COASTAL GEOMORPHOLOGY

This is an aspect of physical geography that entirely deals with resultant features developing on a given coast as a result of coastal processes like weave action, sea level changes and coral formation.

DEFINITIONS:

A coast

This is a zone of contact between the land and the sea or ocean. It is characterised by being a low lying area. Some coats are indented while other are somewhat straight eg the European/Asian coasts and east African coast respectively.

Coast line

It is the limit at which wave action takes place. It is the margin of land where sea water stops.

A shore

Is a trip of land that lies between high water and low water levels.

Shore line

Is the line where the shore and the water meet.

A beach

Is an accumulation of sand, shingle, Pebbles, shells on the shore. This is due to constructive waves and sometimes eustatism (sea level changes).

Coastal features are mainly produced by three processes i.e

1. Wave action
2. Sea level changes
3. Coral reef formation

FACTORS INFLUENCING THE NATURE AND SHAPE OF THE COAST

The nature, type and character of any coast depends on the interaction between several factors

Influence of waves and tidal currents. These act as agents of erosion (destructive waves) , transportation and deposition (constructive waves) on water bodies. They are caused by movement of winds across the water bodies. Waves play a big role in shaping any given coast since their energy determines the rate of erosion and deposition that leads to different coastal features.

Nature of rocks along the coast. Nature of rocks along the coast also influences coastal evolution. Soft rocks are first eroded compared to hard rocks which remain as head lands. wave effects are most effective in well jointed rocks and un consolidated rock particles which can easily be plucked out by hydraulic action therefore coasts along less resistant or weak rocks usually show a different morphology from those lying on hard rocks.

Special climatic conditions. These have led to evolution of different coastal features e.g some features like coral reefs and mangrove vegetation are limited to the tropics particularly to the East African coast. Fiords on the other hand occupy only mountainous areas in high altitude areas where Pleistocene glaciers have curved out U- shaped valleys below the sea level. This was followed by deglaciation and a rise in sea level filling the valleys to form fiords.

Coastal configuration/trend of the coast. This also determines how a particular coast evolves. If the coastal alignment is such that the waves approach the right angles, then coastal erosion is very effective. This results in to formation of several coastal erosional features. If on the other hand the waves approach the coast obliquely, erosion is limited.

The influence of man also affects coastal evolution. Several artificial features emerged on the coastal areas as a result of man's needs eg marine engineering features like ports, marine artificial harbours, construction of coastal defences eg fort Jesus etc. All these destroy the original shape of the coast.

Time. Any process occurring at the coast needs time in order to change the nature of the coast. The more spent by coastal formation processes, the more the rate of coastal formation and vice versa.

Other factors include: -

- Coral growth
- Effect of glaciation and deglaciation
- Volcanic activity
- Sea level changes

TYPES OF COASTS

Generally, coasts are divided in to four categories i.e

- Those shaped by organic deposition.
- Those shaped by inorganic deposition.
- Emerged coasts.
- Sub merged coasts.

1: SUB MERGED COASTS.

This is caused either by subsidence of land or arise in sea level. Subsidence can be caused by folding or faulting along the coast. Sea level rise may also be as a result of global changes especially during the plestocene period where a worldwide rise in sea level was experience following the melting of continental ice sheets.

Sub merged coasts are characterised by cliffs and wave cut platforms that are about 10m below the current sea level.

Note: Submerged coasts are divided in to submerged highland and submerged lowland coats.

Submerged highland coasts include ria coasts and fiord coasts.

A ria coast is a river valley mouth that has been drowned following arise in sea or ocean level**.** Rias are funnel shaped with deeper sea ward and shallow land ward sides. They provide good and sheltered natural harbours eg at Kilindini in Kenya on which port Mombasa rests.

Fiord coats occur in glaciated regions. Glacial erosion through plucking and abrasion leads to the formation of U- Shaped valleys. Once these valleys are drowned after sea level rise, fiord coasts are formed. Fiords are usually deeper, narrow and steep side inlets. They are common on former glaciated regions like British Columbia, Alaska and Norway.

submerged lowland coats.

These occur in gently sloping low lying coastal areas. Water covers extensive area of land and initial river valleys/ mouths are downed to become broad estuaries.

2: EMERGED COASTS

They occur when the sea level drops or the land near the sea rises relative to the sea due to faulting, folding or isostatic changes. It is divided in to emerged highland coasts and emerged low land coasts.

Emerged high land coasts are characterised by raised beaches found some distance away from the shore. Such raised beaches occur as wave cut platforms or caves. This type of coast can be identified at Mombasa.

Emerged lowland coasts form broad coastal plains sometimes with vegetation eg at Rufiji delta in Tanzania.

3: COAST SHAPED BY ORGANIC DEPOSITION

They are subdivided in to coral coasts and mangrove coasts**.**

Coral coasts are large, organic in origin and they form from small sea organisms called coral polyps. When these polyps die, their skeletons which are made up of calcium carbonate accumulate to form coral limestone. In this way, masses of rocks are gradually built up and are called coral reefs. They are of three types ie fringing reefs, barrier reefs and atolls. They are common at the coast of East Africa.

Mangrove coasts are common in equatorial Africa as well as East African coast. Vegetation plays a major role in coastal deposition by stabilising estuaries, mad banks, dunes and spits. When such vegetation holds or traps more deposits, the nature of the coast is hardened. When such vegetation grows in coastal marshy water, then a mangrove coast is formed.

4: COASTS FORMED DUE TO INORGANIC DEPOSITION

These are in form of marine spits and barrier beaches. Here, there are embarkments of sand which torches to the land at one end and extends to the sea on the other side. Some spits form in a a parallel way to the coast enclosing lagoons. These types of coats are limited in East Africa but are very common on the coast of West and South Africa.

WAVE ACTION

Waves are ripples/ oscillations which appear on water bodies when wind blows over the water body. As wind blows over the water body, a friction drag develops at the point of contact between the wind and the water. The dragging of the water surface heaps the water hence forming waves which push towards the direction of wind movement. As the strength of the wind increases, so does the friction drag and the size of the wave. Also catastrophic events like volcanic eruption, earthquakes and landslides generate waves on the water. They are called Tsunamis. Such waves are capable of making heavy destruction due to the high energy they possess. The movement of water vessels like ships and animals like wales also generate waves.

DEFINITION OF WAVE TERMINOLOGIES

Wave crest and wave trough: The crest of the wave is the highest point of the wave while the troughs are the lowest points of the wave.

Wave height: This is the distance between the crest and the trough. Wave height I usually less than 6m except in the case of tsunamis.

Wave length: This is the distance from one wave crest to another.

Wave amplitude: This is the half height of the wave.

Wave frequency: This is the number of crests that pass a point in a minute.

Wave velocity: This is the speed of movement of the wave crest in a given period of time.

Fetch: This is the maximum distance of open water over which wind can blow.

Swash: This is the body of forming water that rushes to the beach when a wave breaks.

Backwash: This is the water returning down to the sea or ocean.

TYPES OF WAVES

Depending on the effect they have on the coast, waves cab be categorised as **destructive and constructive**.

Constructive waves. The carry out more deposition than erosion. They are low in height with long wave length and low frequency of 6-8 crests breaking per minute. The waves break on a low angle shore. They have wide fetch and reduces energy hence deposition.

Destructive waves. This carry out more erosion than deposition. They are characterised by high energy used to carry out erosion. They break at sharp angles having their swash energy concentrate over a small area. They also have a strong backwash hence causing erosion.

FACTORS THAT INFLUENCE WAVE ACTION.

- Wave strength
- Breaking points of the rocks
- Stability of the sea level
- Tidal range
- The fetch covered by the wave
- Nature of the coastal rocks

WAVE EROSION

This is the wearing away of coastal rocks by the action of destructive waves. Destructive waves break at sharp angles and have strong swashes and back washes. They are large, steep in form and with a short wave length. They carry out erosion through processes like hydraulic action, abrasion, corrosion and attrition.

Hydraulic action. This takes place when waves send powerful swashes against the cliff face. In the process, air is compressed in the cracks that exist in the cliff faces. When water withdraws from the cliff face, the compressed air suddenly expands causing coastal rocks to brake.

Abrasion/ Corrasion: This occurs when the waves use the materials they are carrying as tools to wear down coastal rocks. The waves carry boulders, shingles and sand etc. which they hurl against the beach and eat away the rocks. This the most effective method of erosion especially on beaches which are attacked by storm waves.

S**olution/ corrosion**: This where the beach is made up of soluble rocks such as limestone. The solvent action of the water dissolves away the rocks and the rocks are carried away in solution.

Attrition: In attrition, the debris already eroded is transported while knocking each other and thus broken in to smaller pieces.

NB: Destructive waves are also called steep or spilling waves

EFFECTS/LANDFORMS OF WAVE EROSION

Wave erosion leads to the landward extension of the shore line a process known as coastal retro gradation. This has resulted into a number of wave erosional feature:

A notch. The hydraulic and corrosive action of waves leads to the undercutting of the coast to form a small opening known as a notch. Notches are common in well-developed limestone rocks which have been removed the chemical action of waves.

ILLUSTRATION

A cliff: Is a steep rock face along the sea coast. It is formed by the wearing back of the beach through under cutting. Its formation begins with the development of a notch on the beach. Through hydraulic action and abrasion, the notch is enlarged. Soon the top of the notch is left hanging and collapses in t the water forming a cliff face. The cliff steepens as its base is attacked by wave action again. Examples in East Africa include Watamu coast in Kenya and near fort Jesus in Mombasa.

Illustration

Wave cut platform

These are raised flat pieces of land that are formed at the foot of the cliff. They form between high and low water tides. During cliff formation, the combined effect of wave erosion at the base and weathering above leads to the collapse of the upper part of the cliff. The fallen rocks become further broken by being swept backwards by the backwash and forward by the swash. This results into the formation of wave cut platforms just at the foot of the cliff. Most wave cut platforms are buried under water and are only exposed during low tides. Example are found south of Mombasa port at Mamangina.

Illustration

Headland. A headland is the projection of land into the sea or lake. Its produced by differential wave erosion on coast with alternating hard and soft rocks. Through hydraulic action, corrosion and abrasion, soft rocks are eroded to form bays while the hard ones resist erosion and remain as jutting into the water as headlands eg at Watamu coast and Entebbe peninsular.

Illustration

Caves. It's a cylindrical tunnel drilled in a cliff face. Its wide at the entrance and narrow at the end. It commonly develops on cliff faces that have joints. Hydraulic action and solution contribute to the opening of the joint which in time becomes a cave. When waves break at the cliff face, they compress air in the joints and when water withdraws, the air expands suddenly with shockwaves which break the rocks along the joints. This enlarges the joint further to form a cave. Examples are at Kilifi in Kenya, Kasenyi and around Entebbe peninsular in Uganda.

Illustration

Blow hole/gloup. It's an erosional feature associated with caves. It develops when hydraulic action and solution drill a joint vertically from one end of the cave up to the surface of the earth. Waves compress air within the cave and when the water withdraws, the air expands shuttering the rocks of the joints. Slowly by slowly, the joint is drilled up to the surface of the earth to form a blow hole.eg at Malindi on the Kenyan coast, Kasenyi on Lake Victoria, Botanical gardens on Entebbe peninsular, Mamangina Drive in Mombasa.

Illustration

A Geo. This is a long narrow steep sided inlet running inland form the face of the cliff. Its formed when hydraulic action leads to the collapse of the roof of the cave. Before its formation, a blow hole is usually formed at the end of the cave. But due to the pressure of hydraulic action along the joint, the roof of the cave is forced to collapse hence forming a geo.

Illustration

An arch. An arch is formed when a cave is drilled on the side of a headland by hydraulic action or abrasion and ultimately opens on the other side. It can also form when two caves are drilled both sides of the headland and eventually meet each other creating a water passage through the headland. This leaves a raised bridge like roof above the passage called a natural arch.

illustration

A stack

This is an isolated rock feature completely detached from the main land. A stack forms when an arch is gradually eroded until it collapses resulting in to a detachment of a mass of rock from the headland. The two are separated by part of the sea.

A stump

This is formed when a stack is gradually attacked by wave erosion to leave a residual feature called a stamp.

Good examples of stacks include, the rock pillar near Entebbe airport, at Kasenyi, at Malindi and Mombasa, Ukerewe islands of Lake Victoria etc.

Illustration

A bay

It is an extension of sea or lake in to the land. Bays are formed as a result of differential erosion of rocks with different resistance levels. The soft rocks are eaten off quickly by abrasion, hydraulic action and solution in case soluble rocks exist. This leads to the landward extension of water forming bays eg Sango bay, Homa bay, Murchison bay, Kavirondo gulf, Napoleon bay etc.

Illustration

NB: Avery wide and big bay is known as a gulf.

Avery long headland is known as a peninsular eg Entebbe peninsular.

WAVE DEPOSTION

Materials eroded by waves are eventually transported and find their resting place along the shore. Waves that carry out deposition are called constructive waves. Such waves are usually low in height, flat in form and with a long wavelength. The waves have a strong swash but a weaker backwash. This enables deposition of materials such as, sand, shells, and shingles to take place. The deposition of the materials creates various features such as beaches, spits, bars, tombolos, mud flats, and cuspate fore land.

Long shore drift = swash, oblique, backwash runs down straight, zigzag.

1. A beach; the term beach is used to refer to deposits that accumulate along the shore. These deposits may be sand, shingles (pebbles), shells etc. such beaches that develop on the shores are called normal beaches.
   Sometimes waves are strong and throw materials beyond the high water level or the shores. These are known as storm beaches.

Different beach types may be distinguished depending on the pre-dominance of beach materials e.g. a beach with sea shells is called a shelly beach. Beaches predominantly composed of sand are called sandy beaches e.g. Lido and Kasenyi on the northern shores of Lake Victoria.

A barrier beach; it is along ridge of sand that lies parallel to the coast and separated from it by a lagoon. A wave breaks before reaching the shore hence depositing materials in the sea. When the materials accumulate an off shore beach or barrier beach is formed. Some of these beaches may be drowned under water or can be exposed to the surface depending on whether the sea level has risen/ fallen respectively. A good example is on the coast of east Africa in Madagascar and on the coast of Benin and Nigeria

Bay head beaches-accumulation of sand between two headlands

2. **Beaches** are also associated with berms. These are ridge like depositional features formed by the accumulation of heavier stones and boulders at the upper limit of the beach. They are formed by a strong swash that it capable of transporting bigger materials towards the shoreline. A good example is on the wami delta in Tanzania.
3. **A spit;** is a long narrow accumulation of san and shingles attached to the land on one side while the other terminates in the sea. It is formed by deposition of materials especially along indented coasts and those broken by river mouth. Examples of spits include Kabo spit and Tonya spit on Lake Albert. Spits are however categorized into two i.e. hooked spits and cuspate spits.

   Hooked spits are those where the sea ward end of the spit curves towards the land. They are formed when constructive waves reach and deposit materials on the shore line obliquely. In this case, the sea ward end of the spit ids forced to curve towards the land hence forming a hooked spit. A good example is Butiaba on Lake Albert.

Cuspate spits form a triangular shape. This shape is formed when two spits develop and grow towards the sea and later converge when a simple spit grows and as it curves, it joins the headland/shoreline at both ends

4. **Cuspate foreland;** this is a triangular shaped deposits of sand and shingles projecting sea wards. It is formed when long shore drift creates two spits which grow towards the sea and converge in the water. The enclosed water (lagoon) is later filled with deposits of sand and shingles and is then colonized by vegetation. The area colonized by vegetation is known as cuspate foreland e.g. Tonya point on lake Albert

A bar; is a ridge of materials usually sand or mud which lies parallel or almost parallel to the coast and is not attached to the land. Bars form on gently sloping coasts and irregular shorelines. Their formation is associated with both beach drifting and long shore drift which deposit materials at further point from the shore. The long shore waves break before reaching the shore line while the beach drifting drags materials from shore seawards. This results into accumulation of deposits on the break point forming a bar. They are of different types such as bay bars, offshore bars, and barrier bars.

Offshore bars develop on gently sloping sea beds away from the shore and are usually temporarily submerged in water e.g. at Lamu along the coast of Kenya.

A bay bar, bay bars are formed when deposits accumulate across a bay enclosing a lagoon e.g. Lake Nabugabo bay from the rest of Lake Victoria.

A barrier bar is an accumulation of deposits away from the shore. Normally a bar is made up of a large quantity of deposits such that it extends beyond the general level of the sea

A Tombolo

This is a kind of natural bridge joining an offshore island to the main land or an island to an island. It is formed when longshore drift operating between the main land and the sea/ between two island deposits sand and shingles between the two eventually linking them up. A good example is tombolo that formerly linked Bukakata on the shores of Lake Victoria to Lambu Island.

A Lagoon

Wave deposition has also resulted into the formation of lagoons. This is a mass of water trapped behind an accumulation of deposits. Lagoons are formed when long shore drift deposits materials like sand and shingles in the sea at some distance from the shore thus enclosing a mass of water. When the water level falls in the main sea, the material traps the water behind it hence forming a lagoon. Example Lake Nabugabo on Lake Victoria

Mud Flats

This is a plat form built of mud, silt, and other alluvium. It develops when rivers and waves deposit materials along gentle coast especially in bays and estuaries. These deposits may be exposed at low tides but are submerged during high tides. Sometimes mud flats are colonized by salt tolerant vegetation like mangrove swamps. Examples are found at Mouth of river Rufigi, at Katanga in Tanzania and Lambu in Kenya.

Wave deposition also leads to the formation of salt mashes. These are coastal swamps that colonize mud flats. They have salts to tolerate with aerial roots fixed in the mud to support them. A good example is mangrove on the coast swamps on the coast of Mombassa and Dar es Salaam

IMPORTANCE OF COASTAL LAND FORMS

Mud flats along the east African coasts have provided habitats for the growth of mangrove forests and swamps. This has boosted the lumbering and craft making industry in east Africa.

The beautiful sceneries created by cliffs, headlands, arches, stucks, and beaches along the coast of east Africa attract tourists leading to foreign exchange inflow.

Coastal features have boosted mining industry for example sand mining along beaches such as Kasenyi, Lutembe, and Nabugabo on Lake Victoria. In turn, this has boosted the construction industry.

Bars and spits protect the coast lands against flood and destruction waves. They are able to check the strength of power of the wave before it approaches the shore.

Bays and headlands have contributed to the development of fishing industry. They provide a conducive, stable, and quiet environment for fish breeding e.g. at Kasenyi and Majanji on Lake Victoria.

Beaches are used for recreation purposes. They are often frequented by people who wish to spent leisure as such hotels have also developed on most beaches e.g. Speke resort Munyonyo.

Wave depositional and erosional features have boosted research in oceanology and field work e.g. thousands of students each year flock to the coast of east Africa for study purposes.

DISADVANTAGES

Strong swash currents are characterized by flooding of the shore line and fishing villages e.g. along Lake Victoria and Lake Kyoga.

Depositional of materials like snail shells as led to the spread of diseases like bilharzias along the coast of east Africa, mud flats and cuspate forelands are also dominated by swamps which are breeding grounds for mosquitoes which cause diseases.

Waves have been known to carry poisonous snakes onto the shore. This may result into fatal snake bite e.g. along the coast of Sri Lanka and India where death reportedly from snake bite is very common. In east Africa along the shores of Lake Kyoga, snake bites are also common during flood time

Sand bars and stamps below the water level are the major causes of devastating accidents on water. Boats tend to capsize on heating such submerged onbastcles.

SEA LEVEL CHANGES (EUSTATISM)

This refers to the rise and fall in sea level relative to the land. It can be positive or negative. Positive sea level change occurs when sea level rises relative to the land or when the land sinks relative to the sea. This results into submergence of coastal areas, a process other wise termed as marine transgression.

A negative change on the other hand occurs when sea level falls relative to the land or when land rises relative to the sea. This results into the emergence of coastal areas also termed as marine regression

The rise and fall in the level of the sea is caused by several factors.

CAUSES OF SEA LEVEL CHANGES

1. Glaciations and de-glaciation; when there is climatic change involving a drop in global temperature, water freezes on high mountains and Polar Regions into large ice masses. This leads to a fall in sea level. This is what happened during the Pleistocene period that was characterized by a fall in world temperatures. On the other hand, climatic change involving increase in temperature causes melting of ice. This releases water back into the ocean basins causing a major rise in sea level. This happened during periods of warmer that followed Pleistocene.

2. Earth’s movements that involve uplift and down warp also cause a change in sea level. Uplifting and up warping that occur in sea level coast result into a fall in sea level whereas down warping results into a rise in sea level.
3. Sedimentation of ocean basins also causes a rise in sea level. Rivers such as Tana, Rufiji deposit large quantities of alluvium into the sea. This displaces the water gradually leading to a rise in sea level. Similarly, the water poured into the seas by rivers such as the Nile in the Mediterranean, Rufigi and Tana in the Indian Ocean lead to a rise in sea level. The growth of other marine sediments like coral reefs along the coast of east Africa has also led to a rise in sea level.
4. Climatic changes involving periods of draught and rainfall also results into a change in sea level. During draught there is excessive evaporation that causes a loss of water from rivers, springs, and ocean basins. This results into a fall in sea level e.g. east Africa has been experiencing draught conditions for the past 50 years which has reduced the sea level exposing several features which were formerly submerged.

   Heavy rainfall on the other hand leads to an increase in the amount of water draining into seas as well as ocean basins. Hence it results into a rise in sea level with the associated submergence effect on coastal areas.

5. Contraction and expansion of ocean basins leads to a change in sea level. Some geologists have articulated that some tectonic and other sub marine earth movements result into the contraction and expansion of the ocean basins affecting the sea level. When the ocean basin expands, say during sea floor spreading it causes a fall in sea level and when it contracts, it causes a rise in sea level
6. Local change in global temperatures is another cause of sea level changes. As global temperatures rise, it causes melting of ice globally and water is discharged into the ocean basins through rivers. Rising temperatures are also responsible for heating the water which expands causing a rise in sea level.

   On the other hand, when temperatures drop, water molecules tend to contract. This leads to a relative drop in the sea level such an occurrence may take place in winter in the mid latitudes.

7. The influence of solar winds also leads to a rise in sea level. As the sun burns, it releases hydrogen particles (solar winds) into the air. On reaching the ozone layers, the hydrogen particles combine with oxygen forming water droplets. The water then finds its way into the ocean basin either directly from the sky or indirectly through springs and rivers. Over a long period of time, the water accumulates causing a sea level rise.
8. Human activities like construction of sea defenses, dumping sewage and hard core stones into the sea etc may lead to a rise in sea level.

LAND FORMS/ EFFECTS OF SEA LEVEL CHANGES

Sea level changes result into a number of land forms which are classified into two i.e. land forms of emergence and land forms of submergence.

LANDFORMS OF SUB MERGENCE

These are due to drowning of coastal areas following a rise in sea level. A rise in sea level may be caused by;

-Deglaciation i.e. melting of glaciers

-Earth movements involving down warp of the land relative to the sea

-Contraction of the ocean basins

-Volcanic activity occurring on the floor of the ocean

-Sedimentation of ocean basins which displace water upwards

-Increased rainfall

-Human activities that involve dumping of materials in the ocean

-Global warming

-Solar winds

The features formed due to a rise in sea level/submergence include Rias, fiords, Dalmatian coast sounds, estuaries, creeks, peninsulas, mud flats and swamps.

Rias; is a submerged river valley in a highland area. It is usually long, narrow, and deep inlet into the coast. It is funnel shaped and decreases in depth and width landwards.

Rias form on coast lands where hills and rivers meet the sea at right angles. After flooding (or a rise in sea level), the stream which form the river valley is completely submerged in water to form a Ria. A good example is Kilindini harbor on which Mombassa port is situated. It was formed as a result of submergence of the river valley of river Mwachi and river Kembeni.

Structure of a Ria

Dalmatian (longitudinal) coast and sounds; these appear as chains of islands running parallel to the coast. They form on coasts where ridges and valleys were originally running parallel to the sea before a rise in sea level. With the rise in sea level, the valleys are flooded while the ridges (highlands) become chains of islands running parallel to the coast line. The water that invades the valleys and thus separates the mainland from the off shore longitudinal islands is known as a sound. A good example is on the east African coast of Pemba islands.

Structure of a Dalmatian coast

An Estuary; these are wide shallow drowned river valleys in low land areas. They have a funnel shape. When sea level rises, flooding on the river mouth occurs. If it takes place in a low lying area, then estuaries are formed. Good examples are on the mouth of R. Wami and Rufigi on the coast of east Africa.

illustration

A fiord coast; these are drowned river valleys in glaciated regions. They are characterized by steep sides and deep water at the head and end to be shallow sea wards. Before a rise in sea level, they appear as deep river valleys deepened by glacial abrasion. When sea level rises, water submerges the deepened valleys forming fiords which appear as long indentations. These coasts don't occur in east Africa but are existence on the coasts of Sweden, Norway, and Alaska.

illustration

Creeks; these are former sea inlets which have been drowned to form larger inlets at the coast of east Africa e.g. Mtwara in Tanzania.

Peninsular; this is a piece of highland projecting into the sea. It is formed where highlands occur at right angles to the coast. When sea level rises, the valleys are submerged leaving the highland projecting into the sea. A good example is Entebbe peninsular on the shores of Lake Victoria.

salt marshes; These are deposits of fine silt and alluvial materials from drowned rivers following a rise in sea level. These deposits are usually colonized by vegetation adopted to salty conditions such as the mangroves along the east African coast. Such deposits may also enclose a mass of water cut off from the main lake called a lagoon

FEATURES OF EMERGENCE

Raised beaches

Raised cliffs

Raised wave cut plat form

These features are formed after a fall in sea level or when the land near the sea experiences uplift. When this happens, the features that were initially covered under water are exposed to the surface. These features include raised beaches, raised cliffs, raised terraces waterfalls, knick points etc.

A fall in level of the sea may be brought about by;

- Occurrence of glaciation
- Earth movements that involve uplift of land
- Expansion of ocean basins
- Climatic changes involving drought
- Human activities like irrigation
- Seasonal changes in temperature e.g. winter season

1. RAISED CLIFFS
   As the sea level falls, cliffs which had been in contact with the sea at high tides are gradually left higher up beyond the tide level. Those cliffs are now found well above the present level of wave action and are known as raised cliffs. Caves are sometimes revealed along the old cliff lines e.g. around Mombassa, Bagamoyo, and Kilifi
2. RAISED TERRACES
   The fall in sea level also leads to emergence of raised terraces. These are former wave cut platforms now left high above the sea level. They are therefore, found above the present tide level where a new terrace is developing.
3. RAISED BEACHES

When the level of the sea drops, beaches and terraces formerly close to the water are left higher up on the dry coast. The beaches now have no contact with water since the sea retreats to anew lower area. They are thus known as raised beaches e.g. at Tanga.

4. WATERFALLS AND PAIRED TERRACES

   A fall in sea level may be followed by river rejuvenation. This occurs because the river is forced to cut deeper in order to reach the new base level. In the process, paired terraces, knick points, gorges, and waterfalls are formed along river courses.

   illustration of the above features of emergence

5. In low land areas when sea level falls, coastal plains and even shore lines are formed. Coastal plains area low lying region that forms a continuous belt along the coast. When sea level falls, parts of the continental shelf emerge from the sea forming a coastal plain. Such a plain has no bays or headland e.g. on the east African coast.

EFFECTS OF SEA LEVEL CHANGES ON HUMAN ACTIVITIES

Rias have sheltered waters and therefore form good natural harbors which promote port development e.g. at Mombassa and Dar es Salaam. This has boosted trade in east Africa.

Raised cliffs, terraces and raised beaches attract tourists. Tourists in turn bring foreign exchange to east African countries.

Sand on the raised beaches is quarried and used as an ingredient in the various construction industries e.g. at Lutembe and Kasenyi.

Mud flats with their characteristic salty marshes like mangrove have boosted the forestry and craft industry in east Africa.

Features such as rias, raised beaches, mud flats, and raised terraces are important for study purposes, in terms of research and field work.

Negatively, mud flats attract vectors like snails and mosquitoes which cause diseases such as malaria and bilharzias.

Steep raised landscapes such as raised cliffs encourage landslides which are dangerous to humans.

Raised beaches and terraces are associated with poor soils which don't support agriculture e.g. at Lutembe and Kasenyi beaches.

CORAL LANDFORMS

Coral landforms/reefs are limestone rock platforms which occur along the coast in east Africa. They are common along the coast near Mombasa and on the Indian Ocean islands. Coral landforms were formed as a result of deposition and accumulation of skeletons of tiny marine organisms called coral polyps. Polyps which live in millions of colonies have outer shells which contain calcium carbonate. When they die, their softer parts decay but the skeletons drop and accumulate on the continental shelf. These are gradually compacted, cemented, and compressed into a hard rock known as coral reef.

Other marine organisms like mollusks, echinoderms, and certain cancerous algae help to cement the spaces between the coral reefs. After millions of years, the reef grows to a very big size.

CONDITIONS FOR CORAL GROWTH

Corals grow where there are high temperatures of above 21^0C or higher. For this reason, coral growth is confined to tropical and sub-tropical seas between 30^0N and 30^0S of the equator and on the eastern side of continents where warm currents exist.

Corals grow in a water environment. Coral polyps can't survive for long without water. For this reason, they are rare above the low tide.

Corals grow where there is salty water. They also require water rich in planktons to act as food for the polyps.

They survive in clean and clear water which allows sunlight to penetrate to a reasonable depth. This is because the polyps feed on planktons which require sun light for photosynthesis.

Presence of a continental shell, oceanic ridges and volcanic highlands off the coast on which the corals grow is also a vital condition for coral formation.

Coral growth takes place in rather shallow water where depth doesn't exceed 60 meters. Very deep water doesn't allow penetration of sunlight for photosynthesis necessary for the growth of planktons.

Coral growth also requires relatively calm and steam water. Instability erodes developing corals and stirs up dirt from the sea floor which interferes with the sunlight supply. However, gently breaking waves are good for coral growth because they add plenty of oxygen onto the water on which the polyps depend to live

TYPES OF CORAL REEFS

There are three types of coral reefs and these include fringing reefs, barrier reefs, and atolls.

1) **Fringing reefs**; this is a flattish coral platform attached to the coast and is normally separated from the coast by a shallow and narrow lagoon. This lagoon may disappear at a low water tide e.g. at Kilifi in Kenya and at Shanzu beach north of Mombassa.

   illustration

2) **Barrier reefs**; this is a coral platform which forms quite far from the coast and is separated from the coast by a wide and deep lagoon. Barrier reefs are limited in east Africa because of the limited continental shelf to provide a shallow platform on which corals grow. A good example is a barrier reef of Mayote in the Comoro highlands. The largest in the world is the Great Barrier Reef off the eastern coast of Australia.

3) **Atolls;** an atoll is a coral reef with a round shape. It forms around a lagoon whose floor is flat or nearly flat shaped far from the coast. Atolls are sometimes broken by narrow channels (inlets) e.g. the Aldabara atoll 700km from the east African coast in the Indian Ocean
Illustration

It should be noted that the formation of barrier reefs and atolls presents a puzzle because some of them form in very deep waters and rise above considerable depth yet at such depth corals would normally not survive as there is no planktons on which the polyps can feed hence man attempt to understand the mystery, a number of theories have been suggested i.e. subsidence theory, antecedent theory, and the glacial control theory.

THE SUBSIDENCE THEORY

This was advanced by Darwin in 1842. According to Darwin, the accumulation of magma around central openings or vents led to the formation of sub marine volcanic highlands. These islands provided platforms on which corals grew. As the corals died, their skeletons accumulated on the volcanic platforms and were eventually compacted, compressed and cemented into a hard rock. The fringing reef was therefore the first type of coral to form

Barrier reefs and atolls were formed as a result of subsidence of the sub marine volcanic highlands. This subsidence could have been a result of isostatic readjustment / fall in sea level. As the highlands subsided, the fringing reef grew upwards and outwards keeping pace with the rate of subsidence and maintaining it self at sea level. Therefore, fringing reefs developed into barrier reefs and later barrier reefs developed into atolls as illustrated in the diagrams below.

RELEVANCE OF THE THEORY

The existence of volcanic islands in the Indian Ocean off the east African coast shows that the theory has strength. It’s on these sub marine volcanic islands that Darwin suggested corals would begin to grow.

The theory is also supported by the fact that some coasts in close proximity to barrier and atoll reefs reveal evidence of submergence e.g. along the east African coast, there are drowned river valleys forming Rias at Mombassa and Dar es salaam.

WEAKNESSES OF THE THEORY

The first weakness is that some corals have been found to develop in areas where there is no evidence of sub mergence at all but instead where uplifting has occurred e.g. on Hawaii island.

Secondly, the theory doesn’t explain why some corals are formed at great depth beyond 60 meters of depth.

The theory doesn’t also adequately explain why in some cases both atolls and fringing reefs appear in the same group of islands.

ANTECEDENT THEORY

This was propounded by John Murray in 1880. He explained the origin of barrier and atoll reefs in different ways.

For barrier reefs, he advanced that there was only a fringing reef growing along the coast and separated by a shallow lagoon. This reef was eroded by waves yielding coral fragments which were gradually deposited and accumulated on a sea ward sides. So the reef built further and further into the sea. He added that as the coral built outwards from the fringing reef, the coral on the inner side died due to lack of food. The dead coral was then dissolved in water to form a deep and wide lagoon hence a barrier reef.

Structure of a barrier reef

As far as atolls are concerned, Murray suggested that sub marine volcanic peaks or accumulation of pelagic deposits reaching within 60m of sea level existed before the corals. On these platforms, corals begun to grow more on the outer sea ward side where there was plenty of food. The inner corals therefore lacked food and died dissolving in water to form a deep and wide lagoon hence atoll reefs.

illustration

Relevance

Recent research has established the existence of pelagic deposits at a depth of 600m on the Mikini islands in the Indian Ocean. This is in line with what Marry suggested giving credence to his theory.

The other strength of the theory is that most atolls rest on truncated volcanic cones as was suggested by Marry.

Weaknesses

The first is that coral reefs once formed are so hard and can't easily be eroded as Mary suggested.

In addition, lagoons formed by barrier and atoll reefs are so deep and wide that they are unlikely to be formed by dissolving of the corals.

Also the theory doesn't explain why come corals are found so deep where conditions favoring their formation don't exist.

GLACIAL CONTROL THEORY

This was advanced by Daly and was based on changes in sea level. According to the theory, the sea level lowered considerably during the cold glacial times thus all the pre-glacial islands and reefs were planed down by marine erosion to the sea level of that time. This then provided platforms for coral growth during post glacial time.

As temperatures of the sea increased, and hence sea level rose later, corals also grew upwards and outwards maintaining their positions at sea level. Thus fringing reefs developed into barrier reefs and barrier reefs finally into atolls as the corals strove to keep pace with the rise in sea level.

Formation of coral reefs from glacial control theory

Strength

The theory is relevant in that it helps to explain the existence of the narrow steep sided reefs which make up most of the atolls.

Corals grow upwards at a rate of 1 meter in 30 years. Therefore, it is true that they keep pace with the rising sea level.

We have gone through four ice ages. It is therefore true that the sea level has been rising and falling as suggested by Daly.

Weaknesses

Old corals are very hard and can’t easily be eroded. Erosion is very slow at a rate of 2mm per year. It is therefore doubtful that the submarine wave cut platforms which formed new surfaces for coral growth would have been formed by erosion

Conclusively, all the theories of coral formation have strength and weaknesses in equal measures. Suffice to say that they have been very helpful in providing a basis for understanding the formation of coral land forms.

IMPORTANCE OF CORAL LANDFORMS

1) Fringing reefs may shelter ports from sea waves and tidal currents e.g. Loven and Andromache reefs at Mombassa and Kitoka reef at Kilifi in Kenya.
2) Coral limestone is a raw material for the manufacture of cement e.g. at Bamburi in Kenya and Wazo at Tanga in Tanzania. The two factories use coral limestone ass a raw material.
3) The existence of corals along the east African coast is a possible indicator of the presence of petroleum. The polyps which die have fats which may accumulate into strata of sedimentary rocks. Therefore, this provides for oil exploitation in east Africa.
4) Corals are quarried to make aggregates and blocks used for house construction. Such houses are common at Pemba and Zanzibar.
5) Corals are rare and appear in a variety of shapes and colors e.g. sea fan corals, mushroom corals, soft corals etc. hence they attract tourists increasing foreign exchange inflow into east Africa.
6) The lagoons enclosed by fringing reefs are good avenues for recreational activities such as bathing and swimming. They also provide a conducive environment for fish breeding boosting the fishing industry.
7) Corals are weathered down to reproduce soils suitable for tree crops such as coconuts, mangoes, and cashew nuts. These are widely grown at Zanzibar and Pemba.
8) Coral reefs are used for study and research purposes
9) Corals have also boosted the art craft industry. Corals especially those with hard cores can be curved to form jewelry.

However, corals may also hinder economic and human activities in the following ways;

1) They weather down into poor shallow soils. This explains why only mangoes, coconuts, and cashew nuts can reasonably do well in Pemba and Zanzibar characterized by poor coral Wanda soils.
2) Barrier reefs are a major hindrance to navigation. Under high tide, they are submerged in water and therefore not easily spotted by sailors. This results into fatal, accidents.
3) Coral growth on the continental shelves interferes with marine fisheries. This is because they interfere with the movement of the fishing vessels and besides can tear nets.
4) Lagoons enclosed by fringing reefs are sometimes colonized by vegetation and turned into swamps. These later become habitats for mosquitoes which spread malaria.

ROCKS /GEOLOGY OF EAST AFRICA

A rock is an aggregate of mineral elements which make up the solid part of the crust. The mineral elements may include silica, quartz, chlorides, oxides, and carbonates. Rocks may posses these minerals in combination or as a single mineral e.g. diamond, gold, copper etc. Apart from their chemical composition, each mineral within a rock exhibits other properties such as hardness, color, lines of weakness, level of crystallization etc. which in turn affects the nature of the rocks formed.

CLASSIFICATION OF ROCKS

Rocks can be classified according to the mode of formation and these include; igneous rocks, sedimentary rocks and metamorphic rocks.

IGNEOUS ROCKS

These rocks are described as fire formed rocks. They are formed as a result of solidification of molten rocks (magma) either in the interior of the earth or on the surface. The molten rocks are a product of high temperatures in the interior of the earth that keeps the mantle in a molten state but under high pressure. When lines of weakness are formed as a result of earth movements, the pressure is reduced. This forces the molten rock to rise through the lines of weaknesses to solidify either in the interior or on the surface of the earth forming igneous rocks. The character of the rocks formed depends on the depth at which the cooling took place and the chemical composition of the magma.

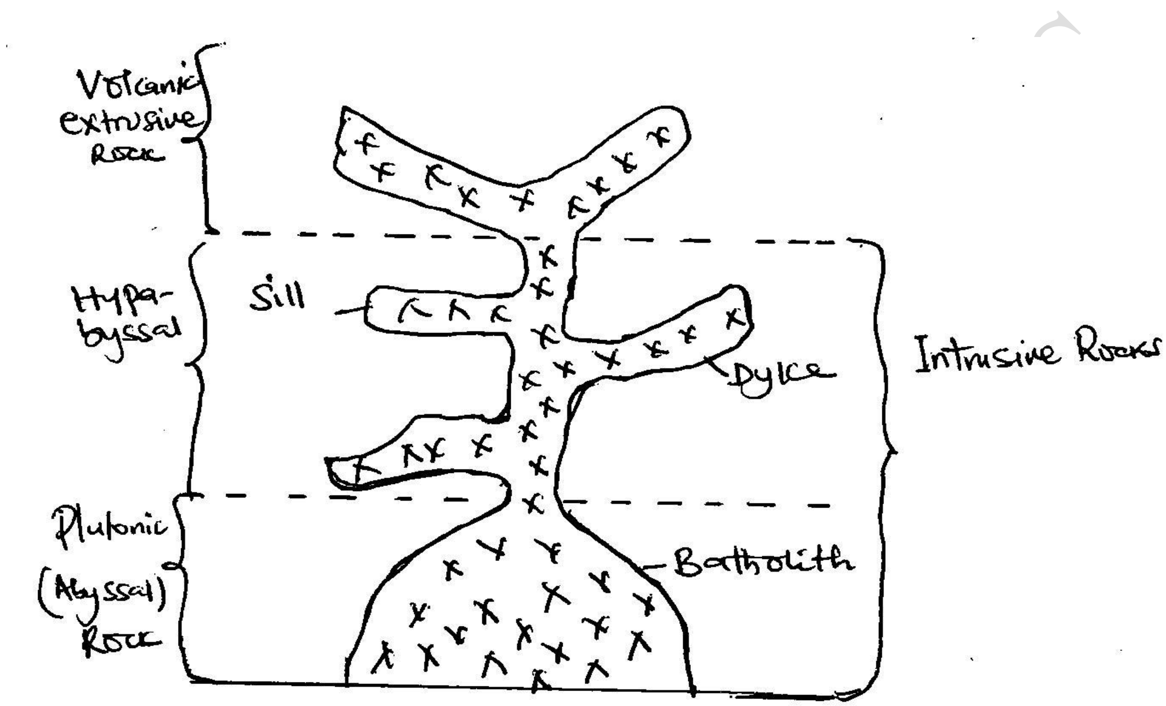
When magma reaches the earth's surface, it loses its gaseous content and is called lava. Once in open air where temperature and pressure are comparatively low, rapid cooling and solidification of the lava occurs forming volcanic igneous rocks with small crystals and a fine texture. In some cases, solidification is so rapid that crystallization doesn't occur. This results into the formation of glass like rocks such as obsidian. Other examples of volcanic igneous rocks include basalt, rhyolite and andesite. Examples of these rocks in east Africa are found around Volcanic Mountains such as Mt. Elgon, Mt Kilimanjaro and Mt. Kenya.

Sometimes magma doesn't reach the surface of the earth solidifying at great depth within the earth crust. The resulting rocks are called Plutonic igneous rocks. The magma forming these rocks rises for a short distance and then cools very slowly due high underground temperature. This results into rocks with large crystals or coarse structures. Examples of these rocks include granite, dolerite, gabbro and peridotite.

Some igneous rocks are formed at positions intermediate or between volcanic and plutonic rocks. These rocks are called Hypabyssal. They are formed when magma solidifies at a shallow depth and therefore undergoes immediate cooling. This results into rocks with medium sized crystals like dolerite and Quartzite.

Though plutonic and hypabyssal rocks are formed inside the crust they may be later exposed to the surface by weathering and erosion e.g. the exposed Mubende Batholith and Inselbergs in North Eastern Uganda.

DIAGRAM ILLUSTRATING THE DIFFERENT IGNEOUS ROCKS DEPENDING ON DEPTH



The formation of igneous rocks is also influenced by the chemical composition of the magma / lava. Magma with high silica content is very acidic and solidifies very quickly as soon as it is ejected. This results into intrusive (Plutonic) rocks like granite that are characteristically with large crystals.

Magma with intermediate silica content has a slower rate of cooling compared to that with high silica content. As a result, the rocks formed i.e. hypabyssal rocks have medium sized crystals e.g. dolerite.

Basic lava is the one with low silica content. Such lava is fluid and mobile and often cools rather slowly. It forms rocks such as basalt which may cover extensive areas e.g. around Kisoro in Uganda and Laikipia in Kenya.

Importance of Igneous Rocks

1. Igneous rocks break down to yield fertile volcanic soils capable of supporting the growing of various crops e.g. coffee, bananas like is the case on slopes of Mt. Elgon
2. Igneous rocks have formed volcanic highlands e.g. Mt. Kilimanjaro, Mt. Elgon and Mt. Kenya which are sources of rivers that can be used for irrigation.
3. The volcanic highlands from igneous rocks provide favorable conditions for the growth of montane forests. This has boosted lumbering e.g. on Mt. Elgon.
4. Igneous rocks are made of various minerals which have boosted mining in east Africa e.g. in Mwadui near Shinyanga in Tanzania, diamond is extracted from volcanic pipes which are comprised of igneous rocks.
5. Igneous rocks such as granite and basalt can be broken down into smaller aggregates which are used for making concrete during construction e.g. at Muyenga quarry near Kampala.
6. Several relief features have been formed from igneous rocks e.g. volcanic mountains, calderas, inselbergs, explosion craters etc. These constitute tourist attraction features to east African countries hence earning foreign exchange through tourism.
7. Hot igneous rocks beneath the earth crust have formed hot springs, fumaroles, and geysers. These have been harnessed to produce geothermal energy e.g. at Olkaria in the rift valley in Kenya.
8. Some igneous rocks have been intruded along the river courses forming water falls. These can be harnessed to generate hydro electric power e.g. along river Sezibwa, there is Sezibwa falls and Bujagali along the river Nile.
9. Impermeable granitic rocks under the ground trap rain water which seeps into the ground. This acts as a reservoir for under ground water hence a source of spring water for domestic use in most rural areas.
10. Volcanic highlands have influenced rainfall formation on their wind ward sides hence promoting agriculture.
11. Volcanic mountains formed from igneous rocks have boosted wild life conservation and tourism e.g. Mt Elgon National park
12. Igneous rocks provide firm foundations for bridges, dams, and railways e.g. the Owen falls dam was sited where the underlying rocks are strong and firm
13. Negatively, igneous rocks are formed from violent eruptions which are destructive to human and plant life as well as property.
14. Igneous rocks form volcanic highlands are prone to landslides which kill people and destroy crops and settlements e.g. Bududda landslides on Mt. Elgon in 2010.
15. Exposed granitic rocks are a set back to agriculture development as they hinder machine operations. This is a serious problem in Kabale and Kisoro in Uganda.

16. Igneous rocks have formed massive highlands which have limited transport and communication networks in areas such as Kabale and Kisoro.
17. Igneous rocks such as granites take long time to weather down to produce mature soils thus some areas with igneous rocks have thin and poor soils which do not support agriculture e.g. Turkana land in Kenya.
18. The volcanic highlands which are products of igneous rocks cause rainfall only on the wind ward side. The opposite side of the mountain is often semi arid limiting human activities e.g. the North West side of Mt Kilimanjaro.
19. Some igneous rocks are very permeable leading to loss of underground water. This has resulted into shortage of water in areas like Kisoro in Uganda.
20. Steep slopes of volcanic highlands are prone to soil erosion.

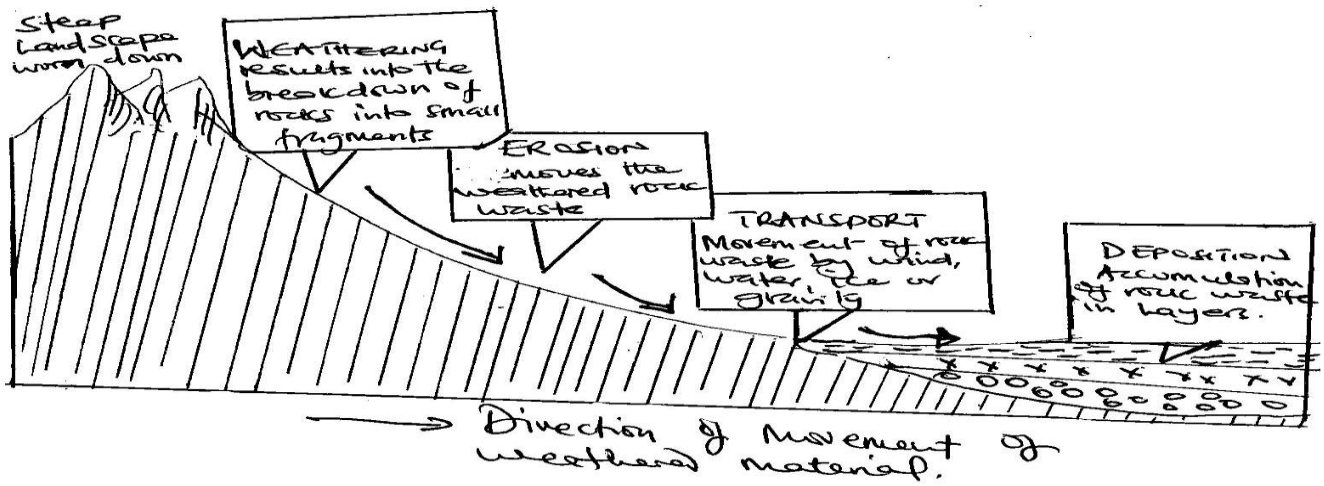
SEDIMENTARY ROCKS

These are rocks built from sediments derived from other rocks types. The weathered materials are transported by erosional agents like water, ice and wind and are later deposited in strata (layers) either on flat land or in valleys or under water in seas or oceans. The sediments when accumulated in an area are squeezed, cemented, and hardened by pressure of the overlying strata to form sedimentary rocks.

Sedimentary rocks are characterized by the existence of fossils which are derived from dead plants and animals. The rocks are also non crystalline and exist in different strata. Their strata / layers are separated by bedding plains of cementing materials which are horizontal, gently sloping or steeply inclined.

The formation of sedimentary rocks takes a long period. It starts with weathering of the already existing rocks by chemical and physical processes. The products of weathering are then eroded and transported by erosional agents such as ice, wind, water, or waves. The materials are later deposited in layers, each layer representing a specific generation of deposition. As more layers are built the weight of the overlying layers compacts and hardens the layers underneath a process that may take so many years. The laid down layers are then cemented by calcareous, siliceous and ferruginous materials to eventually form sedimentary rocks.

Diagrammatic summary of formation of sedimentary rocks



Sedimentary rocks are classified into three depending on their mode of formation or origin of sediments. These are mechanically formed, chemically formed and organically formed.

Mechanically formed

These are derived from agents of erosion like rivers, wind, ice, and waves. These agents cause erosion on one part of the earth crust, transport and deposit the particles on another. The deposited materials accumulate and become compact forming rocks which are either fine textured or coarse. Wind deposition creates a rock known as loess, rivers deposit alluvium, glacial deposition creates moraines while wave deposition creates spits, bars, beaches etc. Generally, examples of these rocks include mudstones, clay stones, gravel, sandstones, boulder clays etc.

Chemically formed

These are formed as a result of chemical precipitation. Original soluble rocks are dissolved in water or other solvents to form a solution. Later under high temperatures evaporation occurs leaving evaporates or rock precipitates. Good examples include rock salt at Lake Katwe, Soda ash from Lake Magadi and gypsum in Garissa in Kenya, laterites of Iron and Aluminum in Buganda.

Organically formed

These sedimentary rocks are formed from decomposition of remains of living plants and animals. When animals and plants die their remains may accumulate forming organic rocks. Good examples include coral limestone which is formed when tiny sea animals called coral polyps die and their accumulated skeletons are compacted under the sea forming a rock e.g. at the coast of east Africa.

Equally, carbonaceous rocks are formed when plant remains accumulate over a period of time and are compressed and hardened to form rocks such as coal e.g. in the Ruaha valley in Tanzania.
Siliceous rocks may be organically formed from remains of animals such as sponges and radiolaria (a tiny animal whose remains has silica) and plants called diatoms.

Importance of Sedimentary Rocks

1. Mechanically formed sedimentary rocks are collections of various rock materials hence weather down to produce very fertile soils e.g. alluvium on the Rufiji delta along swamps, rivers and lakes such as Victoria.
2. Some sedimentary rocks are source of raw materials for industries e.g. coral limestone is a raw material for the manufacture of cement at Bamburi in Kenya, Potash is used for making fertilizers, rock salt for the manufacture of common salt.
3. Sedimentary rocks have boosted the mining sector which contributes to the east Africa's economic development e.g. sand mining at the coast of east Africa and at Kisenyi on the shores of Lake Victoria.
4. Clay which is a form of sedimentary rock has boosted the construction sector. As it's a raw material for brick making and tiles e.g. at Kajansi and most swamps in east Africa.
5. Sedimentary rocks in swamps and along rivers are colonized by hydrophytes some of which are raw materials for the craft industry e.g. papyrus.
6. Coral reefs at Mombasa, Tanga, Dar-es-Salaam and the coast together with karst sceneries at Nyakasura in fort portal are tourist attractions.
7. Some sedimentary rocks are sources of medicine as well as food to man and livestock e.g. rock salt
8. Sedimentary rocks contain fossils which when squeezed for along period of time produce oil. Oil and natural gas are important sources of fuel. The presence of oil in the Albertine basin in Uganda is due to the existence of sedimentary rocks in the region.
9. Lagoons enclosed by coral reefs provide a breeding ground for fish e.g. at Mombasa.
10. Sedimentary rocks like corals also provide good sheltered harbors hence promote the shipping industry e.g. at Mombasa
11. Negatively, Sedimentary rocks are made up of very fine materials such as silt and clay particles. These are not very porous hence are poorly drained. During the rainy season, they are prone to flooding.
12. Sedimentary rocks like coral reefs are barriers to shipping. Under high tide, they may be concealed under water and not spotted by sailors. This may result into devastating accidents.

13. Besides, coral reefs are also a hindrance to fishing as they may tear nets and obstruct navigation.
14. Some sedimentary rocks like clay are poorly drained and hence are heavily leached. This makes them infertile for crop cultivation e.g. laterites in Buganda region.
15. Sedimentary rocks tend to form immature young soils which are unproductive for agriculture e.g. in the Semiliki valley and the coastal areas of Mombasa.
16. Areas such as swamps that are dominated by sedimentary rocks are breeding grounds for insect vectors like mosquitoes.

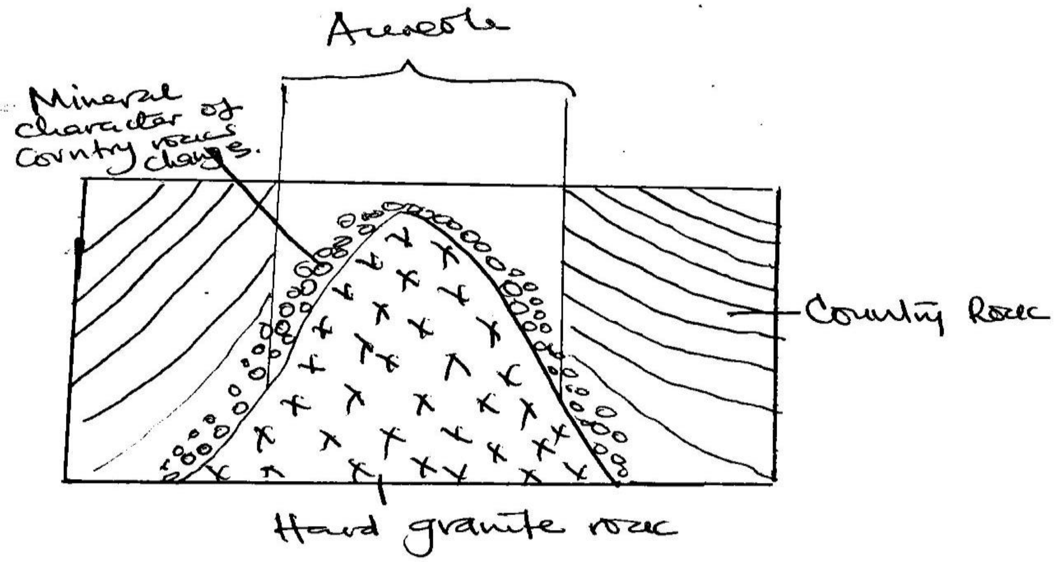
METAMORPHIC ROCKS

These are rocks formed from pre-existing rocks igneous or sedimentary after being subjected to heat or pressure or both. The pressure or heat changes the physical and chemical characteristics like mineralogy, texture and internal structure of the original rocks forming metamorphic rocks. Such rocks are generally more compact and harder than their original rocks and examples include marble from limestone, slate from clay, gneiss from granite and quartzite from sand.

Metamorphic rocks are classified into two i.e. those from contact/thermal metamorphism and those from dynamic metamorphism.

Contact / Thermal metamorphism rocks are formed when pre-existing rocks are changed by great heat but limited pressure. The heat may originate from the interior of the earth where temperatures are high. This forces the rocks in close proximity to change their character to metamorphic rocks. Alternatively, some rocks may come into contact with rising magma and the rocks are melted. Re-crystallization takes place as well as re-mineralization. The zone where mineral character changes is known as “a metamorphic aureole” as illustrated in the diagram below.

Diagram illustrating a Metamorphic Aureole



Metamorphic rocks due to dynamic metamorphism are formed due to pressure and heat exerted by earth movements on a large scale (region) to pre-existing rocks. Such earth movements may be in form of folding produced by compressional forces. When convergent forces push country rocks from opposite directions towards each other they experience immense pressure hence change in the nature of their internal structures to metamorphic rocks e.g. shale may be changed to slate or schist, limestone to marble, granite to gneiss, sandstone to quartzite etc.

Metamorphism due to both pressure and heat is termed as thermal-dynamic metamorphism. It is the most effective type of metamorphism that changes rock characteristics.

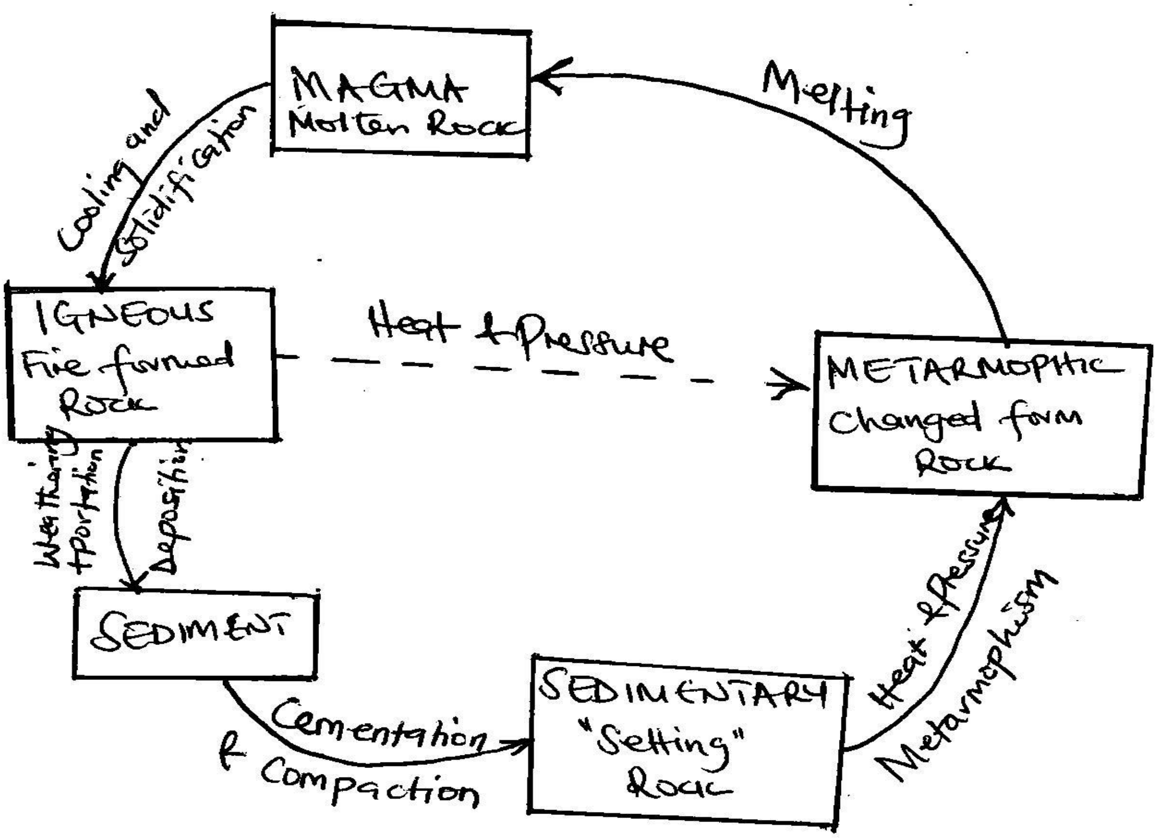
Importance of Metamorphic Rocks

1. Metamorphic rocks are always harder than the original rocks. As such they are quarried to provide aggregates for construction purposes. Besides, marble chips are used in the decoration of houses while slate can be used for roofing.
2. Minerals such as copper, gold, and diamond often occur in metamorphic rocks. Thus the rocks have boosted the mining sector in east Africa e.g. the diamonds at Mwadui in Tanzania, copper at Kilembe and gold in western Kenya.
3. Landforms built by metamorphic rocks like Block Mountains, fault scarps, create impressive sceneries that attract tourists.
4. The rocks are sources of raw materials for industries e.g. phosphates at Tororo, are obtained from previously metamorphosed igneous rocks and is a raw material for making fertilizers.
5. Some of the landforms built by metamorphic rocks such as Mt. Rwenzori have promoted nature conservation i.e. such areas have been gazetted into game and forest reserve.

6. Metamorphic rocks are generally compact and resistant to erosion. Soils formed from such rocks are very resistant to erosion.
7. They tend to be hard and compact. As such, they act as natural reservoirs. Man is able to get water from these rocks through springs or sinking of boreholes.
8. In rural areas, some of the metamorphosed granites are used as grinding stones.
9. Negatively, metamorphic rocks usually result into the formation of poor and shallow soils. The poor soils are due to the loss of minerals during the process of formation as well as the long time of exposure to environmental factors like erosion. The soils are shallow owing to their hardness. A lot of time is needed for them to be broken down to produce soils.
10. The resistant landforms built by metamorphic rocks such as faults scarps, Block Mountains, fault guided valleys etc are barriers to transport and communication. It is very expensive to blast metamorphic rocks if a road is to be constructed. The result is that some areas remain remote and under developed e.g. Bundibugyo in Uganda.
11. Landslides are a common occurrence along steeply built metamorphic highlands. E.g. along Mt. Rwenzori. These are very destructive to life and property.

The summary of all processes leading to the formation of different types of rocks is contained in the rock cycle which was propounded by James Harton as seen below.

THE ROCK CYCLE



RELATIONSHIP BETWEEN ROCKS AND LANDFORMS
OR INLUENCE / EFFECTS OF ROCKS ON LANDFORM DEVELOPMENT

Every where on the earth crust, there is a close relationship between rocks and land forms. Each rock type and structural feature produces its own characteristic landforms

Rock Types and Land Form Development

There are three types of rocks e.g. igneous, metamorphic, and sedimentary rocks. Each of these types produces different landforms.

Igneous rocks

These are formed from volcanic eruptions. They are of three types i.e. volcanic, hyper-basal, and plutonic. Since magma solidifies at different levels both intrusive and extrusive landforms are produced. Intrusive landforms include batholith, Lopolith, Phacolith, Laccolith, sills, dykes, etc. These may be exposed to the surface by denudation. Extrusive land forms include composite cones, cumulo domes, basalt domes, ash and cinder cones, volcanic necks, calderas, explosion craters, geysers, hot springs etc.

Sedimentary rocks

These are formed through organic, chemical, and mechanical processes.

- Organically formed rocks produce coral reefs like fringing reefs, barrier reefs, atolls.
- Karst sceneries (limestone features) such as caves, stalactites, stalagmites, clints, pillars, Uvalas, dolines, and grykes.
- Alluvial features both riverine and lacustrine deposits. River deposition produces alluvium, flood plains, deltas etc. Wave deposition produces beaches, spits, bars, cuspate forelands etc.
- Moraine landforms from glacial depositions and fluvial glacial deposition. Glacial deposition produces erratics, drumlins, and different types of moraine. Fluvial glacial deposition produces outwash plains, kames and kame terraces.

Metamorphic rocks

These form the basement complex of east Africa. The rocks are over 300million years old. They include those formed from contact metamorphism and regional metamorphism. Such rocks have been metamorphosed, folded, faulted, and warped in various degrees.

- Where faulting has occurred, rift valleys, block mountain, escarpments etc have been formed.
- Cross folding in Ankole has produced arenas
- Granitisation has affected most parts of pre-cambian rocks which have now been exposed and weathered to form Inselbergs, Peneplanes and tors.

Effects of Rock Structure on Land Form Development

Rock structure is generally used to refer to all the ways in which rocks differ from each other in their physical and chemical characteristics. These differences can be in form of color, permeability, hardness, softness, jointing, mineral composition, age, porosity, faults, folds etc. Due to these difference rocks react differently to endogenic and exogenic processes. In east Africa, there are many land forms that illustrate the relationship between lithology (physical characteristics of rocks) and landforms.

1. Rock hardness and softness. Hard rocks are resistant to weathering and erosion and as a result stand out as residual hills such as Inselberg. An inselberg is an isolated hill that stands above a level plain. It is formed when erosion removes the top most layer of the crust exposing the massive resistant granitic intrusion. Examples in East Africa include Mesasi in Tanzania, Nakasongola and Mubende hills in Uganda, and Maragoli hills in Kenya.

For diagram refer to intrusive landforms.

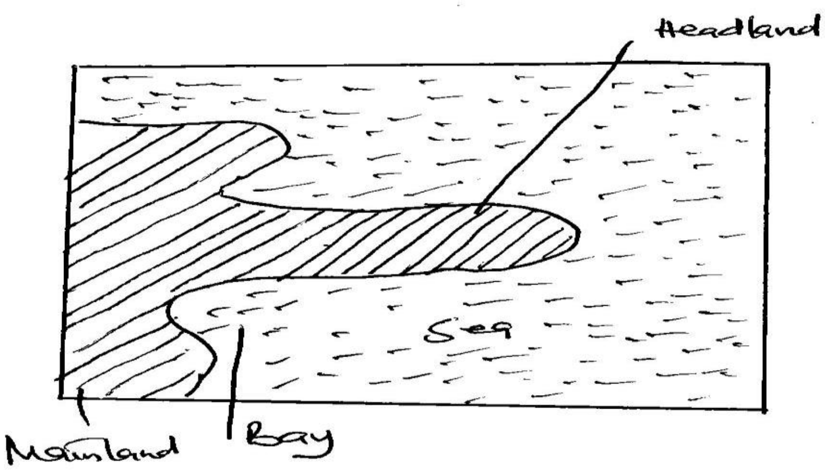
If the granitic rocks are less resistant than the surrounding country rocks, the granitic rocks are eroded to a much lower level leaving behind arenas e.g. Rubanda arena along Kabale Kisoro road.

Other landforms related to rock hardness and softness includes trenches, ridges. Volcanic plugs, flat topped hills from erosion of country rocks surrounding sills, Water falls. Refer to notes on Volcanicity for diagrams and explanation.

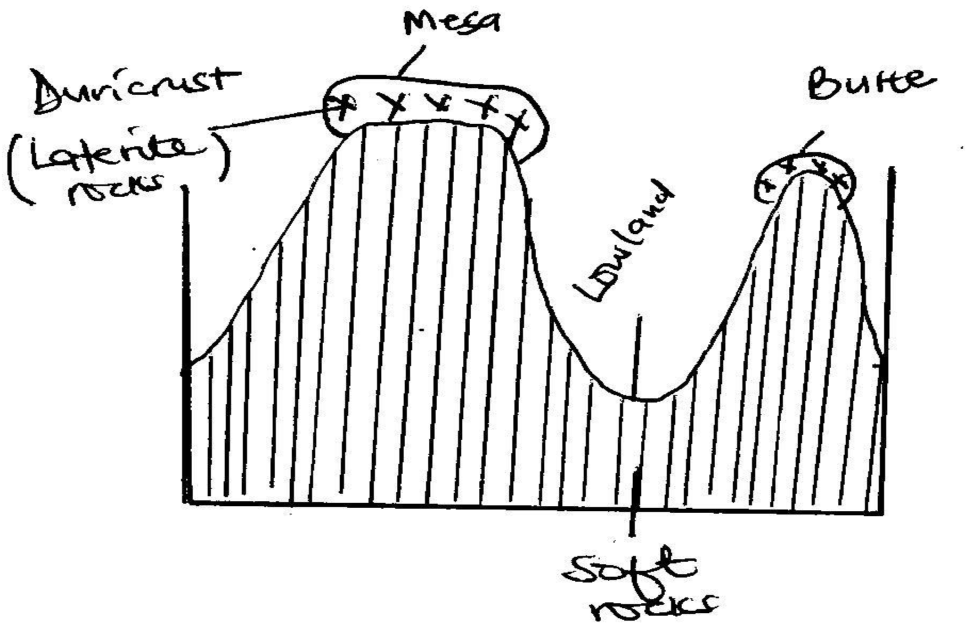
2. Existence of alternating hard and soft rocks along the coast has led to the formation of bays and headlands. A bay is an extension of water into the land. Wave erosional processes such as hydraulic action, abrasion, and solution eat away softer coastal rocks resulting into the extension of water into the land hence forming bays.

The area of resistant rocks is not affected in the same hence remains projecting into the water as a head land. Examples of both can be seen at Kasenyi on the shores of Lake Victoria.

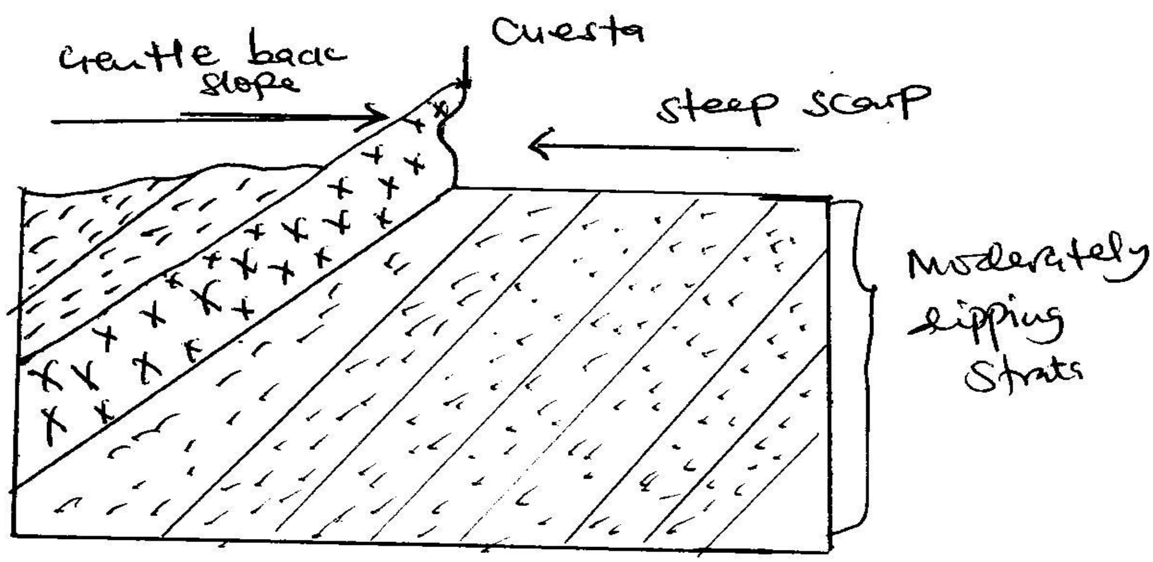
Structure of a bay and headland



Where hard lateritic rocks (duricrust) overlie softer rocks Mesa and Butte are formed. These are prominent flat topped tabular hills usually capped with a resistant rock stratum or duricrust. The duricrust protects the softer rocks underneath from erosion and weathering while the softer surrounding rocks are eroded to form lowlands. The flat topped hills are mesa or butte, a mesa being more extensive than a butte e.g. Mutundwe hills.



Cuestas are other landforms that illustrate the influence of hard and soft rocks on landforms. A cuesta is a ridge or upland with a steep slope and a gentle back slope. It is formed where there are alternating soft and hard rocks that have been tilted and then subjected to differential erosion. The weaker rocks are worn down leaving more resistant rocks to form a cuesta with a moderately dipping slope.



3. Rock jointing. Joints in rocks indicate areas of weakness that can be exploited by weathering and erosion resulting into a number of features such as caves, geos, and blow

holes along a coast. A cave is a hole drilled in a cliff face. It is formed as a result of coast erosional processes of abrasion and hydraulic action which erode a joint on a cliff face. The process is slow and the joint is gradually widened into a cave. Continued erosion of the roof of the cave, may result into a depression at the surface of the cliff called a blow hole.

Refer to coastal geomorphology for diagram

4. Joints/Cracks have influenced the formation of other landforms such as granitic Tors, cirques and karst sceneries etc.

The existence of faults in rocks has resulted into the formation of fault guided valleys. Such areas along faults or cracks are always weak and so are easily weathered down to produce depressions. These depressions in many cases form river valleys e.g. the Aswa river valley. Refer to diagram in faulting.

The existence of faults in rocks has also facilitated the formation of escarpments. An escarpment is a steep face that over looks the rift valley. They are formed when faulting has taken place and one part of the crust slips down in relation to the other. Examples include Butiaba and Kichwamba in Uganda.

5. Rock solubility has influenced the development of landforms. Soluble limestone rocks dissolve in weak carbonic acid to form karst landscapes with features such as stalagmites, dolines, sink holes, pillars, etc. These features are common in east Africa in areas such as Nyakasura in fort portal, Tanga in Tanzania, and Kilifi in Kenya. Refer to notes on weathering for explanations and diagrams.

6. Rock permeability also affects landform development. Running water is one of the main agents of erosion of the landscape. Rocks that allow water to percolate reduce the rate of run off and hence less erosion. Areas of permeable rocks tend to form uplands e.g. carbonate rocks forming the Sukulu hills in Tororo, Coral reefs along the coast of East Africa form raised landforms e.g. at Bamburi and Mombasa.

DENUDATION

The term denudation is derived from a Latin word "denudare" which means to strip bare, uncover or remove. The term includes all processes which work together to wear down the earth's surface. It includes the combined effects of weathering, mass wasting, erosion, and transportation. These processes operate at or near the earth's surface and are therefore referred to as sub aerial or exogenic processes. They wear down highlands with the ultimate goal of creating a uniformly flat landscape.

WEATHERING OF ROCKS

Weathering is the gradual decay or disintegration of rocks by either chemical or physical processes and the weathered material (regolith) is left in situ (in one place). Weathering is generally divided into two types i.e. chemical and physical weathering.

This division of weathering into two types may not imply that these types of weathering are exclusively independent. There is always inter- dependence as well as complementarity between these different types. Certain weathering types however, predominate in certain environmental conditions e.g. physical weathering is dominant in arid regions while chemical weathering is dominant in humid regions.

PHYSICAL WEATHERING

This is also known as Mechanical Weathering. It involves the mechanical break down of rocks into smaller particles in situ without change in the chemical composition of the rock. It is mainly brought about by temperature changes, influence of plants, animals, and man.

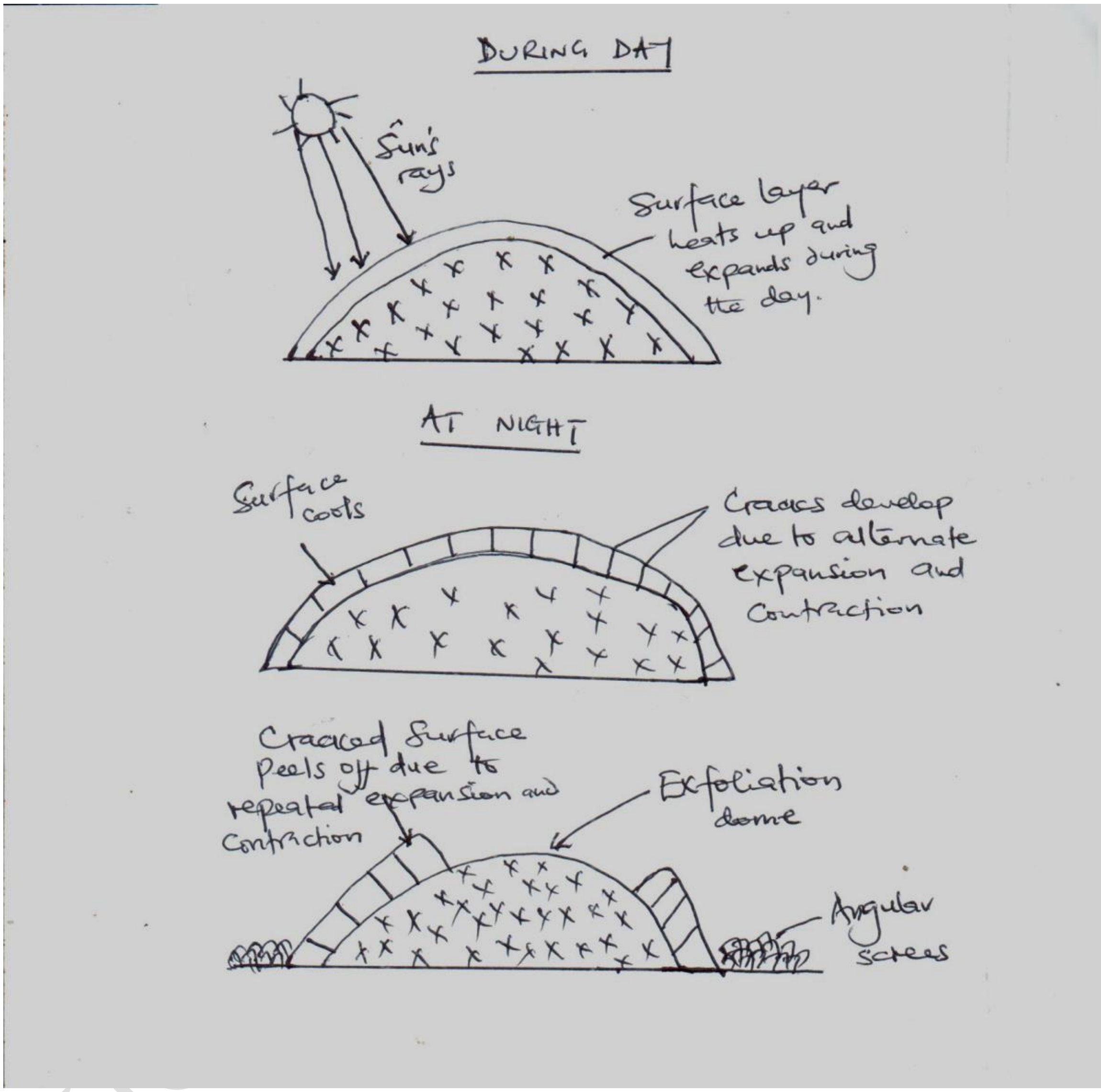
The conditions favouring its occurrence mainly prevail in arid areas and these include prolonged dry season, high day and low night temperature and hence a large diurnal temperature range. Arid areas also experience low humidity, low cloud cover, very low rainfall and scanty vegetation. In east Africa, it's common in areas such as Karamoja, Turkana land region, Ankole-Masaka corridor, semiliki, and Albert flats and central Tanzania.

Physical weathering is accomplished through the following processes: Exfoliation, Block disintegration, Pressure release, Frost shattering, Granular disintegration, Aridity shrinkage, Salt crystallization, and biological-physical weathering.

Exfoliation

This is also called insolation or onion weathering. It's common in arid areas with high diurnal temperature range. It involves the heating up and expansion of outer rock surfaces during the day, and the cooling and contraction of the rock layers during night. Repeated heating and cooling creates internal stress within the top few centimeters of the rock. This results into cracks on the rock surface. With continued expansion and contraction, the rock surface peels off leaving behind a smooth landform known as an exfoliation dome.

Stages of exfoliation

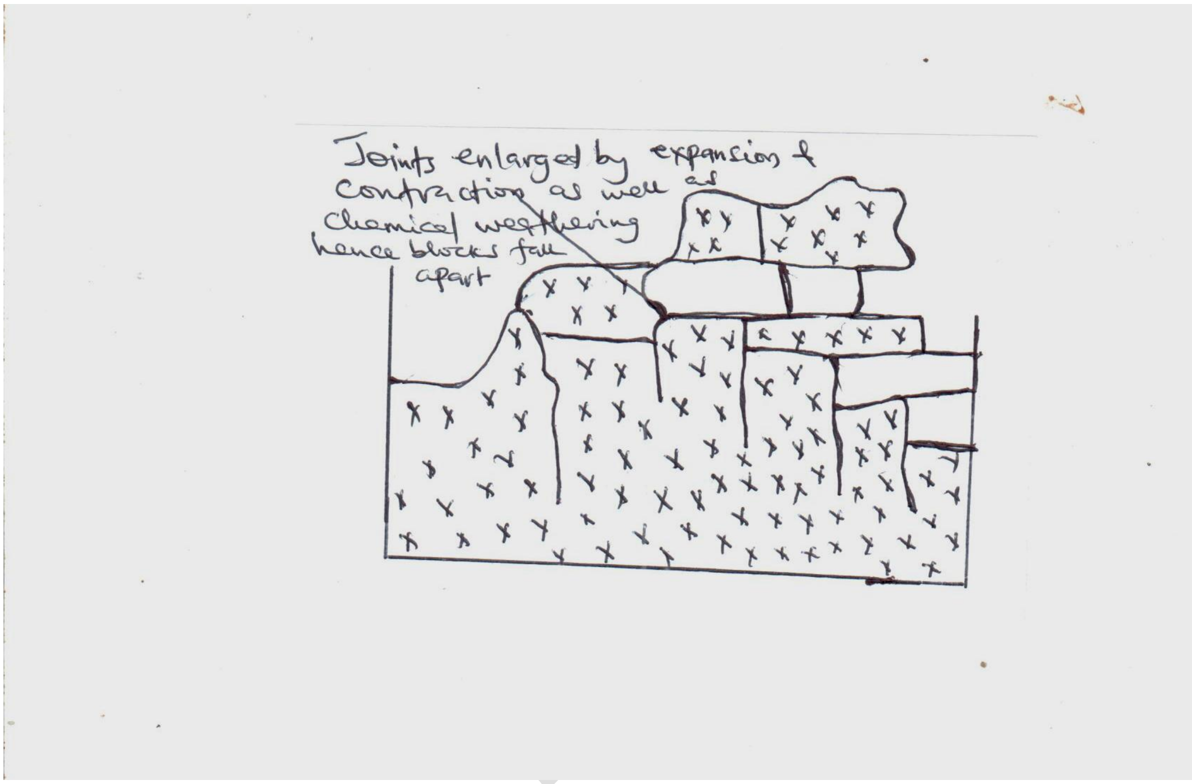


Good examples of exfoliation domes include Pany Jok rock in Apac in Uganda, Hells Gate at Naivasha and Mudanda along Nairobi-Mombasa highway in Kenya.

Block Disintegration

This is also brought about by temperature changes and is common in well jointed rocks. During the day, rocks experience high temperatures and expand. During the night temperatures fall and rocks contract. The mechanism of contraction and expansion continues along the joints. Chemical weathering may also take place along the joints widening them further. When the joints are wide apart, large rectangular shaped blocks fall apart hence block disintegration. This process results into the formation of granitic tors or inselbergs e.g. Kachumbala Tor in Kumi, Kit Mikai in Kenya and Bismarck rock in Tanzania.

Block disintegration



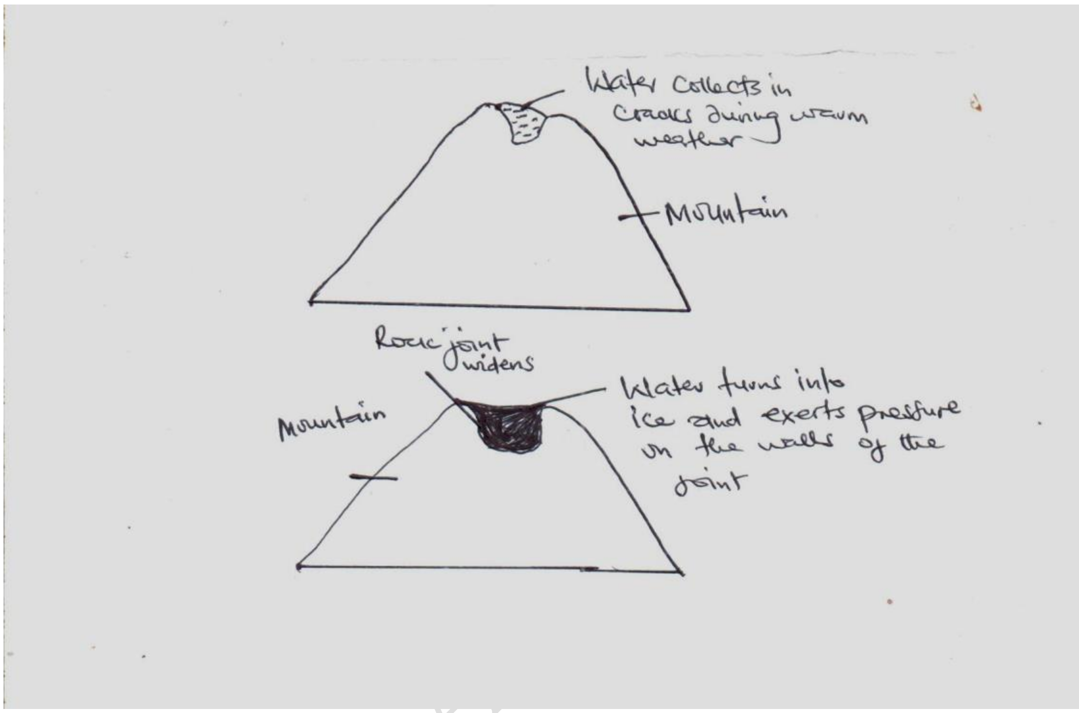
Pressure Release

This is a physical weathering process common in igneous and metamorphic rocks because they were formed under high pressure and heat. It takes place after hitherto or initially covered rocks are exposed to the surface by denudation processes or human activities. The release of pressure or exposure to the surface is accompanied by expansion as the rock adjusts to new conditions. Cracks are then formed on the surface and later widened by repeated expansion and contraction and chemical weathering along the joints. The surface layer then peels off in the similar way to exfoliation, a process known as spalling or sheeting. Examples of pressure release weathering can be seen on the emerging granite surfaces in Maganjo near Kampala, Nakasongola in Uganda and Iringa and Mwanza in Tanzania.

Frost Shattering

Frost shattering in the tropics occurs in glaciated areas which rise to an altitude of 4800m above sea level and areas where temperatures alternate below and above 0^0C. It is most effective in rocks which have cracks and joints.

During the day, temperatures are warmer and this forces the ice to melt. When ice melts, the water enters into rock cracks/joints. During the night, temperatures fall below 0^0C and the water in the joints/cracks freezes. However, when water freezes, it increases in volume by about 10% hence it exerts pressure on the walls of the joints/cracks. Repeated freezing and thawing of ice gradually widens the joints leading to the disintegration of the rocks into small rock fragments.



Frost shattering is sometimes called congelifraction because it produces block fields of angular scree called felsenmeer which may cover an extensive area. In east Africa this process occurs at the tops of mountains Rwenzori, Kenya and Kilimanjaro and has been partially responsible for the formation of glacial features such as pyramidal peaks, cirques, arêtes etc.

Granular Disintegration

This is a form of physical weathering which occurs in heterogeneous rocks or rocks composed of different minerals. As rock minerals have different rates of expansion and contraction, as the rock is subjected to a rise and fall in temp respectively internal stress and strains are created between the mineral grains resulting into the crumbling of the rock. Different rock minerals with different colors also absorb heat and expand at different rates. This also leads to internal fracturing as the bonds binding the rock particles are weakened.

Salt Crystallization

In this process, saline water may collect in rock cavities or in pores between rock particles. As the water evaporates due to high temperatures, salt crystals form and grow in size. When the crystals become larger, they exert pressure on the rock cavities causing the rock to crumble. In east Africa, this weathering process is common in areas with carbonates and other salt bearing rocks e.g. around Lakes Nyamununka, Magadi, Katwe, Natron, Albert etc.

Aridity Shrinkage

This is a physical weathering process in which there is alternate wetting and drying of porous rocks especially swamp clays. During the wet season, the clays swell because of absorption of water. As the dry season sets in, evaporation occurs and the rock shrinks hence disintegration. Evidence of this weathering type is the appearance of cracks during the dry season on bare compounds and dry swamp beds of seasonal swamps.

Spheroidal weathering

This is common in areas which receive heavy rainfall e.g. around Lake Victoria basin. Once it rains, the outer layers of rocks absorb water which reacts with the rocks minerals. In the process the rock surface swells and eventually peels off from the under lying rock e.g. in limonite rocks.

Biological-physical weathering

This is a physical weathering process in which living organisms break rocks physically. Tree roots growing in rock joints and spaces between rock particles widen the joints and spaces eventually causing the rocks to disintegrate. Also animal hooves walking on the rocks, burrowing animals such as rabbits and rats and human activities like agriculture, mining, quarrying and road construction also cause rocks to disintegrate physically.

CHEMICAL WEATHERING

This is the gradual disintegration of rocks insitu by chemical processes brought about by the reaction between atmospheric gases such as carbon dioxide, oxygen, hydrogen in solution and rocks mineral elements resulting into changes in the chemical composition of the rock.

Chemical reactions usually take place on the exposed surfaces of the rock but may also take place inside the rocks if water can enter through pores and joints.

This type of weathering is common in humid regions which are characterized by high temperatures and high humidity, thick cloud cover and heavy rainfall. These areas in east Africa include the Lake Victoria basin, Kigezi highlands, Kenya highlands, Southern Tanzania and the coastal areas of Kenya and Tanzania as well as slopes of mountains such as Rwenzori, Kenya, and Kilimanjaro. Chemical weathering is accomplished through the following processes: Hydration, carbonation, oxidation, hydrolysis, reduction, solution and organic-chemical weathering

Hydration

This is a chemical process of weathering in which rocks absorb water, expand and after getting softened, are broken down into new compounds. It is a simple process involving less fundamental chemical changes in the rock. When the bi- product is heated, the reactions are easily reversible. The commonest examples include the changing of hematite rock to limonite.

The other example is the formation of gypsium. When calcium sulphate absorbs water, it gives rise to gypsum.

Hydration is very common in east Africa e.g. gypsium is found in Garisa and Wajir in Kenya and Bundibugyo in Uganda.

Carbonation

This is a chemical weathering process in which carbon dioxide ions react with the rock elements to break down the rock. Carbon dioxide in the air combines with rain water to form a weak carbonic acid. When the acid comes into contact with limestone or dolomite rocks (magnesium oxide), they are changed to soluble calcium bi-carbonate and carried away in solution.

This type of weathering is common in limestone areas such as Kilifi in Kenya, Tanga in Tanzania, and Fort Portal in Uganda. It leads to the formation of karst scenery features such as solution lakes, caves, stalactites, stalagmites etc.

Hydrolysis

This is a chemical reaction in which hydrogen in solution reacts with rock minerals to give rise to different chemical compounds. It is common in feldspars (minerals commonly found in igneous rocks) where it gives rise to sand, silicic acid, and kaolin clay. Feldspar reacts with hydrogen ions in water to produce a hydroxide and almino silicic acid. This is followed by another reaction in which the hydroxide reacts with carbon dioxide to form a potassium carbonate in solution. The almino silicic acids decompose further to form silica and residual clay as the final products.

Hydrolysis is common in the broad valleys of Buganda, Bukoba in Tanzania, Kajansi in Uganda etc.

Oxidation

This is a chemical weathering process that involves the addition of oxygen to minerals of Ferro magnesium rocks such as iron, magnesium, and aluminum. Oxidation takes place when rocks are exposed to oxygen in water. It usually results into the change of color of the original rock. Good example is the oxidation of ferrous oxide which is grey or blue to ferric oxide which is reddish brown.

Oxidation is also responsible for the formation of lateritic soils. These occur especially in tropical latitude where high rainfall and temperature cause rapid chemical weathering. Clay is produced which breaks further into silica and oxides of iron and aluminum. Silica is then leached leaving behind oxides of iron and aluminum. It is the concentration of these oxides that gives the soil the deep red appearance e.g. on Buganda hills.

Reduction
This is the reverse of oxidation. It's a chemical weathering process in which oxygen ions are removed and hydrogen ions are added onto the rocks. The reddish color of ferric oxide is chemically reduced to give a grey or grey-blue appearance of ferrous oxide. This form of weathering is common in areas that are waterlogged such as lowlands, swamps, lake shores and along rivers.

Solution
This is a process of chemical weathering where water dissolves soluble materials which are carried away in solution. A good example is calcium carbonate and calcium chloride which dissolve when mixed with water and are carried away in solution. This type of weathering is common in limestone areas such as Tanga in Tanzania, Kilifi on Kenyan coast and Nyakasura in Fort portal.

Organic Chemical Weathering
As vegetation decomposes into organic matter, it releases organic acids such as humic acids which contain elements such as calcium, magnesium and iron which enhance chemical breakdown of rocks. The action of bacteria and respiration of plant roots increases carbon dioxide levels which accelerate carbonation and solution process. Plants such as mosses, algae retain water on the surface of the rock helping to enhance chemical weathering.
Although these processes of chemical weathering are discussed separately, they are Inter-dependent, i.e. in any chemical process of weathering there are a number of other chemical weathering processes taking place as well.

FACTORS LEADING TO (CONDITIONS INFLUENCING) WEATHERING OF ROCKS
These include climate, relief, parent rock, living organisms and time; these factors generally influence the type and rate of weathering,

Climate
This operates through its elements such as rainfall and temperature. Higher amounts of rainfall between 1500-2000mm with high temperatures between 21-27^{0}C like those experienced in Lake Victoria and coastal regions of E. Africa, promote rapid chemical weathering through processes like hydration, hydrolysis solution, and oxidation. Weathering can go further than 400 meters deep. Equatorial climate also limits physical weathering due to the formation of thick layers of chemically weathered material that protects the underlying layers.

Tropical climate is characterized by high temperature and seasonal rainfall. The alternating wet and dry seasons alternate the occurrence of both physical and chemical weathering processes. During the dry season, physical weathering is active and during the wet season chemical weathering processes are dominant.

Arid and semi arid areas are characterized by high day temperatures and low night temperatures, low rainfall, low humidity, and low cloud cover. These conditions are favorable to physical weathering processes like exfoliation, block disintegration, and granular disintegration. The alternate expansion and contraction speeds up rock disintegration resulting into features like exfoliation domes, granitic tors and screes common in arid areas like Chalbi desert in Kenya and Nakasongola in Uganda.

Montane climate characterized by very low temperature some times dropping below 0^0C, leads to a physical weathering process called frost shattering. During a warm period, ice melts and water enters into rock joints and therefore expands in volume. As it expands, it exerts pressure on the walls of the joints eventually leading to rock disintegration.
High rainfall and high temperature also influence weathering through their effects on vegetation and animals where flora and fauna are abundant, both physical and chemical weathering processes are faster.

Relief

This refers to the nature of the land. It can be flat, rugged or mountainous. The role of relief in weathering is mainly indirect.

On the wind ward side of high mountains, moist conditions exist because of relief rainfall. Therefore, there is predominance of chemical weathering. On the lee ward side, there is very little rainfall and physical weathering process like exfoliation, pressure release, and block disintegration are dorminant.

High mountains of Kilimanjaro, Rwenzori, and Kenya which rise to over 4800m above sea level have ice capped peaks. This has promoted frost shattering as a physical weathering process.

On steep slopes weathered layers are rapidly removed and the under lying rocks are exposed to further physical weathering. However, chemical weathering is limited on the steep slopes due to rapid runoff which reduces water medium for chemical reactions.

Gentle slopes and flat landscapes have a high water retention capacity. The presence of water along these slopes accelerates chemical weathering through processes like hydration solution and hydrolysis. However, physical weathering is inhibited along gentle slopes due to the accumulation of soils and thick vegetation.

Valleys with their characteristic impeded (poor) drainage experience mainly chemical weathering through processes like reduction and hydrolysis. The processes are rather slow owing to permanent saturation under water in the valleys. Physical weathering mainly occurs through aridity shrinkage.

Nature of the parent rock

The parent rock refers to the original rock that is broken down to form smaller rock fragments**.** Rocks influence weathering mainly through their structural differences. Rocks with different minerals react to weathering agents differently e.g. granite which is made up of silica is very resistant to weathering than gabbro/mica. Rocks with iron compounds such as hematite easily break down by oxidation and hydration to limonite.

Aspects like rock jointing, faults/cracks on rocks accelerate movement of water into rocks hence an avenue for rapid chemical weathering processes such as hydration, solution, hydrolysis, and carbonation e.g. in limestone areas such as Nyakasura in fort portal. Jointed rocks also facilitate physical weathering processes such as frost shattering and block disintegration. The presence of joints also facilitates penetration of plant roots leading to physical and chemical break down of rocks.

The rock color also influences weathering. Dark colored rocks like granite are weathered faster by physical means other than light rocks like obsidian. When subjected to temperature changes, dark colored rocks absorb heat expand and contract more easily. As a result, they are broken down by physical weathering processes such as exfoliation, block disintegration, and granular disintegration. On the other hand, bright and shinny rocks such as obsidian reflect much of the heat and so take long to be heated. As such they are resistant to physical weathering.

Different rock types also react to weathering processes differently. Igneous and metamorphic rocks when exposed to weathering processes are highly affected by chemical weathering because they were formed under high temperature and pressure different from the conditions on the earth's surface. Hydration and hydrolysis break them down easily. Sedimentary rocks on the other hand tend to be stable more than igneous and metamorphic rocks which slow down the rate of weathering.

Living things

These include both plants and animals. Plants aid physical weathering as rocks disintegrate under the pressure of their growing roots. Plant roots also cause chemical weathering as they add chemicals like nitric acid, humic acid as well as gases like ammonia and carbon dioxide to the soil. Plant roots also increase spaces in rocks through which water penetrates to cause chemical decomposition. Other plant types like lichens, algae, mosses cling on the rock surfaces where they retain moisture hence activating chemical weathering.

Animals contribute to physical weathering in many ways. Hooves of larger animals such as cattle, buffaloes, elephants etc break down rocks when they step on them. Smaller animals like termites, earthworms, rodents, ants also break rocks physically by their burrowing activities. Decaying animals release acids such as urea, ammonia, lactic acids which react with rocks to cause chemical weathering. Bacteria and other soil organisms increase chemical activities through nitrogen fixation and release of carbon dioxide.

Human activities such as construction, agriculture, mining etc can accelerate physical weathering as they involve physical break down of rocks. Man can also add fertilizers onto his fields and the reaction between some of these inorganic fertilizers and rock minerals brings about chemical weathering. Man can also expose rocks to further weathering processes by clearing vegetation cover.

Organisms influence the rate of weathering mainly through the number of organisms or biomass. In humid tropics, weathering is faster partly due to greater amount of biomass

Time

This is significant in weathering because the longer the time weathering processes have been in operation, the deeper the weathering and the shorter the time, the lesser the degree of weathering.

WEATHERING IN DIFFERENT CLIMATIC ENVIRONMENTS

Different weathering processes pre-dominate in different climatic environments.

Weathering under equatorial climate

Equatorial regions are characterized by heavy rainfall of over 1500mm per year, high temperatures over 27^{o} C, high humidity, low diurnal and annual temperature ranges. These conditions give rise to the predominance of deep chemical weathering. Chemical weathering here is manifested though hydration, hydrolysis, carbonation, oxidation, solution, reduction and organic activities.

Hydrolysis attacks most rock minerals. Quartz, being the most resistant is broken down by chemical weathering. Minerals such as Mica and feldspar in granite are attacked by hydrolysis to form new compounds like clay iron and aluminum. The iron and aluminum compounds then combine with oxygen through oxidation to form laterites (from iron and bauxite). In valleys and water logged areas, de-oxygenation takes place resulting into reduction weathering which forms gleyed soils (grey or bluish in color).

Limestone areas under equatorial climate are affected by carbonation to form karst topography as in coastal Kenya and fort portal in Uganda. Where solution pits, sink holes, dolines, stalactites, and stalagmites have been formed, soluble salts like rock salt are dissolved and carried away in rock solution.

Heavy biomass presence also facilitates the occurrence of both physical and chemical weathering.

Chemical weathering in equatorial regions produce features like rock extracts, colloidal materials, suspensions, oxides of iron and aluminum, clay minerals and unweathered residues of quartz to make sand.

Weathering under Tropical Climate

Tropical climates are characterized by rainfall totals between 750 and 1500 mm. This rainfall is concentrated in rainy season of about 3-7 months and the rest of the year remains dry.

During the rainy season, conditions are approximate to those of equatorial climate. As such, chemical weathering through hydration, hydrolysis, carbonation, solution, and reduction pre-dominate. Due to loss of vegetation cover, both runoff and percolation of water are high causing leaching of products of chemical weathering especially iron and aluminum oxides. These oxides dry out during dry season to form lateritic duricrust. Hydrolysis in granites produces clay e.g. in Gulu, Amolatar, Lira, and Awoja in Soroti

Physical weathering is active during dry season. Exfoliation through temperature changes is common. Aridity shrinkage is also an important weathering process together with colloidal plucking especially in areas of limonite and Hematite. Granular disintegration mainly takes place in granite through differential expansion and contraction. In the drier tropics, salty solutions accumulate in the rock cavities where salt crystals begin to form and grow until the rock is disintegrated by salt crystallization. Intrusive granite may also be exposed by the force of denudation to be attacked by pressure release to cause spawling.

Tropical regions also allow a wide range of game animals to survive. That is why most game parks are found in savannah regions. The animals can break the rocks by trampling on them. There are also small animals like rats, rabbits etc that break rocks. Through human activities like construction, quarrying etc, rocks can physically break down.

Weathering in Arid and Semi Arid Areas

Deserts and semi arid deserts are characterized by low rainfall (less than 750 mm), high rates of evaporation, large diurnal and seasonal changes of temperature and cloudless skies. Vegetation cover is either absent or very limited due to little rainfall. As a result of the above conditions, physical weathering dominates in arid and semi arid areas.

Exfoliation through temperature changes is very pronounced. Granular disintegration of granites is also common through differential expansion and contraction of rock. Salt crystallization also occurs and not only affects granites but also dolomite and limestone both of which are reduced to dust and sand. Salt solutions rising through rocks by capillary action become concentrated as some of the water is lost through evaporation. Salt crystals grow between rock particles and eventually the rock crumbles.

However, even in arid and semi arid areas there is an appreciable amount of moisture that brings about chemical weathering. There are sporadic showers, night dews and other sources of moisture to enhance chemical processes like hydration which causes changes in the structure of the rock causing them to swell and disintegrate.
Hydrolysis through cation exchange causes the formation of clays while oxidation forms reddish black minerals common in desert environment. Desert limestone is affected by carbonation to produce dust while solution dissolves soluble salts and are brought and deposited at the surface by capillary action as in salinization and calcification.

Animals like donkeys, camels etc are also common in dry areas and hence promote physical break down of rocks.

INTERDEPENDENCE BETWEEN PHYSICAL AND CHEMICAL WEATHERING

Physical and chemical weathering processes are interdependent and complementary i.e. they usually aid each other and take place together. However, each type is predominant in a particular environment.

Ways through which physical weathering aids chemical weathering:

1. Physical weathering involves expansion and contraction of rocks which leads to the creation of cracks and joints. The presence of joints and cracks allows deeper penetration of water into the rock which enhances chemical weathering processes such as hydrolysis, oxidation, hydration and carbonation.
2. Frost shattering in areas of 4800m above sea level opens and widens rocks through which dissolved carbon dioxide penetrates to cause carbonation. In addition, the presence of water in rock joints in those areas promotes chemical weathering processes such as hydration, hydrolysis etc
3. Animals such as worms, rodents are good agents of physical weathering. They break rocks by drilling holes into rocks which allow water penetration to aid chemical weathering processes such as hydration, hydrolysis, and oxidation. These animals as they burrow into the soil release carbon dioxide which when dissolved in soil water promote carbonation weathering.
4. Human activities such as road construction, agriculture, mining and quarrying result into physical breakdown of rocks and exposure of new rocks to the surface. This increases the surface area for chemical weathering to take place through processes like hydration, oxidation, and reduction.

5. Roots of plants and hooves of animals create cracks on rocks which increases permeability of the rock resulting into more chemical weathering processes. Plant roots also produce carbon dioxide which may be dissolved in soil water to cause carbonation weathering.

Ways through which Chemical weathering aids physical weathering:

1. Chemical weathering processes such as hydration which involve the absorption of water by the rock makes the rocks to expand. Such rocks easily undergo physical weathering due to high temperature which causes evaporation of water and the resultant contraction. This results into aridity shrinkage and granular disintegration which are physical weathering processes.
2. Chemical weathering processes such as hydrolysis, hydration, carbonation etc change the molecular structure of rocks. The rocks' internal bonds are weakened and generally the rocks become soft. This facilitates physical weathering processes like frost shattering and exfoliation.
3. Salts such as sulphates, chlorides, carbonates which are a result of chemical processes may crystallize in rock cavities between rock particles exerting pressure which causes physical disintegration
4. Presence of thick vegetation with a network of roots aids physical disintegration of rocks. However, when vegetation dies, it decomposes into organic matter which enhances vegetation growth which eventually increase root action as a form of physical disintegration.

In conclusion, physical and chemical weathering processes don't work in isolation although a certain weathering type may predominate in certain environmental conditions. In all cases one is aided by the other hence complementary to each other.

LANDFORMS RESULTING FROM WEATHERING

There are two types of weathering i.e. chemical and physical weathering. Each of these types of weathering produces distinct landforms.

Chemical Weathering

This is a weathering process in which rocks are broken down as a result of the reaction between atmospheric gases in solution water with the rocks' mineral elements. It results into changes in the chemical nature of the rocks and is common in humid areas. It is accomplished through hydrolysis, oxidation, solution, reduction etc. Chemical weathering results into a number of features.

1. In limestone areas, carbonation and solution processes have led to the formation of karst landscapes with features such as stalactites, stalagmites, pillars, dolines, limestone pavements, sinkholes etc. When it rains, water mixes with carbon dioxide gas to form a

weak solution of carbonic acid. The acid dissolves limestone rocks resulting into the formation of several of the features mentioned above.

Caves

These are natural underground chambers in limestone rock areas usually joined to the land surface by a system of inter-connected shafts and pillars. They are formed due to the dissolving away of limestone rock through carbonation and solution weathering. Sometimes, mechanical erosion by underground streams as well as rock collapse may also produce empty cavities hence the formation of caves e.g. at Nyakasura in Fort Portal.

Stalactites

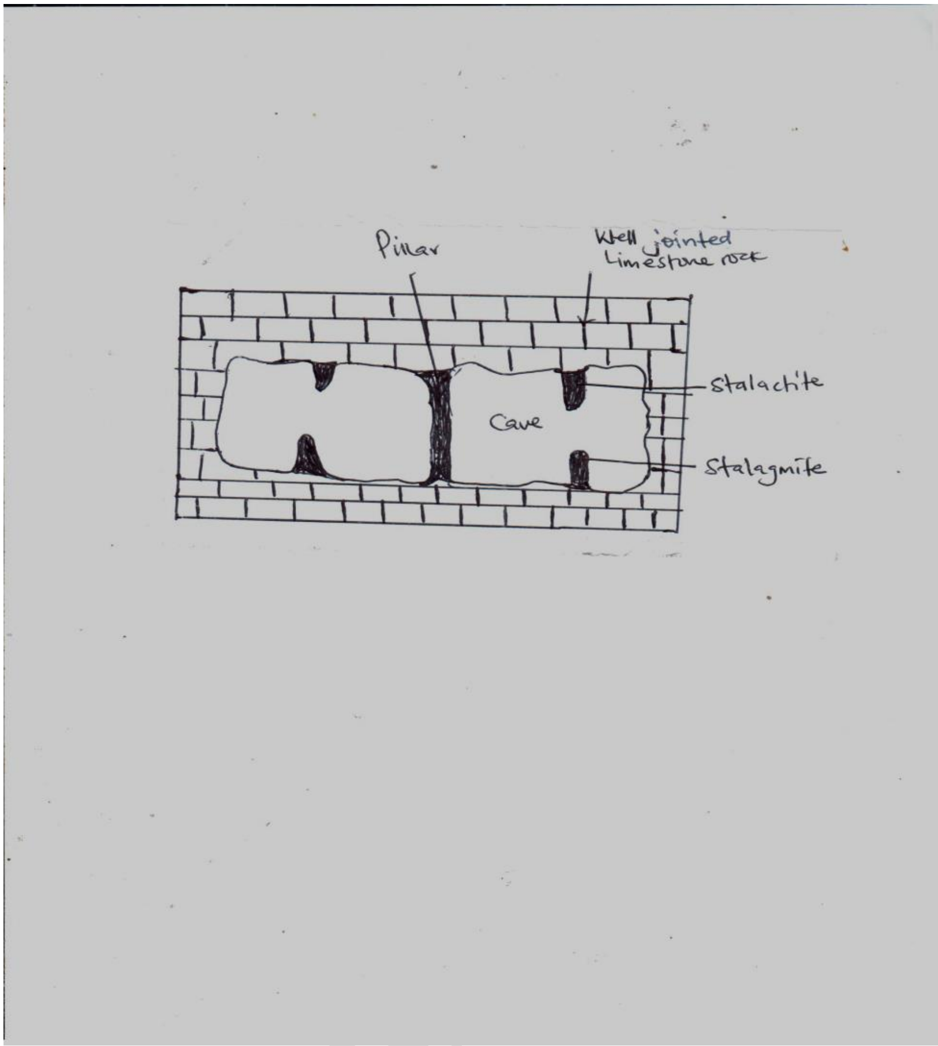
This is a column of calcium carbonate hanging from the roof of a limestone cave. They are formed when carbonic acid dissolves limestone rock in a cave and the solution starts dripping from the roof to the floor of the cave. When the water evaporates, dripping stops, leaving behind protrusions on top of the cave. These harden to form stalactites. Examples are found at Nyakasura in Uganda where they are termed as "Mabere Ganyina Mwiru" and Tanga in Tanzania.

Stalagmites

These are whitish or grey protrusions on the base of a cave in limestone regions. They are formed from accumulation of dripping limestone in solution after the process of solution weathering. When water evaporates from the dissolved limestone, it leaves behind a dry and compact mass of limestone which hangs from the base of the cave called a stalagmite e.g. at Nyakasura.

Pillars

These are vertical stands of calcium carbonate which form after the stalactite and stalagmite grow and converge to form a stand or pillar e.g. at Tanga and Nyakasura



Sink Holes / Swallow Holes

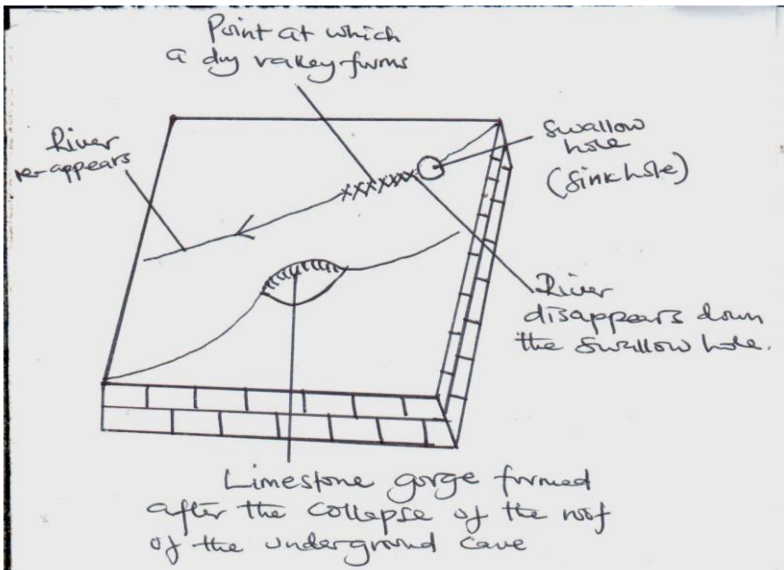
This is a deep hole with nearly vertical sides leading into an underground cave. Through the process of carbonation and solution, limestones from the surface up to the cave may be dissolved and removed in solution to leave behind deep holes which penetrate into the cave. Alternatively, they are formed due to sub surface collapse.

Dry Valley

This is a valley with no permanent stream and often with steep sides. Rivers disappear underground through the sink hole on entering a limestone region and re-appear on the surface at the junction of the limestone rock and impermeable underground rocks. The resulting surface valley is the one termed as a dry valley e.g. on River Molopo in South Africa.

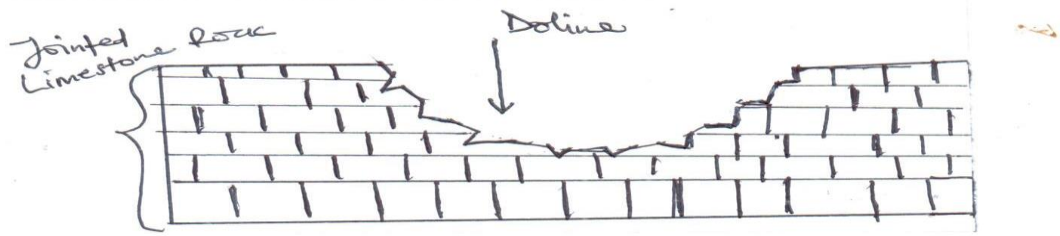
Limestone Gorge

This is a deep narrow steep sided valley which is formed when the roof of an underground cave collapses. Sometimes it forms when a river cuts across and down into a limestone region e.g. the cave of river Manambolo in Central Madagascar.



Dolines

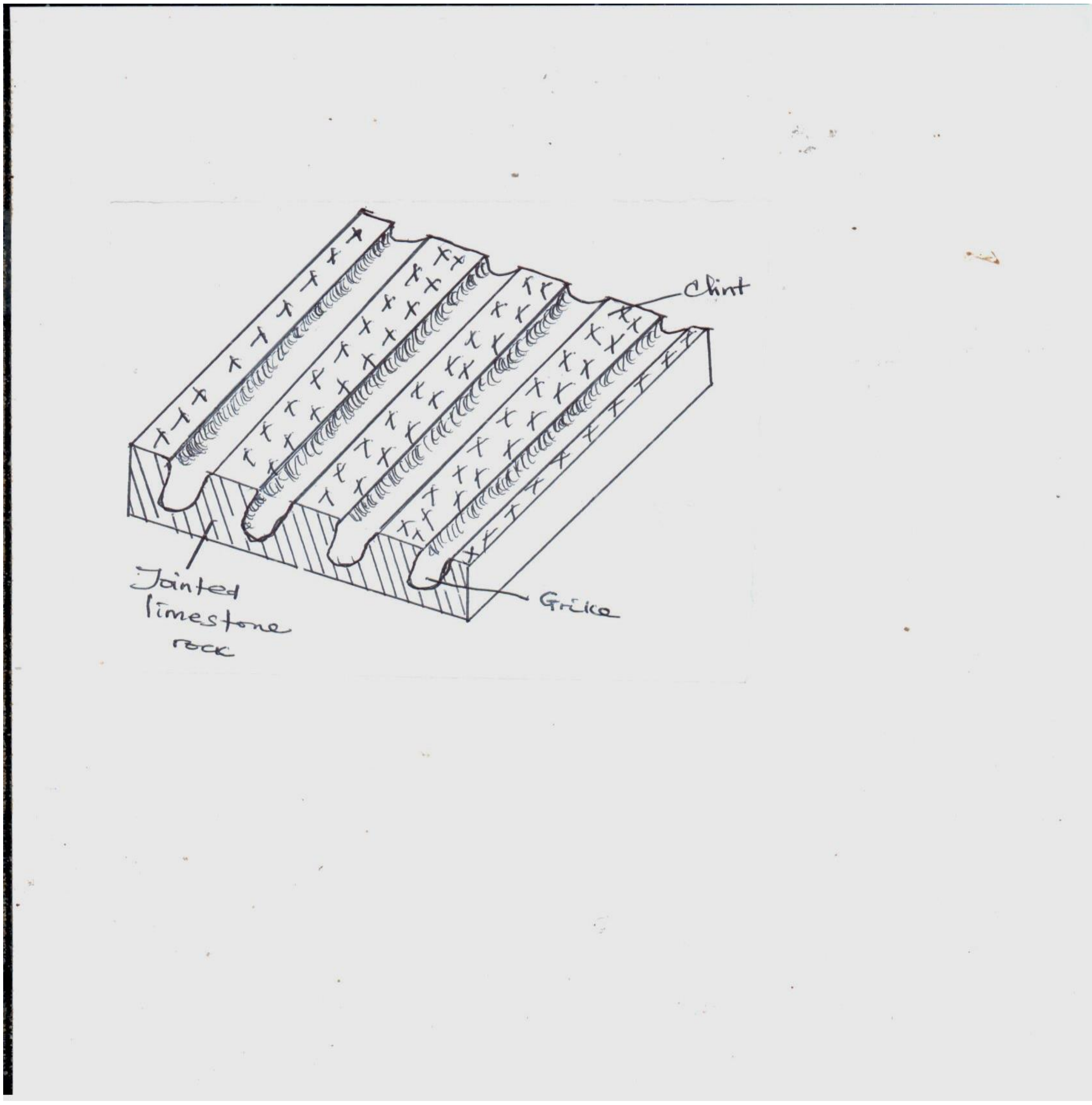
These are shallow depressions or hollows with gently slopping sides generally circular or oval in shape. They are formed at the intersection of major joints where there is concentration of chemical reactions which quickly dissolves limestone rocks to form small basins.



Limestone Pavements

This is a bare rock surface which is criss-crossed by many grooves where differential solution weathering has worked along the joints. The relatively resistant limestone forms flat topped ridges called clints while the less resistant limestone forms hollows called grykes.

Illustration



Uvala
This is a large depression intermediate in size between a doline and a polje. They are formed when dolines are enlarged or joined due to the solvent action of carbonic acid on limestone rocks e.g. at Nyakasura.
Polje
This is a shallow but very large steep sided depression with a generally flat bottom. It covers hundreds of square kilometers. They are formed when Uvalas or dolines are enlarged and joined by solution weathering. Polje may get filled up with water to form Solution lakes.
Importance of Karst landscapes in EA.

- They form unique features that attract tourists earning foreign exchange to east African countries.
- Limestone rocks when metamorphosed turn into marble which is used for decoration purposes.
- Limestone is used in the manufacturer of cement which is used for construction purposes.
- Limestone is used as an agent in the steel and iron industry for separating iron from other impurities.
- Thin soils which are associated with limestone rocks support the growth of short grass which is used for grazing animals.
- Negatively it beaks down to form poor soils that are unsuitable for arable farming.
- Limestone rocks may form steep slopes which may lead to land slides.
- They are very permeable rocks and leads to loss of surface drainage resulting into occasional water shortages.

2. Oxidation process results into the formation of lateritic soils through the oxidation of iron and aluminum.
3. Hydrolysis results into the formation of residual clays.

Physical Weathering
This is the disintegration of rocks by physical means. It's brought about mainly by temperature changes, influence of plants, animals and man. It's accomplished through processes like exfoliation, block disintegration, pressure release, granular disintegration, etc. It is responsible for the formation of various land forms.

Exfoliation domes
These are smooth and round toped hills formed due to alternating high day and low night temperatures. During the day, rock surfaces expand and contract at night when temperatures drop. Repeated expansion and contraction results into the peeling off of outer surfaces of the rock leaving behind an exfoliation dome. These features are common in arid areas like Chalbi desert.

Castellated Tors

These are pillars of rounded weathered boulders rooted in the bed rock. They are formed through the physical weathering process of block disintegration in rocks that have vertical and horizontal joints. Through repeated expansion and contraction during the day when temperatures are high and nights when the temperatures are low, joints are enlarged and pieces of blocks fall off leaving upstanding pillars called Tors. A good example is Kachumbala Tor in Kumi district.

Inselberg

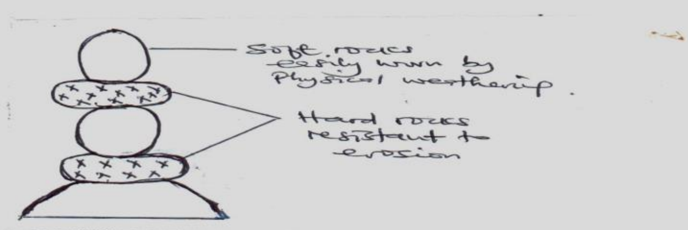
These are masses of hard and resistant rock which are exposed to the surface due to weathering and removal of surface layers. Examples are found at Mubende, Nakasongola, Moroto etc. Refer to vulcanicity.

Arenas

These are large circular depressions on the earth surface. They are formed in areas with alternating hard and soft rocks. The soft rocks are attacked by weathering and erosion leading to the formation of basins while the resistant rocks stand prominently around the basins e.g. in Ntungamo and Mbarara.

Rock Pedestals

These are tower like structures of various sizes standing prominently on a flat landscape in desert or arid areas. They are formed where a mass of rock is composed of alternating hard and soft rocks. The soft rocks are attacked by abrasion and physical weathering and shaped into a tower like structure. A good example is the Devils Rock in Niger.



IMPORTANCE OF WEATHERING

Weathering has resulted in to the formation of touristic attraction features such as caves, stalactites, and stalagmites, limestone pavements, inselbergs etc.

It has resulted into the formation of minerals like clay at Kajansi hence encouraging construction industry through brick and tile making. In the same way it has boosted mining by exposing underground ores e.g. at Mwandui in Tanzania

Exposed granitic rocks have been quarried to provide aggregates for construction e.g. Nakasongola rocks was quarried for the construction of Gulu–Kampala Highway.

Weathering is the first and very important process in soil formation. Volcanic lavas have weathered down to produce very fertile soils in east Africa e.g. at the slopes of Mt. Elgon, Kenya, and Tanzania that supports cultivation.

Exfoliated slabs can be curved to provide grinding stones.

Negatively, weathering on steep slopes leaves behind loosened rock materials that are prone to erosion by running water. This has increased erosion of soil on slopes of Mt. Kilimanjaro in Tanzania and in Kigezi.

Weathering in limestone areas such as Tanga in Tanzania, Nyakasura in Uganda, and Kilifi in Kenya has left behind a rugged terrain of clints, caves, and grykes. These have limited cultivation and settlement.

Inselbergs pose a problem towards road construction. They need blasting before a road can be constructed and this is very expensive.
Physical weathering results into the cracking of buildings and their eventual collapse. This increases costs of construction.

Weathering in other areas has resulted into the formation of very hard infertile soils e.g. lateritic soils in Buganda.

SLOPES AND SURFACES / LANDSCAPE DEVELOPMENT

Most of the land surface is made up of slopes which are generally convex in their upper parts, concave in the lower valley floors and to the level of the sea at their ultimate depth. Only a very small part of the land can be said to be truly flat vertically or horizontally. The development of landscapes has been explained by several theories and these include peneplanation, pediplanation and etchplanation.

PENEPLANATION

This was propounded by William Morris Davis and is sometimes referred to as the Davisian cycle of erosion, geomorphic/erosion cycle or slope decline. Generally, the theory explains the modification of the physical landscape as a result of the action of natural agencies in an orderly progressive sequence starting from the uplift of the land into upland to an ultimate low, almost featureless plain.

According to Davis, landscapes / landforms develop through a progressive sequence of stages i.e. the youthful stage, mature stage, old stage and rejuvenation all again. The cycle begins with the uplift of the land leading to building of highlands/uplands. These uplands become the youthful stage and can be due to earth movements like faulting, folding, warping and Volcanicity.

The uplift has to be simple and fast enough that it does not experience significant erosion during this phase. The uplifted land then undergoes a cycle of erosion by rivers, snow, wind, running water, wind and weathering processes. Rivers in the uplifted slopes quickly erode and deepen the valleys, erosion decreases and slopes and valleys become gentler. Lateral erosion is more dominant and valleys now more V-open become broader and broader. This is the mature stage.

As the relief becomes relatively flat due to constant cutting down flood plains begin to form. This is then the old stage where materials eroded from the youthful and mature stages are deposited. Deposition results into meandering of rivers as the relief becomes flattened. A lowland finally develops which Davis termed as peneplain.

When a peneplain stage is achieved uplift occurs so that the cycle starts again. This Davis referred to as a return to a level or point of origin.

In conclusion Davis' cycle points out to the value of structure, process and stage/time in landform evolution.

THE RELATIONSHIP BETWEEN ROCK STRUCTURE AND SLOPE FORMATION

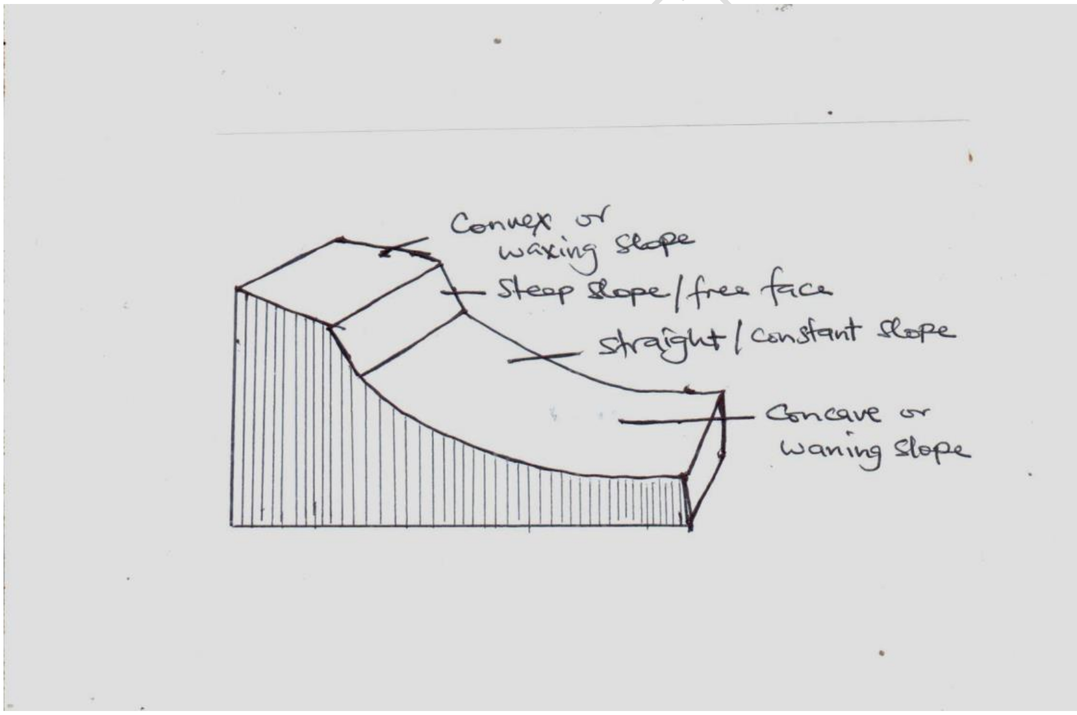
Hard rocks are more resistant to erosion than soft rocks hence form upland areas with convex or waxing slopes on top. Examples of such hard rocks include quartzite, granites and gabbro.

Below the waxing slope is the free face which is very steeply sloping. This is due to erosion, weathering and mass movement.

Down the free face is the constant or straight/even slope that is gently sloping resulting from uniform weathering/erosion of hard or soft rocks and deposition from the free face.

Soft rocks like clay and shale form lowlands that are deeply weathered or eroded to form concave slopes or waning slopes. Such slopes may also result from deposition from the upper slopes.

Illustration



Sample questions

1. “Landform evolution is a result of complex processes” with reference to examples from east Africa illustrate this statement.

2. “Land form evolution is a result of structure process and time” Discuss

3. a) Using the Davisian cycle of erosion concept, examine land scape development in east Africa.

b) Examine the relationship between rock hardness and slope formation.

4. Describe the processes of chemical weathering taking place in humid areas of east Africa.

5. (a) With specific examples, examine the dominant processes of denudation in the savannah regions of east Africa.

b) To what extent have the features resulting from the processes above influenced human activities?

6. Examine the influence of climate on the processes of physical and chemical processes?

7 (a). Draw a sketch map of east Africa and on it mark and label semi arid areas.

(b) Examine the weathering processes taking place in the labeled semi arid areas

8(a) Discuss the processes of chemical weathering.

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

9. With reference to the equatorial regions of east Africa examine the view that chemical and physical weathering processes are interdependent and complimentary.

10.” Climate is by far the most important factor determining /influencing the weathering of rocks”. Discuss

MASS WASTING

This is also called mass movement and it describes the bulk movement of weathered materials (regolith) down slope under the direct influence of gravity. It includes the various forms of creeping, flowing, sliding or falling of the weathered materials from higher to lower slopes due to the pull of gravity. Gravity plays its role when the materials over come their initial resistance to movement. Rain water helps to overcome this resistance as it not only increases the weight but also acts as a lubricant between the slope and the weathered materials.

TYPES OF MASS WASTING

There are various ways in which weathered materials move down the slope under gravity. They are broadly divided into two;

- Slow movements
- Rapid movements

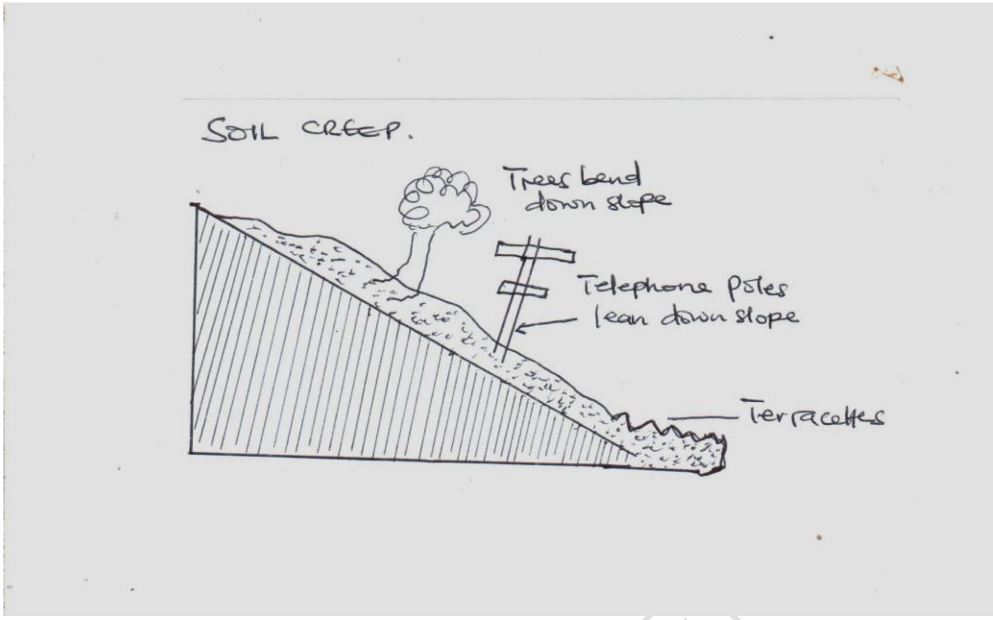
Slow movements

These processes are very slow and are only discernible over a long period of observation. Under this, there are processes such as Soil creep, Talus creep and Solifluction.

Soil creep.

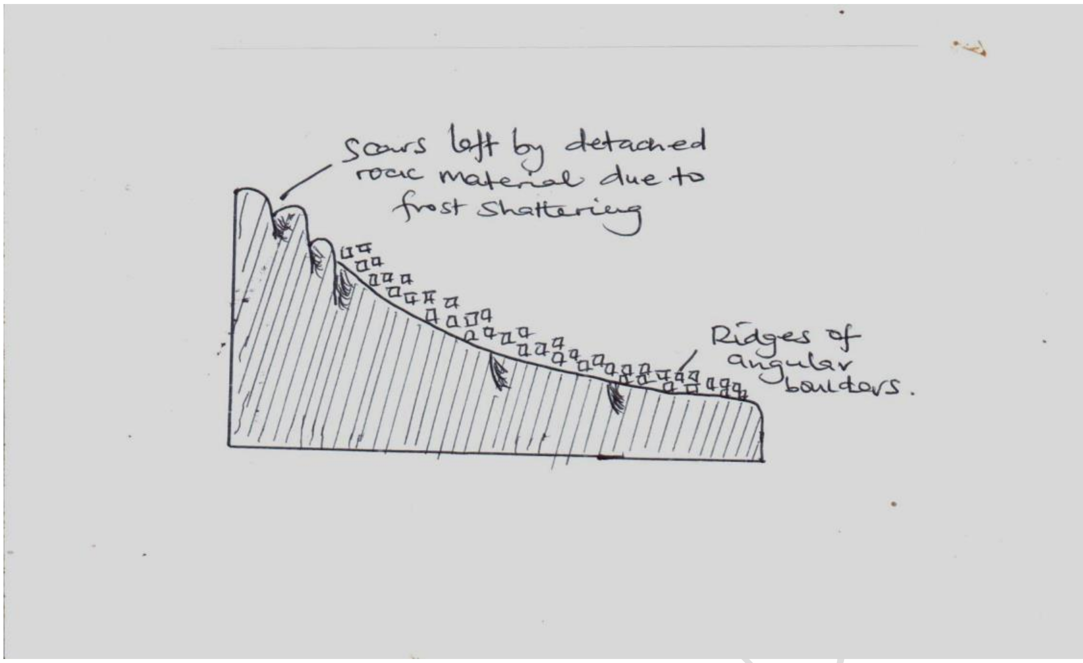
This is the commonest and wide spread. It's a slow movement of fine rock materials and soil down a hill. It takes place on slopes of angles as low as 5^0 or less. It is facilitated by rain water that contributes to soil saturation and lubricates the slope, heating and cooling of the soil, burrowing of animals and trampling of grazing animals. The presence of soil creep can be detected by such phenomena such as trees telephone / electric poles and walls that lean down slope. Soil creep also create terrace like features called terracettes on hill slopes. These features are common in Shema district and Kajara county in Bushenyi District.

ILLUSTRATION OF SOIL CREEP



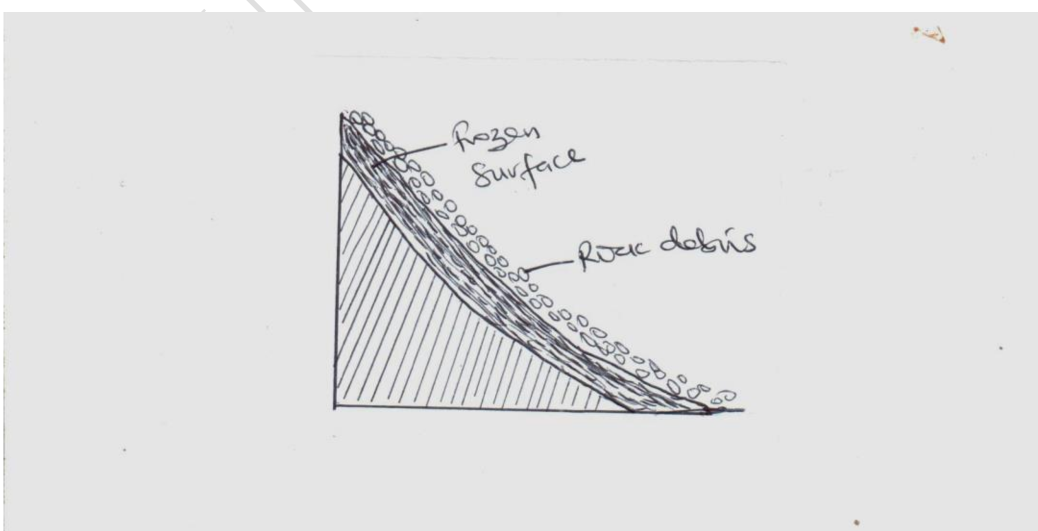
Talus creep

It’s the movement of angular rock debris of different sizes on moderate slopes. The talus in cold areas comes from frost shattering which tears out rock particles from the rocks. Under the influence of gravity and melt water, earthquakes and moving heavy objects, the talus begins to move en-masse along the slope.eg on the slopes of Mt. Rwenzori and Mt. Kilimanjaro.



Solifluction

This is a form of mass wasting common in glaciated environments which are prone to freezing and thawing. During the cold period, the bed rock and the regolith are frozen. As temperatures rise during the warm period, the surface layer melts while the under ground layer remains frozen. The existence of a frozen layer underneath prevents the infiltration of water thus any top soil and surface rock debris becomes saturated. The saturated materials may then flow down slope as an active layer to produce solifluction lobes in valleys at the foot of mountains. In east Africa, this form of mass wasting is common in mountainous areas such as Rwenzori and Mount Kenya.



RAPID MOVEMENT PROCESSES/ LANDSLIDES

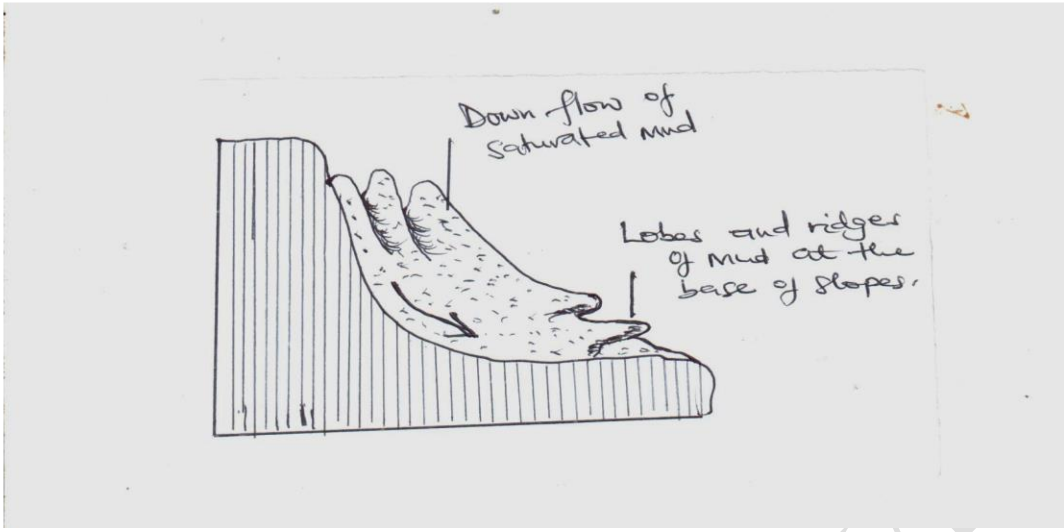
These are generally called land slides. Land slides are defined as sudden and rapid movements of rock and soil debris down the slope under the influence of gravity. The major types of land slides include: earth flows, mud flows, slumping, rock slide, and rock fall. In east Africa, land slides are common in high land areas such as Kigezi high lands, mountains Rwenzori, Kilimanjaro, Elgon, Kenya and Usambara. Other areas include Bundibugyo, Bududa, Bulambuli and Kapchorwa in Uganda, Kenya highlands and the southern highlands of Tanzania. The types of landslides are elaborated below:

Earth flows

This is a rapid down slope movement of water saturated regolith on moderate slopes. It takes place on slope angles between 5^0-15^0, at a rather slow rate. It's estimated that it takes place at a rate varying between one and 15km per year. When it rains, slope materials may be soaked, albeit in a small amount of water and are saturated. The presence of water in the material increases not only the weight but also lubricates the slopes. A sudden movement of material takes place producing short flow trucks and small bulging lobes or turns at the feet of the slope.

Mud flow

This is a rapid movement of saturated soils mainly clay mixed with unconsolidated gravel and boulders occurring on steep slopes. When it rains, the materials absorb water, become super saturated and plastic. Such materials may move down slope at high speed over 15km per hour. A good example is the mud flow in Columbia in 1985 from mount Nevado Del Ruiz that buried the town of Amero moving at an estimated speed of about 80km/hour. In March 2010, a mud flow occurred on the slopes of Mount Elgon killing an estimated 450 people in Bududa District in Uganda.

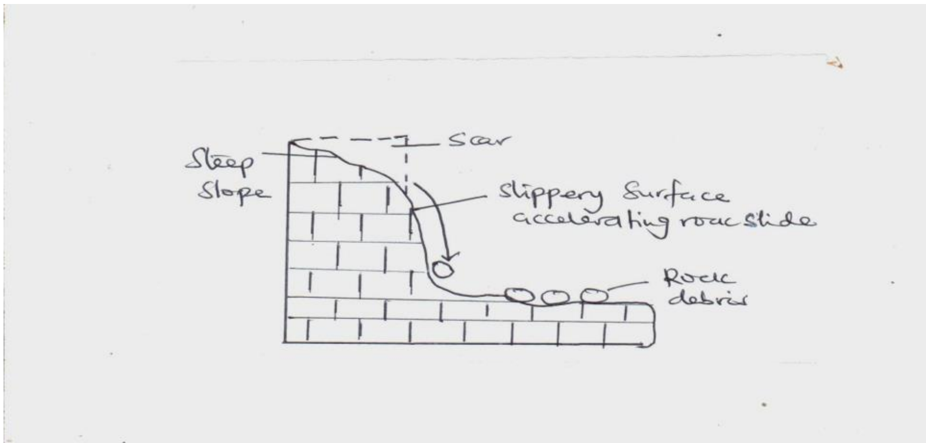


Slumping.

This is the commonest type of land slides. It involves an actual tearing away of rock materials from a surface of a steep face such as an escarpment / cliff. The sliding block doesn't break up but moves rotationally on a curved plain tilting back wards and leaving a fresh scarp on a mountain slope. Slumping is common where massive well jointed rocks such as limestone overlie clay or other weak rocks that may be easily ruptured.

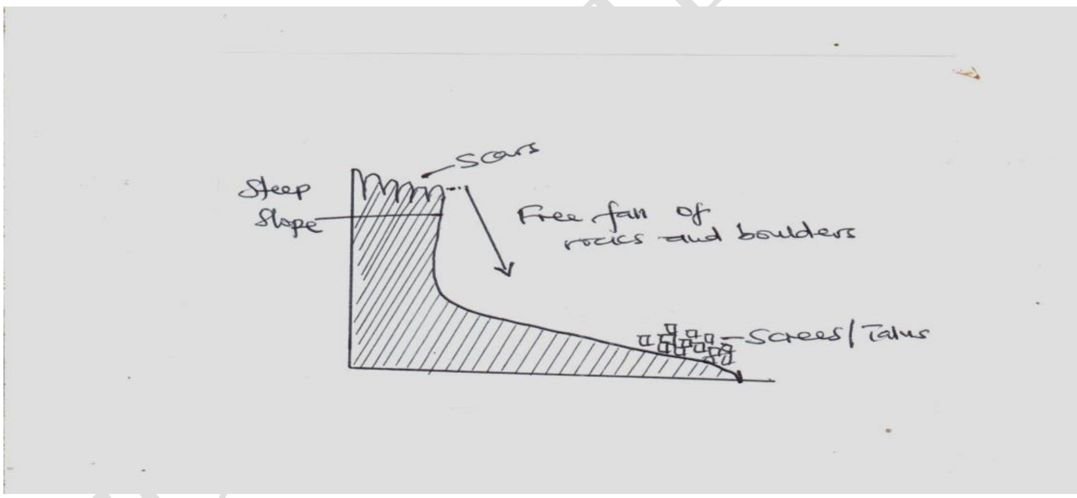
Rock slide (debris slide).

This involves the dislocation of large quantities of rock which roll on the slope at great speed. It takes place where slopes are very steep such as fault surfaces, vertical cliffs, and therefore gravity has a significant effect. It is accelerated by the occurrence of earthquakes that loosens and detaches rocks from steep slopes.



Rock fall (rock avalanche)

This is the fastest type of land slide. It's a spontaneous movement of individual big rocks down a steep slope of over 40^0 like a steep escarpment or a cliff. There is no sliding on the ground but rather a mass of rock detaches from the steep slope and falls freely on the ground where it may cause a lot of destruction. In east Africa, they are common on slopes of mountains Rwenzori, Kenya, Kilimanjaro and Elgon.



CAUSES OF MASS WASTING/ SLOPE FAILURE/ SLOPE COLLAPSE

Mass wasting is caused by several factors both physical and human.

1. Nature of the land scape. This determines the rate of downward movement of the weathered materials. Very steep slopes encourage faster mass wasting types such as rock fall, rock slides and slumping e.g. on slopes of mount Rwenzori, Kigezi high lands,

mount Muhavura etc. Moderate slopes favor the occurrence of talus creep and mud flows while gentle slopes encourage soil creep, earth flows and solifluction.

2. Heavy rainfall. This results into lubrication of weathered materials and the slope, increased weight of the regolith, and loose attachment of rocks / soils which eventually lead to soil creep, earth flow and mud flows.

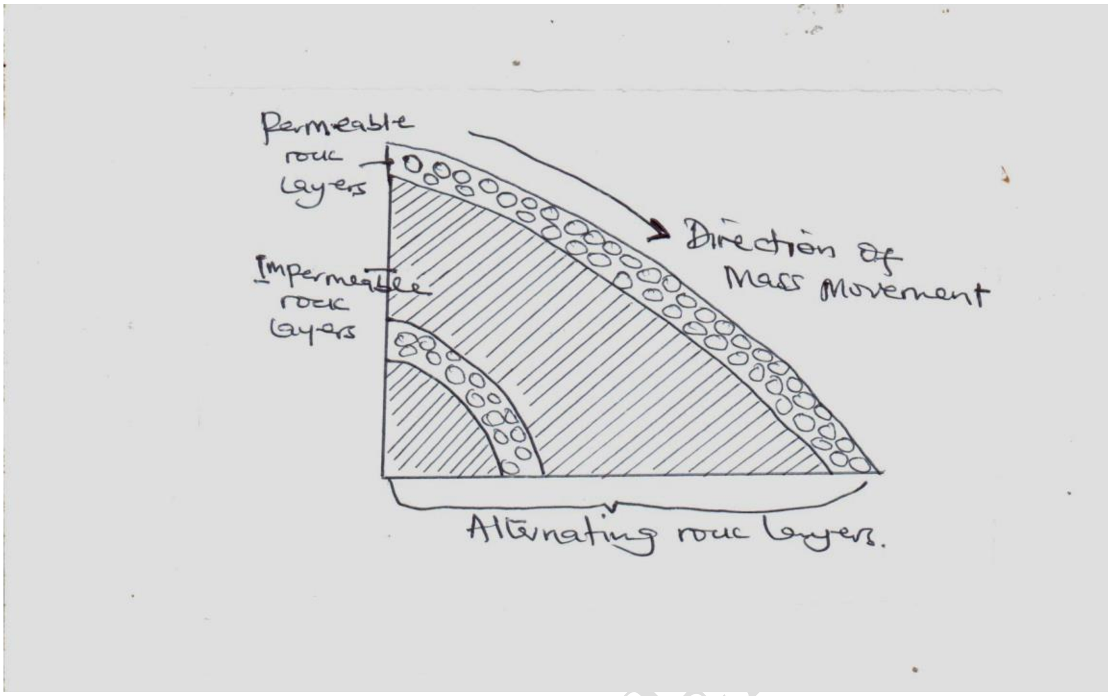
3. Freezing and thawing in cold environments also lead to mass wasting. When temperature rises, ice melts and water is added on to weathered materials. This increases the weight of weathered debris and friction between the rock surface and the debris is reduced. Moreover, water from melting ice contributes to the saturation of the weathered materials thus being able to move on the frozen surface a process termed as solifluction.

4. Volcanic eruption may also trigger mass wasting. As eruption takes place, it shakes the ground hence loosens the rock particles. This may result into rock slides, slumping and rock falls. Eruptions also yield rock particles of different sizes such as cinders that when lubricated may flow down slope in form of mud flows.

5. Earth movements like earthquakes also lead to mass wasting. Once an earthquake occurs, the ground is shaken and ground vibrations loosen rocks resulting into processes such as rock falls, rock slides and slumping. These are common in Bundibugyo and Kabarole in Uganda.

6. The nature of rocks also leads to the occurrence of mass wasting. In areas where permeable rocks overlie impermeable rocks, the permeable rocks get soaked in water when it rains and easily slide off inform of rock slides and slumping. Where jointed rocks overlie hard but slippery surface, they tend to loosen from the mother rock thus mass

movement.



7. Human activities such as cultivation and settlement on steep slopes also cause mass wasting. This is because they contribute to the clearance of vegetation. The roots of trees and other vegetation types bind the rock particles and soils together. When vegetation is cleared, the binding force disappears and the soil particles become loose and unconsolidated. Once it rains, such rock particles and soils become saturated and slippery and may flow down slope inform of earth flows and mud flows.

8. Grazing on steep slopes also offsets mass wasting. Large herds of grazing animals such as cattle, buffaloes, elephants, sheep, and goats loosen soil particles along the slope. Such soils are prone to saturation leading to soil creep, earth flow and mud flows.

9. Mining and quarrying also contribute to mass wasting. Mining weakens rocks and make them prone to rock slides e.g. vermiculite mining in Mbale, tin and gold mining in Bushenyi in Uganda. Quarrying on hill sides create steep slopes which enhance land slides occurrence. Further more, during mining and quarrying, explosives may some times be used to blast and break rocks. The impact of these explosives shakes the ground triggering off movement of the weathered particles to result into landslides.

10. Moving heavy objects such as Lorries, buses and trains exert a lot of force on the ground. The ground tends to vibrate and this destabilizes unconsolidated materials resting loosely on the slope. Such materials can start rolling down slope inform of rockslides and rock falls e.g. along Ntungamo-Kabale road.

11. Poor farming methods like ploughing up and down slope contributes to the movement of materials on the slope. Over cropping results into soil exhaustion and erosions and this promotes the occurrence of mud flows, earth flows and soil creep.

EFFECTS OF MASS WASTING

Mass wasting has a number of effects on both the land scape and human activities.

Effects on the Physical Environment

The effects on the physical environment include the following;

1. Formation of terracettes. Slow movement e.g. soils creep usually create step like features known as terracettes. Theses are common in the hills of Ankole and Kigezi. Refer to soil creep for diagram

2. Formation of patterned grounds (pattern polygons). These are stones which are arranged in polygonal shapes in glacial areas. They are formed from solifluction /soil creep due to frost heaving.

3. Formation of scars. A scar is a hollow left on a hill side where rock debris has been detached. Where debris eventually rests, land forms such as a lobes or tongues are produced.

4. Formation of straight slope soil creep and slope wash fill up cavities or irregularities along the slope resulting into unusual straight slopes e.g. on some hill slopes in Ankole.

5. Drainage blockage. Land slides and slumps on the sides of river valleys may block river courses to create temporary lakes. One of the Tukuyu landslides in Tanzania blocked river Mbaka creating a lake which lasted for 8 hours.

Effects on Human Activities

The effects on human activities are both positive and negative.

1. Negatively, mass wasting causes loss of life. Several land slides especially those associated with earth quakes and heavy rainfall such as rock falls, rock flows and mud flows destroy settlements and kill people living down the slopes. The Bulucheke land

slides on slopes of Mount Elgon between 1997-2001 killed at least 100 people while the Bundibugyo land slides in 1966 destroyed almost half of the town. In Bududa land slides of March 2010 killed an estimated 450 people.

2. Agricultural land and crops are often destroyed in areas prone to land slides. On the steep slopes, soil may be carried away and deposited in valleys e.g. in Kigezi high lands and southern high land s of Tanzania. Crops may also be carried down by the creeping soil and destroyed by land slides. This in the long run may bring problems like famine and poverty.

3. There is destruction of forest resources e.g. the Bulucheke landslides on Mount Elgon destroyed a large section of Mount Elgon forest. Even slow processes like soil creep result into the bending of tree trunks hence reducing the timber quality.

4. Mass wasting also results into destruction of infrastructure. Electric transmission and telegraphic lines are usually destroyed while roads and railways may be blocked or destroyed by slides and creeps e.g. in 1989 telephone and road links with Bundibugyo were cut off by land slides. Earlier in 1985, Kisoro-Katuna road was also blocked by land slides.

5. Besides, mass wasting creates engineering hazards. Construction along steep slopes is made very difficult and dangerous by creeps and slides. There is a poor road net work in Kisoro and Kapchorwa partly because of this factor.

6. Positively, persistent removal of surface rocks from hill slopes may expose underlying rock areas. This contributes to the development of the mining industry e.g. gold in Bushenyi at Kyamuhunga is often exposed by land slides.

7. Mass wasting may also lead to formation of fertile soils on lower slopes of highlands. The soil particles removed from upper slopes in processes like soil creep and solifluction are deposited at lower levels where they can be used for cultivation. In addition, mass wasting facilitates soil formation as new rock surfaces are exposed to weathering processes such as exfoliation.

8. Massive rocks that are detached from hill slopes leave behind beautiful sceneries e.g. scars that are appealing to curious people thus attracting tourists.

STEPS BEING TAKEN TO REDUCE LAND SLIDES

There are various measures that have been taken to curb the impact of land slides. These measures aim at ensuring slope stabilization and maintenance of slope equilibrium. They include the following:

1. Reforestation i.e. planting trees on those slopes where they have been cut. This helps to bind the soil once again, reduce the impact of rain drops and soil saturation as well as binds the soil particles together e.g. in Kigezi highlands
2. Afforestation is being encouraged. Trees are being planted even on slopes where they never existed. Good examples are in Kenya high lands and Kiisi areas of Kenya and Kigezi high lands.
3. Better farming methods have been introduced e.g. terrace farming in Kigezi on the slopes of mount Moroto, Kenya high lands and Mount Kilimanjaro. Terracing reduces the down slope movement of debris.
4. Forest reserves and national parks have been created in high land areas partly to reduce deforestation and reduce slope wash and land slides. In Uganda, examples include; mount Mughahinga, Rwenzori, Elgon, Kadam and Morongole in Kidepo valley.
5. Mining and quarrying have been done in Uganda following safety provisions produced by NEMA. NEMA as an organization is mandated to carry out environmental impact assessment before mining and quarrying can be done.
6. Hill slope draining is being done to reduce excess water that causes over loading and lubrication. Deep trenches have been dug on hill slopes in high land regions especially the Kenya and Kigezi high lands. In Kigezi it takes the form of land reclamation. Another way in which excessive water is being drained is by planting Eucalyptus trees in valleys and other water logged areas.
7. Resettlement of excess people is being under taken. People from densely populated areas have been resettled in less populated areas in order to minimize land slides. E.g. people from Kigezi have been resettled in Kasese, Kabale and Kamwenge areas, People from Bududa have been resettled in Kiryandongo refugee camp while people from Kenyan high lands have been resettled in Kiisi, Mwea-Tebere, Galole etc.
8. Settlement on steep slopes is being discouraged in Kenya highlands, Kigezi highlands and Elgon slopes. This is to ensure that slopes remain naturally intact.

9. Environmental education is being done to create awareness about the dangers of clearing vegetation in highlands. People in mountainous areas are also being taught better farming methods like crop rotation, contour ploughing, mixed cropping etc.

10. Concrete walls are being built along steep faces so as to control mud flows and soil creep. Such walls are common at Kololo, Muyenga, and Naguru in Kampala.

11. Other measures that may control land slides include implementing a policy of controlled grazing i.e. reducing the number of animals grazing on slopes prone to land slides and law enforcement in areas where environmental education fails. This could involve strict punishment for those breaking government legislation like illegal felling of trees. Family planning aimed at reducing population pressure on land is also being encouraged.

Like all natural disasters, land slides can't be completely stopped but rather their impact can be minimized.

SAMPLE QUESTIONS

1. With reference to either Kigezi or Bugishu highlands, discuss the causes of landslides and their effects on human activities.

2. (a) with the aid of a sketch map, identify areas in Uganda where land slides are common.

   (b). To what extent is man responsible for the occurrence of land slides in the areas above.

3. Account for the occurrence of increasing cases of slope failure in East Africa.

4. Examine the factors that influence the nature of mass movement in East Africa.