

## **RIVERS AND DRAINAGE PATTERNS**

A river is defined a body of water flowing over a land surface through a definite channel in a linear manner down the slope and is rather permanent. Normally, a river has a source and a mouth.

The rivers' source is where it originates. This can be a stream, swamp, glaciers melt water etc. the rivers' mouth is where it empties its water. This can be in a lake, another river, ocean etc. some rivers simply disappear in arid areas or in sink holes as in limestone areas. Many rivers that originate from northern Kenya simply disappear in arid areas of north eastern Kenya and Somalia.

### **RIVER SYSTEMS**

Once a river is established, it begins to lengthen, deepen, and widen its channel. This creates secondary slopes on the valley sides on which tributaries to the main river develop

The main stream is called Consequent River and the tributaries subsequent stream. The tributaries soon cut slopes against which other tributaries to the subsequent rivers develop.

#### **River System**

The total arrangement of the main river with its tributaries and sub-tributaries is known as the river system /drainage system. The total area occupies and drained by a river system is called a drainage basin or catchment area

The highland area which separates two drainage basins is water shed or divide. And the highland area separating two tributaries of a river system is called an interfluvium.

#### **The Work of rivers**

As a river flows it performs three tasks i.e. erosion, transportation, and deposition. Through these tasks, erosional and depositional features are formed.

## **RIVER EROSION**

It describes the cumulative effects of a number of processes through which a river degrades and widens its channel. These processes include;

- Corrosion/abrasion
- Corrosion /solution
- Hydraulic action
- Attrition

### **Abrasion**

This is the process which involves the wearing away of channel beds and sides by the grinding action of the material that the river is carrying. These materials such as sand, pebbles act as sand paper or fine on a rock drilling pot holes in the channel.

### **Solution/corrosion**

This involves the solvent action of a river. Soluble rocks are dissolved and carried away in solution. Rocks such as limestone, rock salt etc are quickly worn out by this process. Corrosion occurs at all times and depends the channel composition of the water e.g. concentration of the acids.

### **Hydraulic action**

This refers to the loosening and removing of rock particles by water pressure. The force of moving water can sweep out loose materials while turbulence and swirling together with water entering into cracks compresses air into cracks in tee channel breaking up rocks. Bubbles busting on the river channel send shock waves against the river bank sucking out pieces of rocks.

### **Attrition**

As the river carries its load down stream, boulders collide with each other and in the process disintegrate into smaller pieces.

River erosion results into the following effects to the river's channel;

- Vertical erosion deepens the valley
- Head ward erosion lengthen the channel
- Lateral erosion widens the channel

## **RIVER TRANSPORTATION**

After erosion, the material eroded is transported by the river down the stream and later deposited in the mature and old stages of the river. The materials transported by the river are called rivers' load. Rivers' loads include; large rock particles known as boulders, and very fine materials known as silt.

The capacity of a river to transport any given size of the load is known as river's competence. River's competence is influenced by the volume of water in the channel, the speed of the river and the gradient of the stream therefore, rivers' competence can be high or low depending on whether it can transport the load. A river transports its load in four ways;

1. Solution; this is where a river carries its load in solution form after it has been dissolved. River water contains acids e.g. carbonic acid which attracts rocks e.g. limestone. When dissolved, they become part of the fluid itself and move with it until they become precipitated.
2. Suspension load; the suspension load consists mainly fine rock materials e.g. clay and its silt. Such particles are picked and tossed by the turbulence in a fast flowing river. Suspension load forms the largest part of the total load carried by the river. It normally gives river water its characteristics dark or brown color.
3. Saltation load; this is where a river's load is moving in form of "hops" and "sumps" due to the river's turbulence. Turbulence in the river causes lifting of some rock fragments which are eventually dropped and lifted again touching the river bed at intervals.
4. Traction; in this form of river transportation, bigger rock particles are moved on the river's bed.

## **RIVER DEPOSITION**

This occurs when the stream's energy is insufficient to carry the entire load. Large boulders and other heavy particles are deposited first followed by fine debris. Dissolved load is carried into the sea where they either precipitate or remain in the solution and help to maintain the salinity of oceans. However, these deposits may be temporary because any time the river's energy increases, such deposits are picked up.

## CAUSES OF DEPOSITION

Deposition takes place because of a number of reasons.

1. Drop in gradient; streams flow at a high speed with a steep gradient and when the gradient decreases, the speed of the water also reduces. The river's energy which partly depends on the speed as reduced leading to deposition.
2. Increase in the channels width; wide shallow channels involve greater loss of energy through friction than narrow and steep ones. This is a result of increased surface area over which the water flows. Also when a constricting narrow mountain valley suddenly opens out on a lower flat and wide valley, deposition takes place because of reduction in speed and therefore energy.
3. When a river enters into a stationery water body for example a sea or a lake, the load gets laid down leading to formation of lacustrine and marine delta respectively. A part from the effects of stationery sea water, deposition at the sea coast occurs also because fine clay particles coagulate and settle down when they mix with salty water of the sea.
4. Increase in the size and amount of the load. Materials resulting from erosion and mass wasting often find their way in streams where they become part of the load. If then the river is not competent enough to transport this load for along distance, it is laid down.
5. Deposition may also result from evaporation especially in arid areas. If deposition wasn't build with in flow of water into the river, then the volume of the water will reduce hence the energy of the river. Heavy particles may be laid down as the river may not be competent to continue transporting them.
6. When a section of a river valley is under lined by permeable rocks, there is loss into the crust. This produces the amount of water in the channel hence the river's competence.

## **THE DEVELOPMENT OF A RIVER'S CROSS AND LONG PROFILES**

The cross profile of a river is a section showing the vertical shape of a river from one bank to another. As a result, it shows the width attained by a river valley at a given point. The cross profile is characterized by a narrow valley in the youthful stage and a wider valley in the old stage. This is due to increased vertical erosion than lateral erosion in the youthful stage while in the old stage there is more lateral erosion than the vertical hence the valley is widened. The cross section is also V-shaped in the youthful stage and U-shaped in the old stage. The V-shaped in the youthful stage is due to increased vertical erosion which deepens the valley while the U-shape in the old stage is due to reduced vertical erosion and more deposition which makes the valley shallow.

### **Cross section in the youthful stage**

### **Cross section in the old stage**

A long profile of a river is a section showing the slope of a river from its source to its mouth. It's explained in terms of the distance covered by a river from its source to the mouth. It has three stages i.e. the youthful stage, mature stage, and old mature.

## Illustration

The development of a river's profile can be explained by W.M Davis' theory of peneplanation. According to Davis, all landscape pass through three stages that is; the youthful, mature and old stage. A river usually starts as a rushing torrent from a high altitude source (youthful structures) but develops into maturity in the middle of its course and ends sluggishly (old stage) at its mouth hence the three stages.

### **THE YOUTHFUL STAGE (THE TORRENT, JUVENILE OR UPPER STAGE)**

This is the stage near the source of the river. It's is characterized by;

- Very steep gradient
- Very fast flowing water
- High volume of water
- Intensive vertical erosion that results into valley deepening and formation of V-shaped valley
- Presence of inter-locking spurs
- Waterfalls and rapids
- Less/no deposition at all
- Channel sides are worn out mainly by weathering and mass wasting as opposed to erosion

### **Features Associated with the Youthful stage (river erosion)**

These features include a water fall, potholes, inter locking spurs, rapids and gorges

#### **(i) Waterfalls**

A waterfall is a sharp break in the channel bed over which a river falls. It forms when a river flowing over resistant rocks meets a less resistant rock. The soft rock down stream

is quickly eroded thus steeping the channel bed or creating a sudden break in the slope to produce a water fall e.g. Sezibwa and Bujagali falls.

Glaciation may also over deepen a glacial trough to leave behind hanging tributary valleys whose water plunges into the main valley as a waterfall e.g. Bujuku water fall on Mt. Rwenzori and little Mithi on Mt. Kenya.

Waterfalls also form where rivers flow over plateau edges which are sharp and steep e.g. Aruu falls on river Aswa. A mountain river may also plunge down the steep face of a mountain cliff to create a water fall e.g. Sipi falls on Mt. Elgon

Where a river enters the sea at a cliff line e.g. Pangani falls and river Rufigi water falls.

Where rejuvenation of a river valley has formed a sharp knick point (water sheds) waterfalls can also be formed.

### **Structure of a Plunge pool**

### **Structure of a Water Fall**

(ii) **Plunge Pool:** this is a deep hole at the base of a water fall. It is formed due to progressive drilling and grinding of the valley floor by hydraulic action and abrasive action of the sediments being carried by the river. its formation is favored by the formation of a large volume of water which increases the river's competence. Steep

gradients and large amounts of pebbles and boulders results into increased speed of water and effective grinding of the channel bed respectively. Some are formed where rivers flow on hard rocks but suddenly encounter soft rocks. Plunge pools normally form on rivers with water falls or along the rejuvenated section of a river's profile.

### **(iii) Pot holes**

These are circular depressions in the river's bed caused by swirling water due to an uneven bed of fast flowing water river. Swirling water falling into slight depression turn it into a cylindrical hole called pot hole. This depression gradually gets deeper and larger as erosion continues.

### **Illustration**

### **(iv) Interlocking spurs**

These are characteristic features of rivers flowing in highland areas. Interlocking spurs are projections of highlands which alternate (interlock) on the either side of a river valley. They are formed as a result of river erosion on rocks that offer alternating levels of resistance. The softer rocks usually on the concave slopes are easily eroded to form river cliffs while the convex slopes with relatively resistant rocks experience limited erosion but some deposition. As this continues, the bends along the river become more pronounced which later causes projection of highlands called spurs which alternate on both sides of the river. Examples can be seen in rivers such as Semuliki, river Nile and river Mubuku.



#### **(v) Rapids**

These are bands of resistant rocks along a river's course. They develop when a resistant rock overlying a less resistant rock (soft rocks) dips gently down the river as illustrated in the diagram below.

Examples are on river Nile

#### **(vi) Gorges**

A gorge is a deep narrow river valley with steep sides. Its depth is greater than its width. It may be formed when a water falls retreats (migrates) up stream or when a river maintains its course across country rocks that are being uplifted or when a river renews its erosive power through rejuvenation. Sometimes it's called valley-in-a-valley. A good example is on the great Ruaha in Tanzania.

Big gorges are called canyons e.g. the fish river canyon in Namibia the Grand Canyon on river Colorado in USA.

#### **CHARACTERISTICS FEATURES FOUND IN THE MATURE (MIDDLE) STAGE**

At this stage, the valley changes to a U-shape. The gradient is more gentle compared to that of the youthful stage and this affects the river's energy and speed. Erosive action is concentrated on the sides than the river's bed leading to the formation of a U-shaped valley. Deposition begins to take place due to reduced velocity and energy of the river. River bends are more pronounced at this stage and towards the end of the stage, meanders begin to form.

Features produced in this stage include; river cliffs, slip off slopes, U-shaped valley, meanders etc

- River cliffs/river bluffs; these are the cut ends of spurs that extend down into the river valley that extend down into the river valley. They are formed when a river erodes laterally to widen its valley. The river erodes more of its concave banks and eventually shifts flow towards the concave banks. This creates a steep wall along the concave banks called a cliff/bluff
- Slip off slope; this is a gently sloping deposit of sediments on the convex bend of a river. in a mature stage, erosion of concave bends where a steep wall may be created. At the same time, deposition occurs on the convex bends forming a gently sloping platform of sediments called a slip off slope.

- U-shaped valley; when the river is in a mature stage, erosion is concave on the sides other than the river's bed. This leads to the widening of the rivers channel hence the formation of a U-shaped valley.
- Meanders; these are curved bends of a river channel. They are formed on both the mature and old stage of a river. as the gradient falls towards the old stage, the river's competence reduces and deposition starts. When the deposits accumulate, they cause deflection of the river as it tries to dodge them. As a result, erosion is pronounced on the concave banks while deposition takes place on the convex banks. In due course, the bends become exaggerated forcing the river to meander. Meanders are common on river Rwizi, Semiliki, and Mpanga in Uganda and on R. Ngaila in Kenya.

Alternatively, meanders may occur when a river encounters obstacles on its course or there is uplift of a river's mouth by earth movement.

## **CHARACTERISTICS AND FEATURES FORMED IN THE OLD STAGE**

At this stage, deposition is more pronounced and exceeds erosion. The river has a very gentle gradient and flows in a wide area and therefore, its channel width is very large changing the former U-shaped valley into a more open U-shaped valley. Delta formation occurs due to the high rate of deposition. The river's speed greatly reduces owing to low gradient leading to high rate of deposition. Much of the river's bed is covered by fine materials such as sand, silt, mud and only light materials like leaves can be transported further including materials in solution, meanders and ox-bow lakes are observable in this stage.

## **MAJOR FEATURES IN THE OLD STAGE**

These include flood plains, braided drainage, levees, diffused drainage, meanders, ox-bow lakes, alluvial fans, deltas.

1. Flood plain; this is a wide flat plain of alluvial materials on the floor of a river valley across which the river flows. It is usually characterized by ox-bow lakes formed along meander loops. Flood plains are formed due to an increase in the water volume in the river's channel, it overflows its banks and spreads over the plains in its lower course where it deposits sediments that it was carrying. Every time floods occur, large sediments are deposited so that gradually the flood plains which is more or less marshy rises higher and higher e.g. on the lower Tana, Galana, and Athi in Kenya and R. Rwizi in Uganda.

2. Levees; these are raised ridge like embankments built by floods on either banks of the river valley. They are therefore formed due to successive flooding and deposition of sediments by a river on its banks. These embankments (levees)

rise a few feet above the flood plains. They are sometimes called natural levees. When they are built by a river itself but others are man made

### **Illustration**

3. Differed drainage (channel); It's part of the river that is forced to flow along side the main river for along distance before being able to join the main river. the differed tributary id formed when floods build embarkments across the junctions of a tributary stream to the senile rivers. This causes the tributary to flow for many kilometers without being able to join the main river e.g. on R. Nyando and R. Ngaila.

### **Illustration**

4. Braided channel; this is when a river is forced to flow in form of sub-divided channels separated by deposits. Braiding takes place when a river heavily laden with sediments enters in a shallow channel or area of low gradient. In both cases, the river loses energy/competence and deposits its load along the channel. The deposits block the rivers flow forcing it to sub divide into many sub divided channels. Examples are evident in rivers Rufigi and Kilombero in Tanzania and rivers Tana and Athi in Kenya.

5. Alluvial fans; this is a fan (cone shaped) heap of sediments formed at the foot of a highland or mountain. Its formed where a mountain river deposits its load where it enters the main valley. Alluvial fans resemble deltas and are often referred to as dry deltas e.g. on R. Kilombero and R. Lume.

**Structure of an alluvial fan**

6. Ox-bow lakes;

An ox-bow lake is a horse-shoe shaped lake formed when a meander is cut off from the main river. Usually, active erosion on the concave banks of two meanders result into the bends moving closure to each other. When the bends join, an ox-bow lake is formed.

Alternatively, they are formed when during a flood, the momentum of river flow cuts across the narrow neck of land separating the two bends. The river then flows straight across the neck of land abandoning the old meander course which becomes an ox-bow lake. When water evaporates from an ox bow lake it formed a meander scar. Examples of ox bow lakes are; lower course of river Semiliki, and river Tana

**Stages in the formation of an ox bow lake**

7. Deltas; a delta is a flat low lying plain formed by deposition at the river's mouth i.e. where the river enters the sea or lake. When a river heavily loaded with sediments enters the sea or lake, its velocity and competence are immediately reduced. The result is that the river deposits its load. Deposition is also aided by the mixing of the river's fresh water with the sea's salty water. Sometime the deposited load is carried away from the mouth of the river before it sinks to the bottom but sometimes the deposited load sinks to the bottom in the mouth of the river. In time, layer after layer collects to form a gently sloping platform that extends to the surface and above thus a delta. Example in east Africa include; on river Ome in Kenya where it enters lake Turkana, on river Rufigi where it enters the Indian Ocean, on Victoria Nile where it enters Lake Albert. Elsewhere in Africa, there is the Niger Delta in Nigeria and the Nile Delta in Egypt.

#### **Conditions for Formation of Deltas**

A river must have a large load, and for this to happen there must be active erosion in the upper section of the river such load consists of sand, gravel, and silt.

The river's load should be deposited faster the rate of removal by waves and tides

The river's speed / velocity should be at the lowest level so that deposition can be done effectively.

Presence of a well sheltered coasts such that deposits laid are not washed away.

#### **Process/stages of Delta Formation**

There are three stages in Delta formation. In the first stage, the delta begins to form when the initial sediments collect on the continental shelf around the river's mouth. As deposition continues, layers build upon each other until a plat form builds. The deposition in the river's mouth causes the river to divide into several distributaries. Deposition at the banks of the distributaries produces levees. The areas of water bounded by distributaries become the sites for future lagoons.

Illustration

In the second stage, lagoons begin to fill with sediments which cause further division of tributaries as the initial levees may be broken. The delta at this stage has a mere solid appearance, although it is still swampy and covered with water loving vegetation.

Illustration

At this level, the delta extends upwards and seawards

In the last stage, the in filling of lagoons takes place and there is growth of complete coverage of vegetation in the older parts of the delta. The delta now stands above the water level. As the delta grows larger and larger, the older part merges with the flood plain losing its appearance as a delta.

Illustration

### **TYPES OF DELTAS**

There are basically three types of delta and these include; arcuate, bird's foot, and estuarine deltas.

1. Arcuate deltas; this is the most common type of delta usually they have rounded convex seaward margins. This type of delta forms on rivers which carry a lot of sediments into the sea. As a result of a high amount of load, the rivers have nearly the same density as sea water. The mixing of this equal density water bodies, quickly slow down the expansion of the river front into the sea. This causes sediments to be deposited in a broad arc to form an arcuate delta. A good example is river semiliki where it enters lake Albert. Outside east Africa river Nile and river Niger offer typical examples.

Illustration

2. Bird's Foot Delta; this delta consists of very fine deposits such as silt. Its formed away from the shores where rivers water penetrate into the sea or lake. When the river breaks, the levees like embarkments, other levee deposits are built along distributaries of a river. Over time the river creates a delta in the sea or lake whose plan resembles the digit of the bird's foot.

Illustration

3. Estuarine Delta; these are found at a drowned river mouth in the estuaries or rias, they do not extend into the sea but deposition takes place within the estuaries resulting into many muddy banks. A good example is the Rufigi delta in Tanzania.

Illustration



## **ECONOMIC IMPORTANCE OF RIVER EROSIONAL AND DEPOSITIONAL FEATURES**

They act as tourist potentials because they create beautiful sceneries e.g. waterfalls at the Bujagali, flood plains of river Rufiji.

They are important for study and research purpose e.g. the research about the nature and composition of sedimentary rocks, waterfalls, meanders, gorges, and rapids.

They are important for development of agriculture due to the presence of fertile alluvial soils eroded from the upper stages of the river and deposited within the flood plain e.g. the Nile delta in Egypt is used for growing cotton, vegetables, and sugar cane.

Vegetation that normally grows on the delta can be exploited to act as a source of raw materials for the hand craft industry e.g. papyrus reeds for making mats and baskets.

Mangrove trees on Niger delta in Tanzania provide poles for construction.

Deltas make good sites for development of ports e.g. Alexandria in Egypt and Port Harcourt in Nigeria along river Niger.

Distributaries along side lagoon can be used in promoting the fishing industry as they contain a lot of planktons which is food for fish.

Unfortunately, deltas act as breeding places for mosquitoes and may therefore not produce suitable conditions for human settlement

Lateral erosion produces open flat wide valleys and terraces which tend to limit settlement due to flooding e.g. around river Rwizi in Mbarara.

Waterfalls, rapids, and pot holes along a river's channel are a hindrance to navigation and fishing e.g. along the Nile.

Flood plains and deltas are low lying and as such they are prone to flooding which may destroy infrastructure, settlement as well as human lives.

Deltas can also act as habitats for wild animals which scare away human activities.

### **COMPARISON BETWEEN A DELTA AND AN ALLUVIAL FAN**

#### **SIMILARITIES**

They have a similar shape. Both open up in a funnel shape having an apex at the beginning and being wide forwards.

By comparison, both are made up of sediments with fine materials deposited farthest and coarse materials laid down at the base of the river.

One condition of formation for both is that the gradient must be low which result into reduced speed of the river.

Both divide into distributaries due to deposition.

Both are features formed with the old stage of the river.

#### **DIFFERENCES**

Deltas form on the mouth of the river when it enters into the sea or lake while alluvial fans develop along the course of a river provided there is a break in the gradient of the river valley.

Deltas have marked distributaries which do not flow for considerable distance while the distributaries of alluvial fans are less deferred and do not move for a long distance.

Deltas are associated with swamps, lagoons, spits, and bars while alluvial fans do not have any of the above.

For a delta to be formed there must be absence of strong tidal currents and waves that would normally destroy the delta. Such conditions are not necessary for the formation of alluvial fans.

Deposits making up a delta are mainly fine sediments while those forming an alluvial fan are mainly coarse materials.

### **INTERUPTION OF THE DEVELOPMENT OF A RIVER'S LONG PROFILE**

The ideal river cycle develops from the youthful stage through mature stage and ends with the senile stage. During this cycle, the river is expected to develop a graded profile of a smooth concave shape as shown below.

A graded profile refers to a well developed concave slope from a river source to the mouth. The concave curve which is a parabolic in nature is neither steep nor gentle. The river attains this slope as a result of eroding away obstacles in its course as well as depositing sediments from upper slopes that is after erosion has balanced with deposition.

However, the concept of a graded profile is more or less theoretical. It may only be applicable to rivers that have very short courses where the possibility of a similar rock structure, topography, climatic condition, may be attained.

However, since all rivers are long and flow in different channel and environmental condition, the graded river profile cannot be attained. Interruptions to the attainment of a long graded profile include the following:

- The existence of rocks of different hardness influence the long profile development. Soft rocks can be eroded easily than hard rocks across the channel. Therefore, this disrupts the attainment of a graded profile.
- Human activities like construction of water dams across river valleys disrupt the formation of a graded profile e.g. the Nile at Owen falls dam and Aswan high dam in Egypt. Irrigation activities also reduce water discharge from the river channel disrupting the formation of a graded profile.
- When a river passes through different climatic conditions, it influences its regimes and therefore a long graded profile can't be attained
- Earth movements like faulting, volcanicity, folding etc can disrupt the formation of a graded profile of a river. e.g. it can form reversed drainage patterns, waterfalls, and rapids etc.
- The presence of vegetation such as sads on the Nile, the mangroves on the Rufigi river may disrupt the flow of water in the river's channel and prevent it from attaining a graded profile.
- The occurrence of river capture leads to increase in discharge of water in the river's channel hence rejuvenation

### **THE RIVER'S BASE LEVEL**

Base level refers to the lowest downward level to which a river can erode its bed. Its an imaginary line from the mouth of a river beneath the land below which a river cannot erode. There are two types of base levels that is;

Universal base level

Local/temporary base level

The universal base level is also called the sea level. This is the lowest point to which a river erodes its beds. Once a river has eroded its bed, such that there is no more slope between its source and mouth, then it can no longer flow and therefore cannot erode.

Local/temporary base levels are provided by lakes, other rivers, resistant rocks etc. such base levels keep shifting and exist only for a while e.g. a main river providing a local base level for a tributary.

### **RIVER REJUVENATION**

This is a process by which a river's erosive capacity is renewed due to increased energy. Such a river irrespective of the stage it has attained starts to flow faster and with increased energy. The result is the creation of pot holes and deeper vertical incision of its valley.

There are two types of rejuvenation i.e. dynamic rejuvenation and static rejuvenation.

Dynamic rejuvenation occurs where there is a fall in a base level of a river. This lengthens and steepens the river's channel resulting into an increase in a river's energy hence rejuvenation.

Rejuvenation may also occur without change of the base level. This is called static rejuvenation. This may be due to heavy rainfall or river capture all of which increase the river's erosive power

### **CAUSES OF RIVER REJUVENATION**

There are several causes of river rejuvenation. These bring about both dynamic and static and dynamic types of rejuvenation.

Tectonic movements such as warping, faulting, folding, and volcanicity cause changes in gradient e.g. they may create a break along the slope steepening the channel which increases the velocity and energy of the river hence rejuvenation.

Changes in base level may also result into rejuvenation. Base level is the lowest point to which a river can erode. The universally recognized base level is sea level. Therefore, when the sea level falls, the base level also drops. This has the effect of steepening the river's gradient and making it flow faster hence causing a lot of erosion. In this way, a river is rejuvenated.

River capture may also cause river rejuvenation. River capture results in the water of a weak river being diverted to flow in the channel of the strong neighboring river (pirate). This leads to an increase in the volume of water in the stronger river hence its ability to erode.

High precipitation (rainfall) leads to an increase in the volume of water in a river's valley. The discharge speed is also increased hence the river's energy and ability to erode.

Man's activities e.g damming of a river causes increase in pressure of the water hence its ability to erode. The river is forced to flow at high speed once the water is released in the turbines hence rejuvenation.

### **EFFECTS OF RIVER REJUVENATION**

The manifestations of river rejuvenation in east Africa include: paired terraces, nick points, incised meanders and valley in a valley. These land forms are all formed through river processes such as hydraulic action, abrasion, solution, and attrition. The land forms include;

1. **River Terraces**; these are step like marks on the banks of a river valley its flood plain. They are formed when a river in its flood plain renews its erosive capacity cutting through the flood plain and leaving the floor of the former flood plain above the affected channel. Lateral erosion widens the new channel forming a new flood plain. If another rejuvenation takes place in the floor of the flood plain, a new set of terraces are formed. Most terraces occur at the same time level of both sides of a river's banks and hence are known as paired terraces.

#### **An Illustration of Paired Terraces**

01 and 02 are sets of paired terraces e.g. of these features can be seen on river Kafu, Semiliki and Mpanga in Uganda and River Ngaila in Kenya.

2. **Valley in Valley;** this is a gorge formed after renewal of erosive activity in a river's channel. The river sinks deeply into its flood plain creating a valley in valley.

A good example is on R. Mpanga

3. **A knick point;** this is a break in the slope of a river's valley caused by down cutting of a river's bed due to renewed erosive activity. It may be formed near the sea where the effects of the fall in sea level can cause rejuvenation. It may also occur anywhere along the river's course. Once a knick point is formed, it retreats upstream as the river regrades itself. A knick point usually results into a water fall. A good example is on river Mwachi in Kenya.

#### **Illustration**

4. **Incised meanders;** these are curved bends of rivers whose floor has been greatly deepened. Such that the river now winds between steep walls. They are formed as a result of deep down cutting at the meander bends of a rejuvenated river. there are two types of incised meanders

#### **Entrenched meanders**

##### **In grown meanders**

Entrenched meanders have steep sided symmetrical cross profiles and are formed where down cutting at meander bend is vertical i.e. erosion is equally distributed throughout the valley sides. As a result, the deposits on the meander floor are all renewed so that river cliffs and slip off slopes can't be easily distinguished. A good example is on river Mpanga.

In grown meanders are those meander valleys with one side steeper than the other. They develop where a river flows over resistant rocks. The river usually undercuts the concave banks while the convex banks develop into slip off slopes. The resulting cross profile of the channel is asymmetrical i.e. one side is steeper (concave) while the other is gentle e.g. on R. Rwizi.

### **RIVER CAPTURE**

This is defined as the diversion of part of or the whole of a river from its course into the course of another river. river capture takes place when a tributary stream develops from a powerful river and extends it self by a head ward erosion until it cuts into the divide with the less powerful river. the head water of the less powerful river is then diverted to flow to the valley of the more powerful river.

#### **Illustration**

For a river capture to take place, there should be existence of soft rocks between the weak and strong river and the capturing stream must be at a lower altitude compared to a weak river. examples of river capture include River Tana captured a tributary of R.Athi in Kenya, R.Tochi, Arocha, and Okole were captured by the Nile, R.Birira captured the head waters of river Rwizi and R.Aswa captured R.Pager.



## CAUSES OF RIVER CAPTURE

Several conditions may result into one river capturing another and these conditions include the following;

**Stream power;** two streams may be flowing adjacent to each other on homogeneous rocks. If one of them is more powerful either because of its bigger volume or steeper gradient, it will cut down faster. If a tributary stream develops from a powerful river towards the less powerful one, the head water of the less powerful will be diverted into the course of a powerful river.

**Differences in rock hardness** where two adjacent rivers are flowing over rocks of different hardness. The one flowing over softer rocks will cut down its bed faster. If a tributary develops from it to the one flowing on resistant rocks, the head water of the river flowing on resistant rocks will be captured.

**Existence of obstacles;** if an obstacle of hard rocks is lying on the course of a river flowing next to another (not facing an obstacle), river capture will take place. This happens when a river facing an obstacle tends to migrate by eroding its outside valley sides extending to the neighboring river.

**Before capture**

**After capture**

**River rejuvenation.** River rejuvenation occurring along one of the two rivers flowing side by side may also result into river capture. Rejuvenation especially due to dynamic changes result into the bed of the rejuvenated river being cut to a much lower level. If a subsequent tributary develops from the rejuvenated river to the unrejuvenated one, the head waters would be captured and diverted into the rejuvenated water because it has high energy to carry out head ward and vertical erosion.

### **FEATURES OF RIVER CAPTURE**

1. **Elbow of capture;** this is triangular bend at a point where the head waters of a captured stream is diverted into the capturing stream valley. Its where there is a sharp change in the direction of river flow at the point of capture.
2. **Wind gap;** this is a dry valley below the point where capture has taken place. Its found between the elbow of capture and the point at which the misfit river starts. The wind gap is also known as a dry gap.
3. **Misfit river;** this is the remnant of the captured river which continue to flow downstream after its head waters have been captured. Its known as a misfit or under fit river because its volume of water is far too small to occupy the large valley through which it flows. The misfit river is also called a beheaded stream.
4. **An over fit river;** this is the pirate stream. After arresting water from the weak stream, the volume of water of the capturing stream/river increases beyond the size of its channel hence its called an over fit stream

### **DRAINAGE PATTERNS**

A drainage pattern is a physical outlay of as river and its tributaries made on the earth's surface. Drainage patterns evolve over time and their development is influenced partly by river capture, drainage reversal, the slope, rock structure, earth movement.

There are tow types of drainage patterns namely; accordant and discordant patterns. Accordant patterns are those where the flow of a river and its tributaries show a relationship between the rock structure and the surface drainage. Example s include dendritic, annular, trellis, parallel, pinnate, centripetal, radial and hooked

Discordant patterns do not show any relationship between rock structure and relief. Examples include superimposed patterns and the antecedent patterns. In east Africa there are various types of drainage patterns and these include;

1. **Radial drainage pattern;** this is a drainage pattern in which rivers originate from a central point such as a dome/highland and radiate outwards. The flow of the rivers is determined by the nature of the slope. As erosion continues, the domes/highland is degraded. Examples of such a pattern are evident on Mt. Elgon, Kilimanjaro, Kenya, Muhavura etc. on Mt. Elgon the rivers include Sippi, Sironko, Suam, Malawi, and Manafwa.

### **Structure of radial patterns**

The factors influencing the development of the patterns include the presence of a dome or cone shaped highland. This may be a volcanic cone/mountain. The dome provides the source of water for the rivers.

Radial patterns is controlled by the nature of the slope. Steep slopes usually accelerate the downward movement of water and erosion of the rocks that create channel through the rivers flow.

Radial patterns also develop because of high precipitation in the catchment areas. Precipitation in terms of rainfall provides a constant supply of water that is discharged into the river. some dome shapes in east Africa such as Mt. Kilimanjaro, Kenya, and Rwenzori are glaciated and when glacier melts, it provides a constant source of water for the rivers.

The patterns also develop due to the existence of uniform rock structure. This enables the rivers to erode to any side of the mountain thus development of a radial pattern.

2. **Centripetal Drainage pattern;** this is a drainage pattern in which rivers flow from many different sources and converge towards a central point which may be a basin or a depression. A perfect centripetal pattern has developed on Lake Baringo in Kenya where rivers like Lobo, Ol-arabel, and Oli-mukuton flow into the lake.

**Structure of centripetal pattern (Lake Baringo)**

Other examples are on Lake Natron and Naivasha in Kenya, Eyasi in Tanzania, and Lake Victoria in Uganda.

**The development of this pattern has been a result of many factors:**

The pattern has developed due to the presence of basin land scapes and valleys. These could have been formed by down warping or faulting. These basins steepen the gradient of adjacent river which then flow towards the common low altitude point

The pattern also develops in areas which offer uniform rock resistance. Evenly, soft rocks favor the development of the pattern as they enable the river to erode its way up o the basin.

Heavy rainfall in the catchment areas is also essential as it provides a constant source of water for the rivers.

3. **Parallel Drainage Pattern;** this is a pattern where rivers flow side by with each other but with limited chances of joining each other. The pattern is best developed on rich slopes/escarpments. This is due to the existence of hard rocks in between rivers which makes them unable to join with one another. Good examples are on the Abadare ranges in Kenya where tributaries of river Athi such as R. Nairobi, R.

Thirika, R. Komu, R. Ruiru flow parallel to each other. Rivers that drain into Lake Victoria in western Kenya are also essentially parallel. Other examples are Nkusi and Hoima that flow parallel to each other before entering Lake Albert.

### **Illustration**

The conditions for development of parallel patterns include;

The existence of alternating bands of soft and hard rocks. The soft rocks are eroded to form river channels while hard rocks resist erosion to form a divide which limits the chances of the rivers meeting.

It also develops in faulted regions. In such regions rivers tend to flow by eroding through the lines of weakness created by the earth movement.

Reliable rainfall is also essential in the catchment areas to sustain the existence of the rivers.

4. **Dendritic Patterns**; this pattern derives its name from a Greek word “Dendron” which means a tree. It’s a tree like pattern where tributaries join the main river from many directions and usually join at acute angles. i.e. less than  $90^{\circ}$ . examples of these patterns are evident on river Rufiji, Victoria Nile, R. Malagalasi, R. Nyando, R. Nzoia etc.

### **Structure of dendritic pattern**

The conditions/reasons for development of this pattern include;

The presence of rocks which offer uniform resistance. Such rocks are of uniform structure and hardness. These ease the river's erosion hence the rivers are wide spread, such patterns are common on crystalline granitic rocks.

The pattern develops on gently sloping landscape. This enables the consequent stream and the subsequent streams to flow in the direction of the initial slope or the area over which the pattern was established.

The pattern also develops in areas which receive heavy and reliable rainfall. This is able to support the development of multiple tributaries and that is why the pattern is common in equatorial regions.

This pattern also develops in areas of a common catchment area. The common catchment area usually large gives rise to multiple tributaries.

5. **Trellis/Rectilinear patterns;** this is a rectilinear pattern in which the tributaries join the main river at more or less right angles. It develops in areas with alternate hard and soft rocks that lie approximately at right angles with the general slopes following which the main river flows. The major and minor streams flow in accordance to the slope direction while the obsequent flow in opposite direction to the slope joining other streams at approximately right angles.

this pattern is not wide spread in east Africa but rivers like Achwa and Tochi in Uganda poses the pattern.

#### **Structure of a trellis pattern**

The conditions for the development of the pattern include;

It develops in areas of alternating hard and soft rocks. The soft rocks are usually eroded to create river valleys that join the main river at right angles.

Heavy rainfall in an area is important for the sustenance of the consequent, subsequent, and obsequent streams which constitute the drainage pattern

These patterns cover large catchment areas that experience heavy and reliable rainfall as the streams are spread apart.

They may also develop due to river capture e.g. along river Tiva, Galana, Aswa, Tochi, and Pager.

The pattern is also facilitated by the existence of joint such as those caused by faulting. Such joints provided weak zones through which rivers can flow.

6. **Pinnate pattern;** this pattern resembles a feather. In this case, tributaries join the main river at extreme acute angles so as to make the pattern look like a feather. Good example is in the Kerio valley in western Kenya.

#### **Illustration**

This pattern develops in areas where the following conditions exist;

There must be existence of rocks of uniform resistance. Usually it develops on soft, less permeable rocks that can be easily eroded by small rivers that have limited erosive power thus forming many small tributaries.

Large catchment areas with heavy and reliable rainfall is essential to sustain the many small rivers which make up this pattern.

There should also be a gently dipping slope. This allows the existence of small streams despite having low water volume and content.

7. **Hooked/Barbed pattern;** in this pattern, tributary rivers appear to flow in the opposite direction to the main river before joining it at an acute angle. This

pattern is best developed in areas that experienced river capture and drainage reversal e.g. in western Uganda and northern Tanzania. The examples of the pattern are evident on R. Katanga, R. Kafu, R. Rwizi, and R. Kagera.

### **Illustration**

The factors favoring the developing of this pattern include;

River capture; in this process, a strong river arrests the waters of a weak river forcing the tributaries of the weak river to change direction.

It is favored by the existence of alternating dips (slopes). In this case, rivers joining the main river originate from a higher point opposite to the source of the main river. as a result of uplift in the direction of the main river, the joining rivers reverse to join the main river because they fail to climb or erode through the steep gradient created ahead of them.

There must also be a big catchment area with heavy and reliable rainfall to support the existence of the main tributaries

- 8. Annular Pattern;** this is the pattern in which tributaries join the main river at right angles in a concentric manner. It is developed in volcanic regions where rivers flow sharply in a series of curves around craters/calderas. In east Africa around Ngorongoro craters, this pattern is said to exist.

**Its** favored by the large catchment area with reliable rainfall which supports the growth of the streams. The heavy rainfall sustains the river's ability to erode soft rocks in concentric curves.

**The** dissected plateau/dome/a faulted zone with alternating hard and soft rocks also favors its development.

### **Structure of Annular pattern**



## DISCORDANT PATTERNS

These are drainage patterns whose arrangement doesn't show any relationship between rock structure and relief. They are of two types i.e. superimposed patterns and antecedent patterns.

9. **Antecedent pattern;** this pattern develops when a section (hole) of a river's course experiences uplift but the river maintains its course across the rising land. The river maintains its level by cutting down (incising) its bed at the same rate as uplift is taking place. In this way, the river cuts a gorge into the uplifted section and now flows on a new rock surface.

This pattern is common in areas of recent earth movement where uplifting of the land took place slowly. With slow uplift, the rivers were able to maintain their down cutting and time was insufficient for the drainage to become completely adjusted to the structure of rocks. Examples of this pattern are evident on R. Birira in western Uganda, and the great Ruaha at Iringa highlands in southern Tanzania.

10. **Superimposed Drainage Pattern;** this is a drainage pattern which develops on one set of rocks which are then eroded to uncover an older and different landscape to which they are not related. The original drainage pattern is normally maintained and is not affected by the structure of the current older rocks hence being superimposed.

**Superimposed** patterns develop under the following conditions;

The river must be strong enough to carry out vertical erosion to reach a new rock structure.

The original rocks onto which the river originally developed should be soft and highly eroded thus down cutting.

It also develops where the river is able to maintain its original course and direction on the new rock structure.

There should be no direct relationship between the river and the rocks upon which the river is flowing.

### **FACTORS INFLUENCING THE DEVELOPMENT OF DRAINAGE PATTERNS**

A number of factors have influenced the development of drainage patterns and these include;

1. Rock structure; there are several ways through which rock structure has influenced the development of drainage pattern. Due to differing rock hardness, superimposed drainage pattern has developed. Softer rocks which overlay are eroded by rivers such that these rivers can easily flow over completely new hard and old rocks. A good example is at sabaloka along the Nile in Sudan.

Rock permeability influences the development of drainage patterns in limestone rocks. In such areas, seasonal drainage patterns have developed. During the rainy seasons, the rivers exist but they disappear during the dry season as all the water sinks rapidly below the bed rocks e.g. R. Kanyagareng in Nakaprirpit district.

Rocks that offer uniform level of resistance (homogenous rocks) have led to the development of dendritic drainage patterns e.g. on R. Athi, Nyando, R. Nzoia in Kenya and R. Moroto in Uganda. Dendritic patterns develop where tributary joins the main stream at acute angles and are widely distributed due to similar levels of resistance.

Presence of minor rock structures such as faults and joints have encouraged parallel and trellis drainage patterns to develop. In these patterns rivers flow in channels that follow cracks (joints) and faults e.g. R. Aswa in northern Uganda follows a fault. R. Tochi and Pager also follow rectangular rock joints.

A river flowing on softer rock compared to a neighboring river, erodes its valley and consequently the one on softer rocks captures one on the harder rocks e.g. R. Birira captures part of R. Rwizi, Tochi, Okole, and Arocha were captured by the Nile whereas R. Tiva in Kenya captured part of R. Athi.

## 2. Tectonic Movements (tectonism);

- a. Uplift forces lead to the development of antecedent drainage patterns. As uplift takes place, the river undercuts its valley deeper at the same rate of uplift and maintains its course through the rising land. Eventually a gorge is formed e.g. R. Birira is antecedent at the Mitano gorge in western Uganda while R. Ruaha is antecedent in Iringa highland in southern Tanzania
- b. Up warping followed by down warping which leads to drainage reversal may result into the development of hooked (barbed) drainage patterns. Upward and downward movement reverses the direction of rivers which previously followed towards western Uganda. This caused rivers like Kafu, Rwizi, and Katonga to develop hooked patterns.
- c. Volcanicity has caused the development of radial drainage pattern on rivers such as Sippi, Malaba, Manafwa, and Suam, which radiates from Mt. Elgon. Also on Mt. Kenya rivers like Ewasongiro, Rupin, Rupangazi, and others radiate in different direction. Volcanicity causes the development of domes from which rivers originate forming radial patterns.
- d. Faulting has resulted into the formation of rift valley lakes on which centripetal patterns has developed e.g. on Lake Baringo in Kenya. The rift valley lakes form basins in which rivers from different directions converge

forming centripetal patterns. On Lake Baringo, the rivers include Molo, Lobo, and Olarabel.

- e. \*faulting has also produced parallel escarpments on Butiaba escarpments and on the eastern side of the Abadares. Due to faulting, parallel faults and joints develop and rivers flow following these faults e.g. River Nkusi and Hoima
3. Glaciation on some mountains of east Africa has led to the development of radial drainage pattern. The glacial melt water is a source of some rivers e.g. Nyamwamba, Sibwe, and Mobuku on Mt. Rwenzori.
  4. Climate also influences drainage patterns. Heavy rainfall is essential as it is a source of water that sustains the flow of both the main and subsequent streams.

RIVERS & DRAINAGE PATTERNS

## GLACIATION IN EAST AFRICA

A glacier is a mass of ice flowing out of the snow fluid under the influence of gravity or due to pressure of the over lying masses of the snow which causes the ice to move from the centre of the snow fluid

The formation of glacier begins with the formation of crystals which falls on the earth as snow. If temperature remains below  $0^{\circ}\text{C}$ , the snow gradually accumulates. The underlined layers due to pressure (compact) recrystallise into a hard gradular ice with a glassy appearance called a glacier ice. When this begins to flow outwards or down slope due to gravity of the pressure. It's called glacier.

NB: Glaciation refers to the growth and decay of glaciers together with water erosion, deposition and of the resultant modification of the landscape

Permanent glaciers exist in all continents except Australia and their existence is determined by the snow line (altitude at the permanent glacier above sea level). This height differs from place to place e.g. in polar regions i.e. snow line is at sea level while the equator is about 4800m above sea level as illustrated in the graph below.

### TYPES OF GLACIERS

GLACIERS ARE GENERALLY CLASSIFIED INTO THE FOLLOWING.

#### Valley glaciers

These are also called mountain or alpine glaciers. They are found on the mountain and move down the mountain to occupy former valleys. Their movement is controlled by gravity amount of ice and the valley down to where they flow. This is the type of glacier in east Africa.

#### Continental glaciers (ice sheets)

These occupy and are spread over a continental plateau area. They are broad and cover the entire landscape. E.g. are found in Greenland, Australia, Arctic, northern Canada etc

#### Piedmont glaciers.

These consist of ice sheets that form when valley glaciers spread to the lowland below the snow line joining to form "lake of ice".

### GLACIERS IN EAST AFRICA

Permanent glaciers in east Africa now exist in three highest mountains i.e. Kenya, Rwenzori, and Kilimanjaro. But available evidence shows that other mountains like Elgon also had glaciers only that the glaciers have receded.

Latitudinal location. East Africa lies as far as the where temperature are constantly high. The high temperatures don't favor the formation of glacier ice.

**Altitude.** Much of east Africa lies below 2500. This means that even during the pleistocene period when the snow line was between 2000-3000 m above sea level only

limited areas would be glaciated. At the moment temperature are formation of snow. These areas are limited in east Africa.

**Volcanism.** Alsh high lands of east Africa are volcanic and therefore warm. Mount Kilimanjaro is said to be warmer while Mount Elgon has been known to be warmer than expected due to the hot interior. This warmth prevents the formation of glaciers. But also as in the case of Kilimanjaro, it leads to rapid decay retreats of glaciers.

**Low precipitation levels.** Precipitation in form of rainfall and water vapor is limited. In some areas like in Turkana land, Karamoja, Nyika plateau, rainfall is inadequate. This low precipitation of east Africa are arid and hence unfavorable glacial development.

**Rain fall shadow effect.** The development of the glaciers on the lee ward side of the mountain is affected by high temperatures e.g. on mount Rwenzori, the snow line is higher on eastern side than the western side. This is because the eastern side is on the lee ward side where it experiences warm, dry winds that waste the glacier.

**Global warming.** Due to accumulation of carbon dioxide in the atmosphere and emission of chlorofluoro carbons (C.F.C s) and deforestation estimated that since 1950s the world temperature has been on the rise by an average of 2.5<sup>0</sup>c causing glaciers to retreat.

Erosion by rivers and streams. Flowing on the sides and beneath the glacier to erode the glacier leading to its ablation (wastage).

Also heat reflected from surrounding rocks on the valley sides causes the ice to melt and aid in its wastage.

## THE WORK OF GLACIERS

The influence of glaciations on the landscape of east Africa can be summarized into three.

**Glacial erosion**

**Glacial transportation**

**Glacial deposition**

**GLACIAL EROSION**

A glacier especially the one that carries debris can move and carry a lot of material thus sculpturing the landscape. Glaciers erode in two ways.

Plucking is a quarrying process by which loose rock fragments are removed from the channel as the glacier moves. The glacier freezes on rocks protruding on its valley bed and size and tears them off and are then transported by the glacier.

Abrasion is the process by which rock particles such as pebbles and boulders “grind the channel in which they are being transported by glacier. These particles are dragged and rolled on the underlying rocks which are polished and scratched and abrasion depends on the relative hardness of their grinding tools and channel rocks.

Glacial erosion produces debris as moraine which consists of gravel soils, pebbles and boulders.

**GLACIAL TRANSPORTATION**

Glaciers transport their moraine in several ways. These include

**On the sides of the glacier**

Materials transported on the side of the glacier are called lateral moraine. These materials are derived from frost shattering.

**In the top middle of the glacier**

Moraine transported in this way is called medial moraine. Medial moraine is formed when adjacent glaciers join lateral moraine closest to each other.

At the snout (tongue)

As the glacier advances, it pushes some debris known as terminal moraine with the glacier

This is when material on the surface of the glacier soon falls into crevasses and becomes enclosed within the glacier. Materials enclosed within the glacier are called englacial moraine.

**At the bed (bottom)**

When some of the englacial moraine reaches the bottom of the glacier, it is transported as sub glacial moraine.

### **GLACIAL LAND FORMS**

Glaciations have made a great impact on the landscape in many parts of the world. In east Africa, glaciations are restricted to the areas of above 4800m above sea level and these are tops of mount Rwenzori, Kilimanjaro and Kenya. In general, glacial land forms are classified as follows.

**Erosional landforms (glacial erosion)**

**Peri-glacial landforms**

**Depositional landforms (glacial deposition)**

#### **LAND FORMS OF GLACIAL EROSION**

These are a result of plucking and abrasion processes and include the following.

**Cirques/corries/corns**

A cirque is a steep sided rock basin with an arm chair (semi- circular) shape. It is given different names in different countries. In Germany it's called Kar, in Wales it's called Cwm, Corrie in Scotland.

Cirques are formed when glaciers collect in a small hollows on the mountain sides. Freeze than weathering helps to shatter the rocks on the edges of the hollow and this enlarges the hollow further. A combination of weathering on the sides of the hollow extends the sides of the depression, a process called back wall recession or basal surping. Plucking and abrasion helps to deepen the hollow. With time, a big rock basin is formed and when ice melts, water accumulates in it to form a lake called tarn e.g. Teleki on Mount Kenya. Lac-du-Speke and Lac – Catherine on mount Rwenzori.

**Cross section of a cirque**

#### **Arete**

This is a narrow rock ridge with steep sides developing between or separating two cirques. It is formed by the cutting back of the back walls of two cirques by plucking. The process reduces the area separating the two cirques to only a narrow knife edge called an arête.

**Illustration**

### **Pyramidal peaks**

This is a mountain that is not yet worn by erosion. It is formed at the junction of the arêtes, as a result of steepening of the back walls of several cirques. These peaks become sharpened by frost action and resemble a pyramid. Examples include Margarita peak on Mount Rwenzori. Point John on Mount Kenya.

### **Glacial trough**

This is a broad flat bottomed steep sided valley with a roughly U-shaped cross profile. They are former river valleys that have been modified by ice through plucking and abrasion. Over deepening of the glacial valley is especially a result of abrasion by ice using large amount of moraine at its base. Afterwards, water may occupy the over deepened parts to create along narrow lake known as a ribbon lake e.g. Lac Noir on Rwenzori.

If on the other hand, the lower part of the U-shaped valley is submerged by the sea, a feature called a fiord is formed.

Examples of glacial troughs include Bujuku, Mobuku, Kamusoso, on Mount Rwenzori. On Mount Kenya they include Gorges and Teleki valley while on Mount Kilimanjaro there is Karanga valley.

### **Illustration**

### **Hanging valleys.**

These are depressions associated with glacial trough. They are formed at a much higher level than the glacial trough and are occupied by a small amount of glacial. The smaller glacier in the hanging valley has a less erosive power and therefore carries out minimal deepening. These contrast with the trough that has a large glacier and is therefore intensively deepened. The floor of the tributary valley will be higher on the mountain side and that's why it is described as hanging. When a river descends over a steep edge of the hanging valley to the floor of the glacial trough, it forms a water fall. At the bottom of the waterfall, an alluvial fan develops as sediments and fragments are deposited due to slow velocity of water.

### **Illustration of a hanging valley**



### **Roche moutonnee**

This is a mass of resistant rocks which projects above the general level of a glaciated valley floor. On the side where the glacier approaches, (up stream side), there is abrasion and this is polished and smoothened and made irregular (jagged) due to plucking especially when the rock is well jointed and water freezes on the down stream side of the rock and tears out pieces of rock as it moves down stream.

### **Structure of a rock moutonnee**

### **A rock basin**

This is an irregular depression in the floor of a u-shaped valley formed by an equal glacial erosion of the bedrock. Its formed when the thickness and the weight of the glacier increases e.g. at the junction of two glaciers. This increases the vertical erosive power of a glacier drilling a basin.

### **Crag and tail**

This landform develops when a resistant rock out crop obstructs the movement of ice. Weak rocks on the down stream side are therefore protected from erosion and remain as an elongated tail of weak rocks on which some deposits are laid.

### **Illustration**

## **GLACIAL DEPOSITIONAL FEATURES**

These are divided into two i.e.

- **Depositional landforms made of unsorted ,aterials**
- **Depositional land forms made of sorted fluvio-glacial materials.**

The un sorted materials (till) consists of material deposited directly by the glacier. The sorted material (fluvio-glacial material) is this debris carried and deposited by the melt water from the glacier.

### **DEPOSITION LAND FORMS MADE OF UNSORTED MATERIALS**

#### **Till plain**

This is an extensive area made of the clay and boulders deposited over the land surface. These materials may cover up pre glacial land forms. Till plains can be observed in many glaciated valleys on east Africa's mountains. Example on the floor of Teleki and Naromuru valley on Mount Kenya. Till plains are also called boulder plain.

#### **Drumlins**

These are elongated oval shaped hills of glacial materials. They are about 1 km long and 25-30 m high. The upstream side is usually steeper than the down stream as a result of friction between the rocks embedded in the ice and the solid ground rock. They occur mainly in gorges or swamps.

#### **Structure of drumlins**

#### **Moraines**

These are materials carried by glacier and later deposited as the ice stagnant. The following types of moraines are recognized.

- Terminal moraines. This is moraine mound or ridge extending across the valley. It forms as a result of accumulation of moraine especially where it removes stagnant for a time. E.g. the gorge valley on Mount Kenya, in the Taranga in south east valley on Mount Rwenzori, Kamusoso and Nyamugasani on mount Rwenzori.
- Lateral moraines. These are deposited along the valley forming ridges on the sides.
- Medial moraine. This is usually found in the centre of the glaciated valley. It's made up of former medial moraines which have now been dropped as the ice retreated.
- Ground moraine. This is moraine deposited over the valley floor. It covers the entire width of the valley. It's made up of former englacial and ground moraine which have been dropped by retreating glacier.

#### **Structure of moraine**

### **Erratics**

These are boulders that have been transported from elsewhere and are now deposited in areas of completely different rocks. i.e. they are boulders that have been carried far from parent rocks and now rest in areas where the local rocks are completely different. Erratics are evident below the junction of Nithi and little Nithi rivers in the Gorges valley on Mount Kenya and in the Kamusoso and Bujuku valleys on Mount Rwenzori.

### **LAND FORMS OF FLUVIO-GLACIAL DEPOSITS**

These consist of sorted materials that are carried and deposited by the melt water from glacier. They include the following

#### **Out wash plain**

This is a flat area from the glacier snout composed of sorted materials ranging from coarse gravels near the glacier snout to sand and finally clay very far off respectively. As melt water from the glacier snout issues out, it picks the materials which were originally deposited by the glacier and carries them down the valley. In the process, the deposits are sorted out with coarse materials forming the plain nearer to the terminal moraine and fine ones away from the moraine. E.g. on the Mobuku valley on Mount Rwenzori and in the saddle between Kibo and Mawenzi peaks on Mount Kilimanjaro.

#### **Structure of out wash plain**

### **Eskers**

An esker is an elongated narrow and steep sided winding ridge made of sorted coarse sand and gravel. It's formed by rivers flowing under glacier. Melt water flowing under ice may create a permanent tunnel for itself where it deposits materials which gradually build to form long winding ridges under the glacier. When the glacier finally retreats, the esker is left behind e.g. along river Nithi in Gorges valley and along Teleki valley both on Mount Kenya.

Some eskers are formed when long persistent streams flowing on top of a retreating glacier continuously deposit their materials at the glacier snout. As the glacier snout recedes, the deposits remain forming an esker.

#### **Kettle hole**

This is a hollow / depression forms when a block of ice is detached from the main glacier as it retreats. Such a block of ice may then be buried under glacial melt water deposits. When the ice block melts, it leaves behind a depression which when filled with water forms a lake called a kettle lake e.g. Lake Mahoma on Mount Rwenzori and Lake Elis on Mount Kenya.

## **Structure of a kettle hole**

### **Kame**

A kame is an irregular undulating mound or hill of sand and gravel deposited unevenly by melt water. It is formed when melt water issuing from the top of a glacier which is stationary deposits materials at the bottom of the snout to form a delta like deposit e.g. at the end of Tyndal glacier Mount Kenya and at the end of Moore glacier on Mount Rwenzori.

### **Kame Terrace**

These are ridges of sand and gravel found along the sides of a glaciated valley. Melt water flowing between the valley sides and the glacier deposit materials which gradually build into ridges. They differ from lateral moraine in that they consist of sorted materials. Kame terraces exist at the end of the Tyndal glacier on Mount Kenya and Moore glacier on Mount Rwenzori.

### **Structure of a kame terrace**

## **IMPORTANCE OF GLACIATION**

- The water falls issuing from hanging valleys are potential areas for the generation of HEP
- U shaped valleys form natural root ways in highland regions.
- Glaciated landscapes with their characteristic features such as corries, hanging valleys, ice-capped peaks, and plunging water falls form magnificent scenery which attracts tourists.
- The tarns formed due to glaciations form natural reservoirs for domestic water supplies in glaciated uplands. They also act as potential fishing ground and modify local climates.
- Melt water from glaciers form a permanent water source for farmers e.g. The Chaga of Tanzania use water from Kilimanjaro for irrigation while the Bakonjo use melt water from Rwenzori
- Many glaciated valleys have good pastures giving rise to Alpine grazing
- Terminal moraines and out wash plains provide sand and gravel for the construction industry.

The disadvantages include

- Upland glaciations scour the ground denuding it of fertile soil. This makes glaciated valleys unsuitable for agriculture
- The down hill movement of glaciers causes extensive damage of property and loss of lives.

- Vast areas are covered by out wash plains which may contain infertile soils hence giving rise to extensive areas of waste land
- Ice sheets on the surface of the earth create very cold conditions quite unsuitable for human settlement.

Sample questions

1. Examine the processes possible for the formation of glacial erosional land forms in east Africa.
2. Describe and account for the formation of glacial depositional land forms in east Africa.
3. Account for the formation of land forms in the glaciated low lands in east Africa.
4. Account for the limited glacial coverage in east Africa.
5. (a). Identify and describe the glacial features on the mountains of east Africa.  
(b). what is the importance of glaciations to the people living around glaciated zones

RIVERS & DRAINAGE PATTERNS