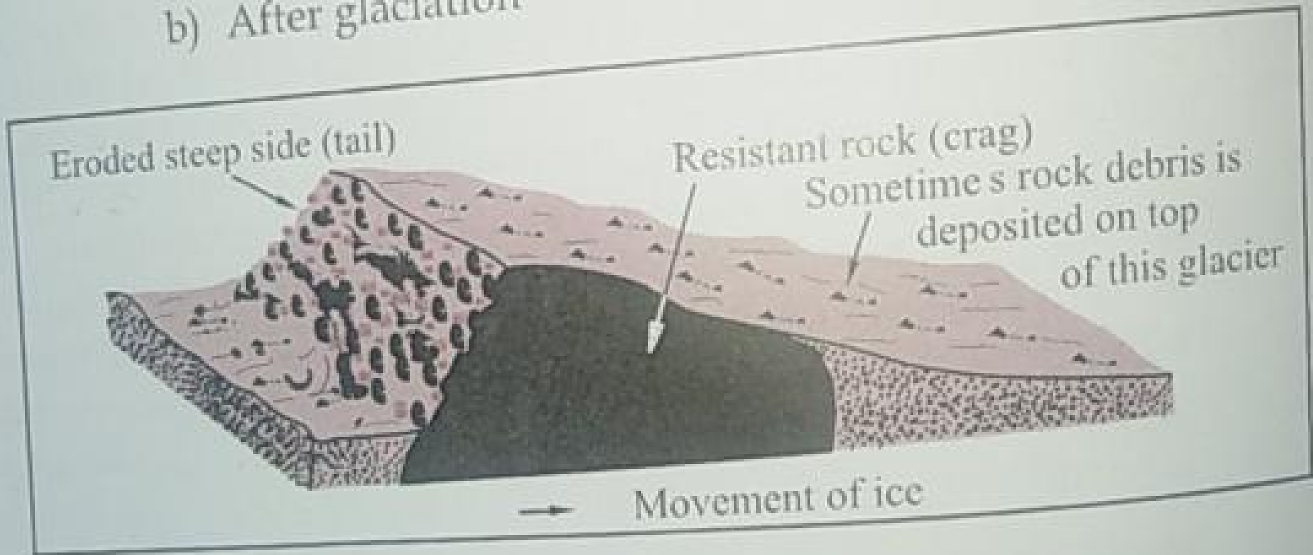
This is a land form that develops when a resistant rock mass obstructs the movement of ice. This mass protects the weak rocks on the downstream side from erosion and survives as an elongated tail of softer rocks above which some deposits are laid. The resistant rock mass that plays a protective role is termed as a Crag. Examples include the till deposits in the lee of parasitic cones on Mt. Kilimanjaro between Kibo and Mawenzi that have formed the crag and tails (till deposits)

Illustration: Crag and tail

a) During glaciation



b) After glaciation



Land form features produced by glacial deposition

In the process of movement, glaciers transport debris and deposit it in low-lying areas forming glacial depositional features which are as follows:

(a) Moraines:

These are unsorted rock fragments of all sizes carried and later deposited by a glacier. There are different types of moraines which are as follows;

(i) Lateral Moraine:

These are materials (debris) carried and deposited along the sides of a glacial trough. They tend to form elongated ridges on the glacial surface. When ridges are formed, they protect the ice below from melting. When the ice melts, this material is deposited on the sides or edges of a glaciated valley floor. They are evident at a point where little Nithi joins the Nithi main river in the Teleki valley of Mt. Kenya.

(ii) Terminal moraine;

These are materials (debris) carried and deposited at the mouth or front of a glacial trough. They are formed when ice melts and material is deposited at the front of a glaciated valley. This can be seen at the front of Kamusoso valley of Mt Ruwenzori and Lake Arris of Mt Kenya.

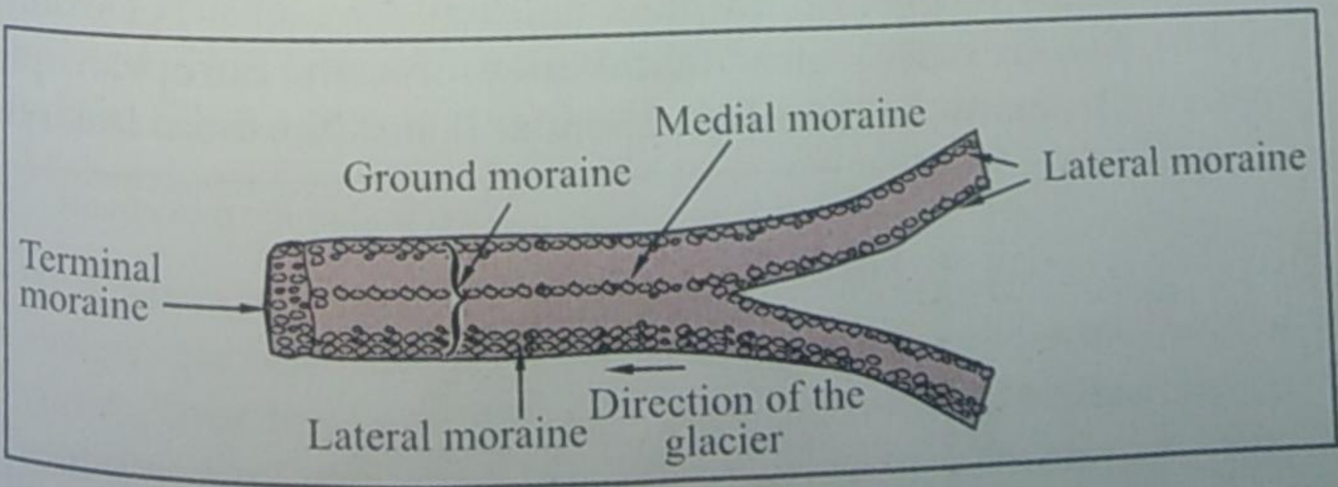
(iii) Medial Moraine:

These are materials carried and deposited in the **middle** of the glacial trough, hence the term medial moraine. They are formed when materials deposited at the valley sides accumulate, with time join up forming a sheet of materials, which after the melting of ice, is left hanging in the middle of a glacial trough as a medial moraine.

(iv) Ground moraine;

The rock fragments which are dragged along beneath the frozen ice and dropped when the glacier melts and spread across the floor of the valley, they form ground moraine.

Illustration: formation of moraines



(b) Erratics:

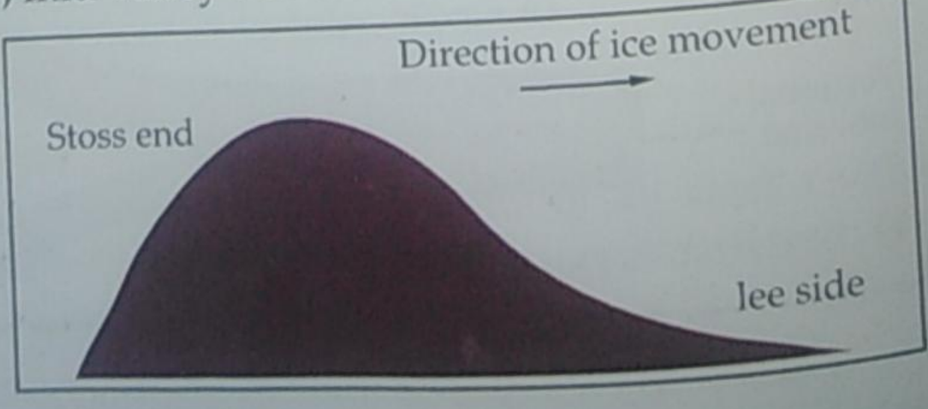
These are heavy boulders transported by moving ice for long distances and deposited in areas of completely different rock make up. They are commonly found in the moraine ridges that exist in glacial troughs for example below the junction of Nithi tributary and major Nithi river, Bujuku and Kamusoso valleys of Mt Ruwenzori.

(c) Till plains:

This is an extensive (wide) area of monotonous low relief created by till or sheet of glacial deposits. It is formed when former valleys and hills are buried by a thick layer of till deposits beneath the ice sheet and plastered into the sub-glacial surface by the pressure of ice. A relatively flat landscape called a till plain is formed. The deposited till materials are made up of boulders, clays and rock fragments. This is evident on the floor of Teleki valley on Mt Kenya and Mobuku valley on Mt Ruwenzori. They also exist in the Dwyka tillites of South Africa near Kimberley.

(d) Drumlins:

This is a low, rounded elongated hill or small mound or hummock or "whale back" of glacial deposits. It is usually up to 1 km long and about 30 – 50 m high. Drumlins are formed from moraine which has been made longer in the direction that ice is moving by the ice passing over it. They are also formed by friction between the ground moraine and the rock below which may become too great for the ice to overcome. In the process, the moraine tends to collect in the uneven mounds under the ice. Drumlins are common in areas where the till plain suddenly widens. For example; in South Africa near Kimberley, North European plain of Germany, mid valley of Scotland and Northern Ireland.



(e) Eskers:

These are long narrow ridges of sand and gravel deposited by moving ice and were once the beds of sub glacial streams. When ice melts, deposits remain behind within a former stream forming long winding and ridge like features called Eskers. For example along river Nithi in the Gorges valley and Teleki valley on Mt Kenya are eskers.

(f) Kame:

This is a mound of gravel and sand formed through deposition of sediments from a stream as it runs from a glacier. They are categorized into kame terraces and kame moraines. When glacier deposits materials along trough sides, Kame moraines are formed and when streams occupy and deposit material between the ice tongue and valley sides, a narrow ridge-like landform called a kame terrace is formed like in the Kamusoso valley on Mt Ruwenzori and Hobley valley on Mt. Kenya. Kame terraces may be similar in form to lateral moraine ridges.

(g) Outwash plains:

These are wide gently sloping plains of gravel, sand, clay and silt. They are formed when melt waters from a stagnant glacier carry and deposit sorted materials near the mouth of glacier and further down slope. Such a plain is evident in Mobuku and Bujuku valleys of Mt. Ruwenzori.

(h) Kettle:

This is a hollow or a depression formed when stranded ice blocks within a till or a kame (with piled up sediments) are melted. This leaves behind a depression called a kettle which when filled with water, kettle lakes are formed e.g. Lake Mahoma on Mt. Ruwenzori.

(i) A Moraine damned lake:

When glaciers deposit materials called moraines across rivers, they tend to block river valleys causing submergence and flooding of waters behind the moraines forming a lake. This is called a moraine damned lake.