WEATHERING

Weathering is the breaking and decomposition of rocks at or near the earth's surface in situ by physical and chemical processes.

Types of weathering

There are **three** types of weathering and these are ;

- Physical/mechanical weathering
- Chemical weathering
- Biological/organic weathering

PHYSICAL WEATHERING

This is a process by which rocks are broken down into smaller particles in situ with no change in the chemical composition of the rock.

Physical weathering occurs mainly due to **temperature fluctuations/changes** which lead to alternate heating and cooling or freezing and thawing as well as the action of plant roots and other living organisms that break the rock into smaller rock fragments **without changing the mineral** composition of the rock.

Physical weathering occurs at **shallow depths** and depends **more on the removal of the weathered layer.**

Physical weathering mainly takes place in the hot and dry (arid and semi – arid) areas of North Eastern Uganda , Ankole – Masaka dry corridor, North, North western and North Eastern Kenya, central Tanzania and on the upper slopes of the glacial mountains such as Kilimanjaro, Kenya and Rwenzori in East Africa.

Processes of physical weathering

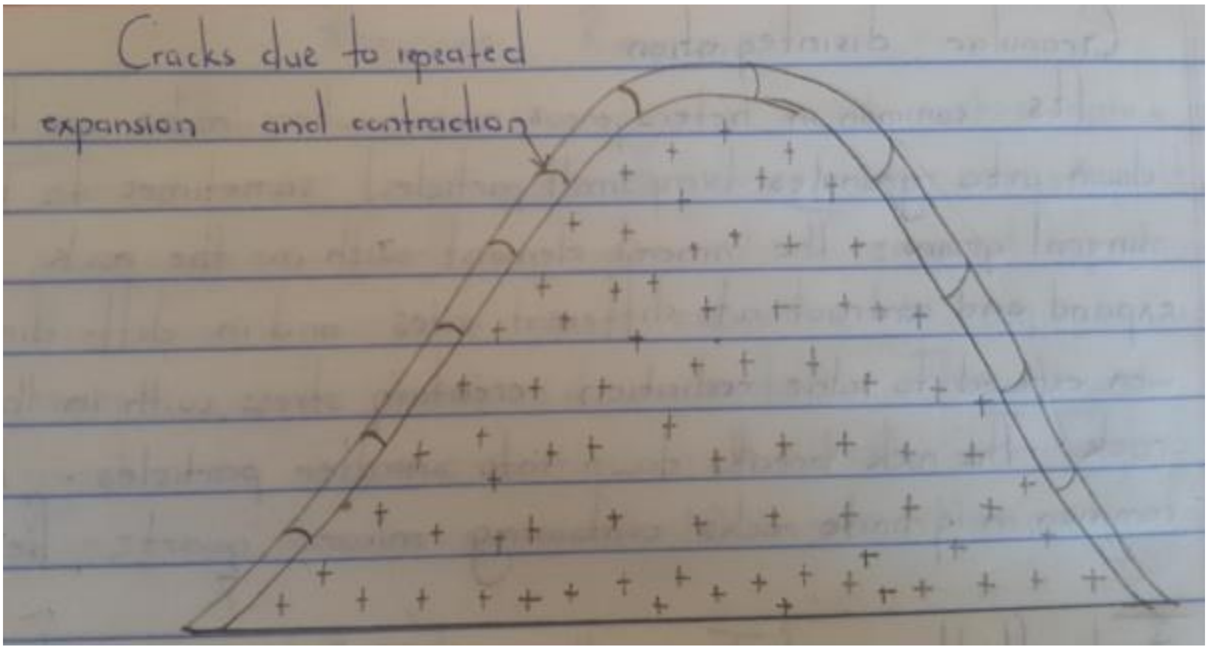
Physical weathering processes taking place in East Africa include;

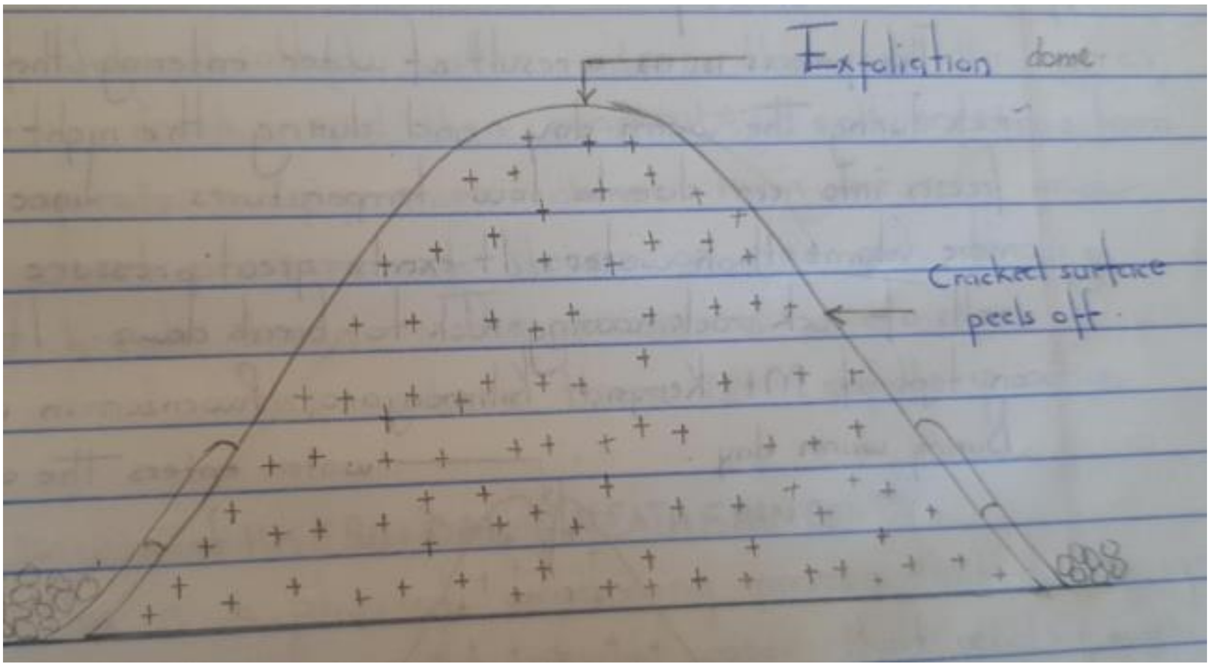
- Exfoliation/onion weathering/spalling
- Block disintegration
- Granular disintegration
- Frost shattering/frost action/Freeze – thaw action
- Pressure release/unloading
- Crystallisation/crystal growth
- Aridity shrinkage
- Action of plant roots
- Action of animals
- Activities of man

Exfoliation

This involves the breaking, splitting and peeling off of the surface rock layers due to alternate heating up of the rock during the day causing expansion and cooling at night causing contraction. Repeated differential expansion and contraction creates stress and strain that weaken the rock causing the surface rock layers to crack down and finally peel off, leaving behind a smooth rounded dome known as an **exfoliation dome** with deposited rock screes at the base.

Exfoliation is common in exposed **homogenous rocks** in arid and semi – arid areas experiencing high diurnal temperature ranges. For example the Bismarck rock at Mwanza in Tanzania , Turkanaland , Nyika plateau in Kenya, Soroti hill in Soroti town, Akia hills in Lira, Kacumbala hills in Kumi (Karamoja) in Uganda.





Block disintegration

This is the breaking down of **well jointed** or **bedded homogenous** rocks into smaller individual **rectangular blocks** due to alternating heating of the rock during the day causing expansion and cooling at night causing contraction. Repeated alternate expansion and contraction widens the rock joints and finally the rock breaks down.

Block disintegration is also common in arid and semi- arid areas experiencing high diurnal temperature ranges. Examples can be seen at Mubende, Nyero rock painting in Teso, Karamoja region in Uganda, Sukumaland in Tanzania and Turkanaland in Kenya.

Block disintegration may also be due to frost action widening the rock joints and breaking up the rock into rectangular blocks such as on the glaciated mountains of Kilimanjaro, Kenya and Rwenzori.

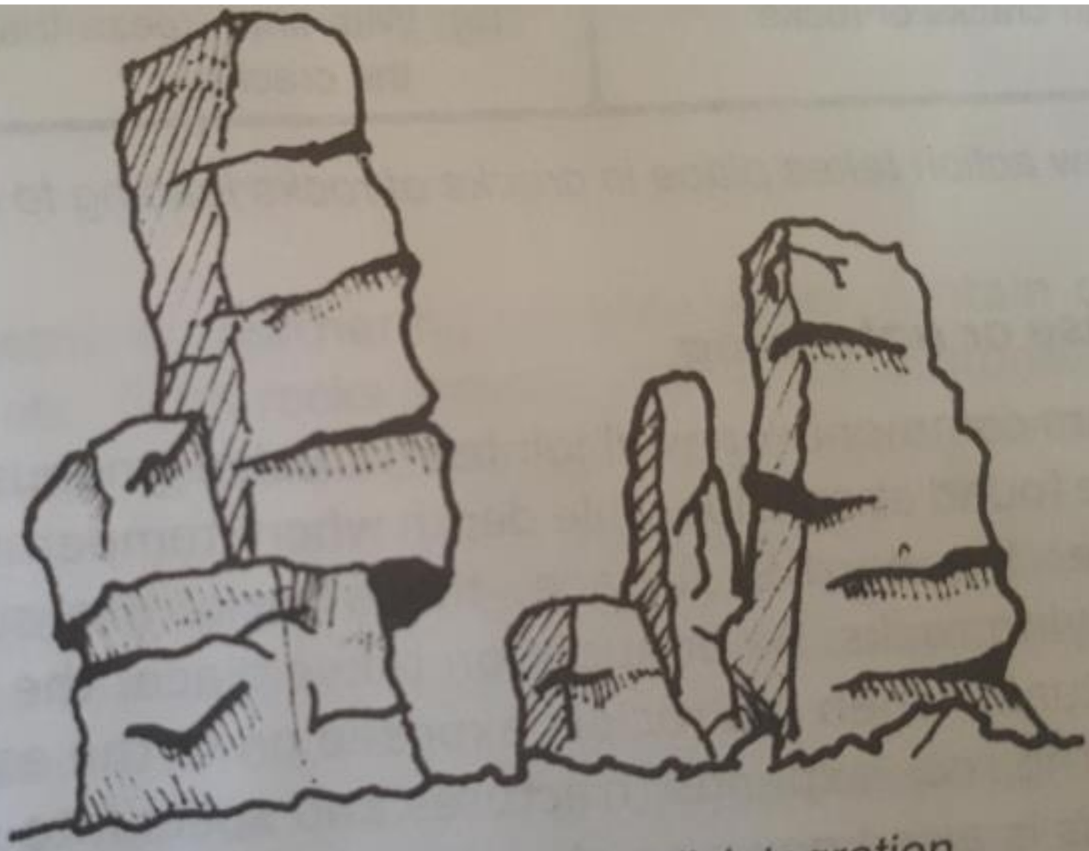


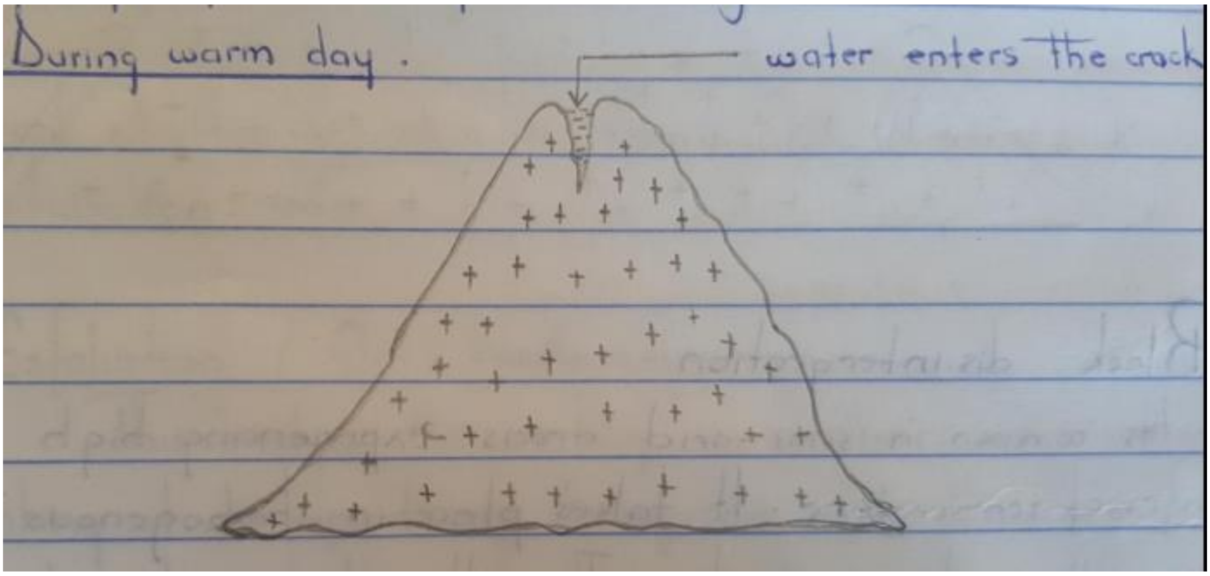
Fig. 3.7: Block disintegration.

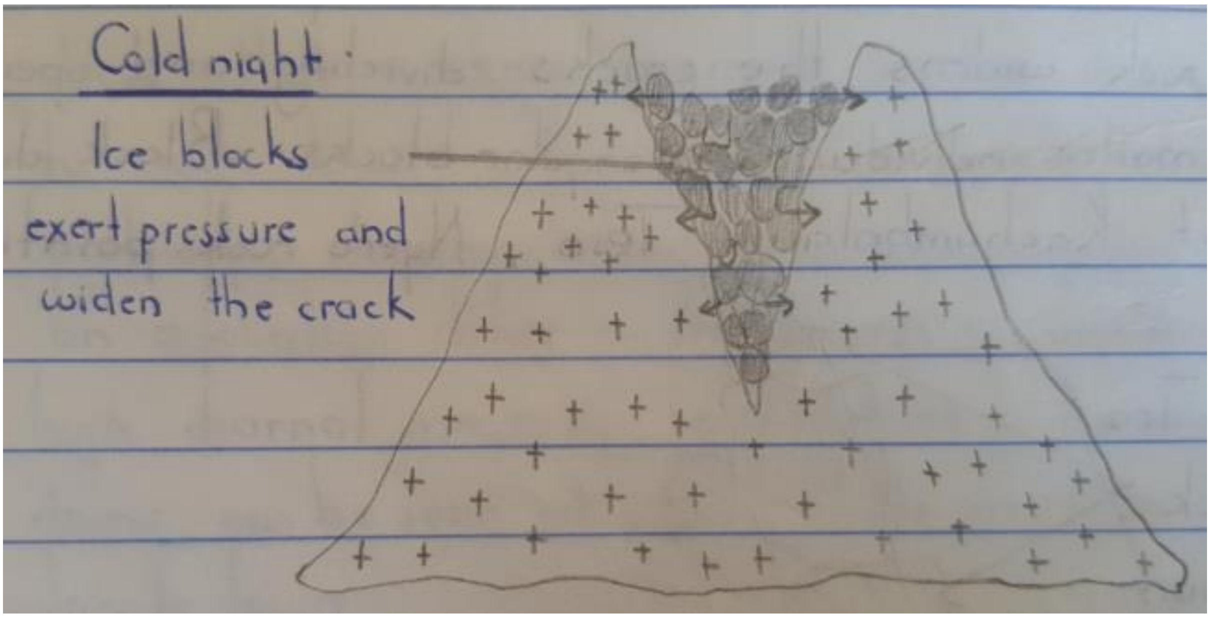
Granular disintegration

This involves the breakdown of **heterogeneous rocks** into smaller particles (grains or granules) due to alternating heating up of the rock during the day causing expansion and cooling at night causing contraction. The different mineral components in the rocks expand and contract at different rates and directions, creating stress and strain within the rock and finally breaking it down into smaller particles/grains. It leads to formation of screes, boulders and rock blocks at the base of the rock. It is common in arid and semi- arid areas experiencing high diurnal temperature ranges. Examples can be seen in Turkanaland in Kenya, Sumukaland in Tanzania and Karamoja region in Uganda.

Frost shattering

This is the breaking up of cracked/jointed rocks due to alternate freezing of water in the rock cracks or joints and thawing. Since ice occupies more volume than water, it exerts great pressure against the walls of the rock cracks. The cracks widen and finally the rock is broken down into rectangular blocks. Examples can be seen on the tops of glaciated mountains of Kilimanjaro, Kenya and Rwenzori.





Salt crystallisation

This involves the breakdown of rocks due to crystallisation of saline solutions in rock joints/cracks. Saline solutions enter the rock through cracks and pores and then evaporate due to very high temperatures to form crystals. As the crystals enlarge, they exert great pressure on the rocks leading to their break down.

The process is common in arid and semi- arid areas experiencing capillary action. For example in Njorowa Gorge near Lake Naivasha, the L. Magadi area in Kenya , around Katwe crater lake at Kasese in Uganda.

Pressure release

This is where rocks exposed by denudational processes or man's activities expand , crack , break up and finally peel off as the weight caused by pressure is released when overlying rocks are removed.

The process is common in well jointed intrusive igneous and metamorphic rocks formed under great pressure. Examples can be seen between Mwanza and Iringa, Serengeti and Rukwa regions of Tanzania , Mubende, Nakasongola and at Matugga along Kampala – Luwero road in Uganda.

Aridity shrinkage

This is the process by which non-porous rocks such as the clay-rich sedimentary rocks absorb water during the rainy season and expand, while during the dry season they lose water and contract as well as cracking leading to their disintegration. Examples are seen in Athi – Kapiti plains of Kenya and along the Doho plains on R. Manafwa in Eastern Uganda.

Action of plants

The plant roots penetrate cracks/joints in rocks and as they grow and enlarge, widen the rock cracks and finally break them down.

Action of animals

Animals such as termites worms, moles and rabbits through their burrowing nature also break down the surface rocks. Hoofed animals such as cattle trampling on surface rocks also cause disintegration.

Human activities

Human activities such as mining, stone quarrying, building and construction, digging/ploughing, weaken the underlying rocks and finally breaking them down.

Factors for the occurrence of physical weathering

Climate

In semi - arid and arid areas experiencing wide temperature fluctuations, hot temperatures during the day heat up exposed rocks and expand during the night there is cooling and contraction of the rock . Repeated alternate expansion and contraction of rocks causes stress in the rocks which eventually breaks up the rocks through the processes of exfoliation , block disintegration and granular disintegration. For example in areas of Karamoja in Uganda, Turkanaland in Kenya, Sukumaland in Tanzania.

The short rains received in arid and semi- arid areas cause non porous rocks such as clay absorb water and swell/expand while during the prolonged dry season, rocks loose water and contract resulting into rock breakdown by **aridity shrinkage**. For example in Northern and North Eastern Uganda.

The thin cloud cover in arid and semi - arid areas lead to hot temperatures during the day that heat up the rocks and expand and at night, rapid loss of heat leads to cooling of the rocks and contract resulting into their break down through processes of block disintegration, exfoliation and granular disintegration .

On high mountains of East Africa like Kilimanjaro, Kenya and Rwenzori, temperature fluctuations result into **frost shattering**, a process by which water collects into rock cracks during the warm day and at night , water freezes into ice and the larger volume of ice exerts pressure against the rock crack which eventually breaks it down.

2. Nature of the parent rock

Jointed or cracked rocks when heated expand and contract on cooling along the joints and break into rectangular blocks by a block **disintegration**. Jointed rocks are also easily affected by **frost shattering** where water enters the joint during warm conditions and freezes into ice under extremely cold temperatures. The ice occupies more volume and thus exerts pressure onto the rock crack walls and eventually breaking it down for example on Mt. Kilimanjaro, Rwenzori and Kenya. Plant roots easily penetrate through cracked rocks and as they grow and enlarge, they exert pressure onto the rock and physically break it down .

Heterogeneous rocks (with different minerals) expand when heated and contract when cooled at different rates resulting into their breakdown by **granular disintegration**.

Dark coloured rocks such as basalt , granite absorb heat faster and expand rapidly leading to physical weathering through the processes of exfoliation , block disintegration and granular disintegration.

Soft rocks break up easily when subjected to alternating heating and cooling through processes of granular disintegration, exfoliation and block disintegration.

Non – porous rocks such as clay absorb and retain water during the wet season and expand, during the dry season it loses the water and contracts resulting into rock break down by **aridity shrinkage**.

Old rocks which have been exposed to prolonged weathering, easily break down by physical weathering processes of block disintegration, exfoliation, granular disintegration.

3. Relief

On steep slopes, the weathered rock materials are easily moved down slope by denudation processes of erosion and mass wasting hence exposing the underlying rocks to further physical weathering .

Steep slopes tend to be affected by mass wasting and soil erosion which again expose the rock to physical weathering process of pressure release/unloading .

4. Biotic factors

Human activities such as mining, quarrying, building and construction, digging break the rock into small particles and also expose the rocks to physical weathering .

Plant roots as they grow and enlarge , to open and widen the rock joints or cracks leading to rock disintegration . for example baobab and cactus plants in semi-arid areas of Northern Uganda, Mvule, iron wood, musizi trees around Lake Victoria basin.

Burrowing animals such as moles rabbits, termites, worms break up rocks into small particles as they burrow in the rocks.

Hoofed animals such as cattle trample on the surface rocks leading to their break down into smaller particles. For example in Karamoja region, Western Uganda.

Again animals like cattle, wild animals through over grazing, termites, ants , locusts through vegetation destruction expose the rocks to alternating heating and cooling which weakens the rocks and physically break down through processes of exfoliation, granular disintegration etc, for example in Northern and North Eastern parts of Uganda.

5. Time

The longer the time, the more the physical weathering processes of frost shattering , exfoliation, block disintegration , granular disintegration or pressure release will take place. The shorter the time, the less the weathering process.

CHEMICAL WEATHERING

This is the decomposition or decay of rocks at or near the earth's surface in situ resulting into a change in the **chemical composition** of the original rock. This process involves chemical reactions taking place between the rock **minerals**, **water** and the **atmospheric gases** such as oxygen and carbondioxide.

Chemical weathering occurs due to **heavy rainfall** and **high humidity** that provide water to act as a medium of chemical reactions and hot **temperatures** to accelerate the rate of chemical reactions.

Chemical weathering reached **greater depths** and depends **less on the removal of the weathered layer**.

Chemical weathering is common in areas of Lake Victoria basin, Nyakasura in western Uganda and along the East African coast.

NB: Chemical weathering is most active in equatorial regions experiencing high temperatures, high humidity and heavy rainfall.

Processes of chemical weathering

Chemical weathering occurs through various processes that include;

- Carbonation
- Hydration
- Hydrolysis
- Oxidation
- Reduction
- Solution
- Spheroidal weathering
- Chelation
- Organic – chemical weathering

Carbonation

This involves rain water dissolving atmospheric carbondioxide to form a weak carbonic acid which dissolves and decomposes calcium carbonate in the lime stone rocks to form calcium hydrogen carbonate/calcium bicarbonate which is easily removed in solution by underground water. Examples can be seen at Nyakasura in Western Uganda and along the East African coast.

$CaCO_3$ + Co_2 + H_2 O $\rightleftharpoons$ Ca ($HCo_3)_2$

Calcium carbondioxide, water calcium hydrogen carbonate

Carbonate (calcium bi-carbonate)

Hydration

This is the process by which rock minerals absorb water and expand causing stress in the rock which eventually decomposes and breaks down. For example haematite when hydrated forms limonite, calcium sulphate rocks absorb water to form gypsum.

$CaSO_4$ + $2H_2O$ ⇌ $CaSO_4 . 2H_2O$

Anhydrite water gypsum

Gypsum can be found in Garissa, Wajir areas of Kenya , Queen Elizabeth national park in Uganda.

Hydrolysis

This involves the hydrogen and hydroxyl ions from water reacting with the rock mineral ions to form different chemical compounds . For example feldspar is hydrolysed to (residual clay) kaolinite and silicic acid.

$2KAlSi_3O_8$ + $2H_2O$ + CO_2 → $Al_2Si_2O_5(OH)_4$ + K_2CO_3 + $4SiO_2$

Feldspar water carbondioxide clay potassium Carbonate silica

Hydrolysis occurs in areas of Taita hills Machakos in Kenya , Kampala suburbs, Kajjansi along Entebbe road in Uganda.

Oxidation

This involves the reaction of rock mineral components suh as iron with oxygen in presence of water to form new chemical compounds (oxides and hydroxides). For example when iron mineral in clay is exposed to atmospheric air, it forms rust, an iron oxide which is reddish in colour. Rust weakens the rock and eventually it breaks down.

$4FeO$ + O_2 → $2Fe_2O_3$

Ferrous oxide oxygen hamatite

Oxidation occurs in areas of Kajjansi, on the flat – topped hills of Buganda where in forms laterites, Lira in Uganda.

Reduction

This involves the removal of oxygen rock minerals or addition of hydrogen to the rock and occurs in water logged areas such as swamps. For instance when reddish coloured iron oxide undergoes reduction it changes to grey colour of the swampy clay soils for example at Kajjansi along Kampala – Entebbe road.

Solution

This is where water dissolves soluble rock minerals such as rock salt (sodium chrolide), gypsum (calcium sulphate), breaking the rock down and carries the minerals in solution form leaving behind cracks, joints or hollows in the rocks. It is common in Daua valley in the North eastern province, Lake Magadi in the rift valley floor in Kenya and Lake Katwe in Kasese in Western Uganda.

Spheroidal weathering

This is the swelling of the outer rock layers due to water penetration causing it to loosen and eventually peels off from the under lying rock mass. It is common in the limonite rocks.

Chelation

This involves exchange of minerals or mineral nutrients between rocks and plant roots. Plants extract mineral nutrients from rocks and in turn release mineral substances into the rock system which weaken and decompose the rocks and eventually chemically break down.

Organic chemical weathering

This involves humic acid derived from decaying remains of plants and animals that reacts with the rock minerals which decomposes the rock and eventually breaking it down. It is common in densely vegetated areas of central Uganda such as Mabira forest.

FACTORS FAVOURING CHEMICAL WEATHERING

Chemical weathering in a given area is favoured by a number of conditions which include;

Nature of the rock

(i) Mineral composition

Rocks are composed of different minerals which react differently to chemical weathering. Rocks such as igneous and metamorphic rocks are highly affected by chemical weathering when exposed by erosion to very low temperatures and pressure onto the earth's surface as opposed to very high temperatures and pressure under which they were formed.

Soluble rocks like gypsum and rock salt dissolve fast in water and removed in solution form leading to rock decomposition through solution weathering . Limestone rocks highly react with carbonic acid (formed when rain water dissolves carbon dioxide in the atmosphere) decomposing to calcium bicarbonate through the process of carbonation . Rocks which contain iron minerals easily react with oxygen decomposing to new compounds/oxides through oxidation process. Rocks composed of feldspar when mixed with water decompose to produce new compounds such as potassium hydroxide and alumina silicic acid through the process of hydrolysis. Rocks containing feldspar and mica absorb water and expand leading to a change in their structure by the process of hydration.

(ii) Permeability

Permeable rocks such as lime stone, rock salt, gypsum, clay allow water to penetrate and chemically weather the rock through processes like carbonation, hydrolysis, and hydration.

(iii) Rock jointedness

Joints or cracks in the rock increase the surface area for chemical reactions and allow water and air to penetrate to chemically weather the rock through processes of oxidation, hydration, hydrolysis and carbonation.

(iv) Rock texture

Rough textured rocks with depression which trap water aid chemical weathering processes.

Climate

Precipitation/rainfall provide the water that aid chemical processes to take place. In East Africa, areas of equatorial climate like Lake Victoria basin receive heavy rainfall almost throughout the year with high humidity levels and savanna areas like western Uganda, parts of Northern Uganda, Miombo woodlands in Tanzania receive moderate rainfall and humidity and such conditions are conducive for chemical weathering processes like carbonation, oxidation, hydration, hydrolysis.

Hot temperatures of over 20^{0}c in the humid areas such as Lake Victoria basin, Western Uganda, Southern Tanzania accelerate the rate of chemical reactions thus promoting chemical weathering.

Cold temperatures experienced on high maintains of East Africa like Rwenzori, Kilimanjaro, Kenya also favour carbonation to take place.

Relief

On gentle slopes and lowlands, water accumulates and percolates into the rocks promoting chemical weathering processes such as hydrolysis, hydration, oxidation.

On steep slopes, rapid erosion and mass wasting expose the underlying rocks to chemical weathering.

Drainage

In areas of impeded drainage like flood plains, valleys chemical weathering is prevalent in form of hydrolysis, hydration, reduction, oxidation and solution processes which decompose the rocks.

Poor drainage on flat lands leads to leaching, where rock minerals are dissolved and taken in solution to deeper layers of the soil profile and in the process, the rock is decomposed.

Living organisms

(i) Human influence

Man through various activities may influence chemical weathering for example;

Emission of industrial gases increases acidity in the rainwater which accelerates the rate of chemical weathering processes such as carbonation.

Dumping of industrial, domestic or agricultural effluents on land or in water which directly react with the rock minerals or increase the acidity in the environment hence promoting chemical weathering by carbonation.

Mining, quarrying, digging/ploughing, building and construction, increase the surface area as well as the accessibility of water and air into the rock for chemical reactions to take place , and exposing the underlying rocks to chemical weathering processes.

Irrigation of crop fields avail water to the rocks and this increases the rate of chemical weathering processes like hydrolysis, hydration, and carbonation.

(ii) Animals and micro-organisms

Animals such as termites, moles, rabbits loosen and mix up rocks and increase the accessibility of air and water to the rock accelerating chemical weathering through hydration, oxidation, carbonation, hydrolysis, solution.

Micro-organism and animals may secrete acids that chemically decompose the rocks for example the uric acids , nitric acid by nitrogen fixing bacteria, to form new compounds.

(iii) **Vegetation**

Decaying vegetation matter combines with water to form humic acid which support chemical decay in the rocks.

Plant roots release mineral substances into the rocks while extracting other mineral substances from the rock and this decomposes the rocks by the process of chelation.

Plants such as lichen, algae keep rock surfaces wet, thus facilitating chemical weathering in form of oxidation, hydrolysis, carbonation.

Time

The longer the period of exposure of rocks to chemical weathering, the more and deeper the disintegration and decomposition of the rocks to form thick layers of weathered materials.

BIOLOGICAL WEATHERING

This involves the breakdown and decomposition of rocks by living organisms , for example, plants, bacteria, animals and man.

NB: In most cases, biological weathering is a combination of both physical and chemical weathering. The main processes involved are ;

Action of plants

Plants through their root system release substances into rocks and then extract other mineral nutrients from the rocks thereby disintegrating and decomposing the rocks by **chelation process.**

Plant roots penetrate into cracks and joints of rocks and as they grow and enlarge in size, exert pressure on the cracks which widens them and eventually breaking the rock down.

Decaying vegetation matter combines with rain water to form humic acid which supports chemical decay in the rocks.

Simple plants such as lichens , mosses and algae keep the rock surfaces moist which encourages chemical weathering leading to disintegration of the rock.

Action of animals

Burrowing animals such as moles, rabbits, termites, worms as they burrow, break up rocks into smaller particles. Hoofed animals like cattle trampling on rocks also cause surface rocks disintegration.

Bacteria

Some bacteria found in the soil secrete acids which accelerate chemical weathering for example nitric acid by the nitrogen fixing bacteria, uric acid.

Human activities

Man through his activities of quarrying, mining, digging/ploughing, building and construction breaks down rocks into smaller particles.

FACTORS INFLUENCING THE RATE AND CHARACTER OF WEATHERING

In East Africa , the rate and character of weathering depends on a number of factors and these include;

1. **Nature of the parent rock**

Parent rock refers to the crustal part of the earth that is affected by weathering, breaking it down to form smaller particles. Rock nature/structure refers to the physical and chemical characteristics of the rock such as rock joints/cracks, colour, mineral composition, permeability , solubility, rock hardness or softness, texture, angle of slope of the rock.

Jointed/cracked rocks expand when heated and contract when cooled along the joints causing stress in the rocks and eventually break down into rectangular blocks by block disintegration process for example Mudanda rock in Tsavo national park in Kenya, Kachumbala rock in Teso, Uganda.

Jointed/cracked rocks are highly affected by frost shattering, where water enters the joints during warm conditions and freezes into ice under extremely cold temperatures and because of it greater volume, ice exerts pressure onto the rock crack walls and eventually break it down. For example on Mt. Kilimanjaro , Mt Kenya and Mt. Rwenzori.

Plant roots easily penetrate rocks through cracks and as they grow and enlarge, exert pressure onto the rock and physically/biologically break it down.

Man through quarrying activity easily disintegrate the rocks along the joints/cracks.

Joints/cracks in the rock increase the surface area for chemical reactions to take place. Also, the joints/cracks allow water and air to penetrate the rock to deeper layers promoting chemical weathering processes such as oxidation , hydrolysis , carbonation, hydration.

Dark coloured rocks like basalt absorb heat faster and expand rapidly leading to physical weathering through the processes of exfoliation, block disintegration and granular disintegration while light coloured rocks such as quartz reflect heat and thus hardly weathered.

Soft rocks like clay break up easily when subjected to weathering processes such as aridity shrinkage while hard rocks such as quartz are hardly affected by weathering processes.

Permeable rocks such as limestone, clay, rock salt, gypsum allow water to penetrate fast and chemically weather the rock by carbonation, solution, hydrolysis.

The mineral composition of the rocks also affects the rate and nature of weathering.

Different mineral elements in heterogenous rocks expand when heated and contract when cooled at different rates creating stress and strain in the rock resulting in sudden break down by granular disintegration process.

Igneous and metamorphic rocks are easily decomposed and broken down by chemical weathering processes because of being formed under extremes of temperatures and pressure conditions different from those being experienced on the surface of the earth. Sedimentary rocks on the other hand are more stable thus hardly affected by weathering processes.

Rocks like gypsum and rock salt dissolve very easily in water hence disintegrating fast through solution weathering process. Limestone rocks highly react with carbonic acid decomposing to calcium – bicarbonate by carbonation process for example in Nyakasura western Uganda. Rocks containing iron or iron oxides easily attacked by oxidation and they decompose very fast to form new compounds.

Rough textured rocks with depressions which trap water may accelerate chemical weathering while smooth rocks promote water run off hence limiting chemical weathering.

Climate

Through its elements of rainfall and temperature, climate is regarded as the most important factor in rock weathering. Rain water provides a medium through which chemical reactions take place while high temperatures accelerate the rate of chemical reactions and speeding up the occurrence of physical weathering process especially in the arid areas.

High rainfall totals and high temperatures experienced in equatorial regions promote the dominance of chemical weathering in form of carbonation, oxidation, hydrolysis, hydration, solution for example in the Lake Victoria basin. Equatorial climate limit physical weathering due to the thick layers of chemically weathered materials which protect the underlying rocks.

Savanna climates influence both chemical and physical weathering processes in the wet and dry seasons respectively. During the wet season, moderate rainfall and high temperatures accelerate chemical weathering processes like carbonation, oxidation, solution . In the dry season high temperatures and low or no rainfall, mechanical weathering in form of exfoliation, granular ,disintegration, crystallisation, block disintegration occurs.

Arid and semi- arid conditions of thin cloud cover, low rainfall totals, high temperatures and high diurnal temperature ranges increase the effectiveness of mechanical weathering . Hot day temperatures heat up the rocks and expand and at night , rapid loss of heat leads to cooling down of the rocks and contract creating stress and eventually break down by the processes of block disintegration, exfoliation, granular disintegration. Also , high temperatures lead to high evaporation rates resulting into crystallisation which disintegrates the rocks . Examples are seen in Karamoja, Turkanaland and Masai land.

Very low temperatures below 0^0c in the montane climate areas facilitate frost shattering , a process where water in the rock crack freezes into ice and due to its greater volume, it exerts pressure onto the rock and breaks it down. Under montane climate, chemical weathering is limited by low temperatures and absence of liquid water with the exception of carbonation due to carbondioxide being soluble at low temperatures. Examples are seen on Mt. Rwenzori, Mt. Kenya and Mt. Kilimanjaro.

Relief/topography

The rate at which weathering takes place is related to the speed at which the weathered material is removed.

On steep slopes , the weathered rock materials are rapidly moved down slope by erosion and mass wasting exposing the underlying rocks to further weathering, hence the rate of weathering tends to be fast. Also , removal of overlying weathered materials results into physical weathering in form of pressure release/unloading. Along steep slopes, rapid water run off limits chemical weathering.

On gentle slopes and lowlands, water accumulates and percolates fast into the rocks promoting chemical weathering processes like hydration, hydrolysis, oxidation. However, weathered rock material on gentle slopes covers the underlying parent rock, hence protecting it from further weathering.

Living organisms

Plants such as trees facilitate physical weathering by the action of their roots penetrating and forcing apart cracks/joints in rocks and eventually disintegrate them. The exchange of mineral substances between plant roots and the rocks, decomposes the rocks fast by the process of chelation. Decaying remains of plants/animals combine with rain water to form humic acid which decomposes and disintegrates the rocks by chemical weathering.

Thick vegetation cover such as forests, tall grass protect the rock surfaces against physical weathering by thermal expansion while scanty vegetation cover like in the arid and semi – arid areas promote physical weathering in form of exfoliation, block disintegration, granular disintegration crystallisation due to rock exposure to insolation.

Simple plants like mosses, lichens and algae keep rock surfaces wet, thus facilitating chemical weathering in form of oxidation, reduction, carbonation.

Hoofed animals such as cattle loosen the surface rocks as they trample on them and physically break the rocks.

Burrowing animals, micro – organisms and insects encourage disintegration of rocks through loosening and mixing of rocks as well as increasing the accessibility of water and air into the rock to aid chemical weathering.

Human activities like mining, digging, quarrying, building and construction disintegrate rocks into smaller particles and exposes the underlying rocks to further physical and chemical weathering processes.

Man through emission of industrial gases, dumping of industrial/domestic/agricultural wastes increases the acidity in the environment which accelerates the rate of chemical weathering in form of carbonation, reduction.

During irrigation, man avails water to the rocks and this increases the rate of chemical weathering processes such as oxidation, hydrolysis, carbonation, solution for example on Doho rice scheme in Eastern Uganda.

Time

The longer the period of exposure of rocks to weathering, the more and deeper the disintegration and decomposition to form thick layers of weathered materials.

CLIMATIC REGIONS AND WEATHERING PROCESSES IN EAST AFRICA

In East Africa, climate is categorised into;

- Equatorial climate
- Savanna climate/sudan type of climate/tropical climate
- Arid and semi – arid climate
- Montane climate

The rate and nature of weathering differs from one climatic region to another.

Equatorial/humid climate

This is experienced by areas around Lake Victoria especially in the Northern and North Western parts of the lake, the islands of Lake Victorial (i.e Kalangala) , along the East African coast at Pemba and Zanzibar.

It is characterised by ;

- Heavy rainfall of over 1500 mm per year.
- Rainfall is of a double maxima and it is received throughout the year with no distinct dry season.
- High humidity levels of about 80 %.
- Uniform hot temperatures of about 27^0c .
- Small diurnal range of temperature of about 2 – 3 ^{0}c.
- Dense cloud cover.

Under these conditions, **chemical weathering is very active** and it is the **most dominant** in the region. The chemical weathering processes taking place include; solution, carbonation, hydration, hydrolysis, oxidation, reduction and spheroidal weathering.

The presence of organic acids from decaying vegetation combined with rain water and high temperatures promotes rapid organic weathering.

Dense rain forests with thick layers of foliage limit physical weathering in the region. However, some physical weathering processes do take place and these include;

- The roots of luxuriant trees can force apart joints and cracks in rocks as they grow and enlarge.
- Man through his daily activities such as digging, quarrying, mining, construction and building physically breaks down the surface rocks.
- Presence of burrowing animals like moles, worms also break down surface rocks through their burrowing activities.
- Hoofed animals grazing in these regions such as cattle trample on the surface rocks and break them down.

NB: Physical weathering is less where humidity levels and rainfall are high.

Savanna climate

This is the most extensive climatic region in East Africa. It is mainly found in parts of Northern, Eastern and Western Uganda, Nyika plateau of Kenya/ Central Kenya , Central, Southern and South Western parts of Tanzania, Savanna climate is also referred to as " Tanganyika climate"/ "Sudan climate"/"Tropical climate".

In this climate, alternate wet and dry seasons are experienced. As such , the rate and type of weathering differs with the seasons.

During the wet season, rainfall and temperatures are high hence chemical weathering is active and dominant and such processes include; solution, carbonation, hydrolysis, hydration, reduction, oxidation etc.

NB: The rate of chemical weathering taking place in the savanna is less compared to that of the equatorial climate.

During the dry season, rainfall and humidity are low, temperatures are high, diurnal range of temperature is high, cloud cover is thin, evaporation rates are high and the vegetation cover is very limited giving less protection to the ground. Under such conditions, physical weathering is active and dominant and processes taking place include; exfoliation, granular disintegration, block disintegration, aridity shrinkage and crystallization.

Semi – arid and **arid climate**

This type of climate is experienced in areas of North Eastern Uganda (Karamoja region), Ankole – Masaka dry corridor , Lake Albert flats, Kasese in Uganda, North Western (Turkana land) and North Eastern parts of Kenya , Masailand and Central parts of Tanzania.

It is characterised by;

- Very low rainfall totals of less than 600 mm per year. Rainfall is unreliable.
- Very low humidity levels of about 30 %.
- Thin cloud cover/clear skies.
- Very hot temperatures during the day and cool/cold temperatures during the night.
- Large diurnal range of temperature of about 10^0c
- Prolonged dry season
- Very high evaporation rates
- Absence/limited vegetation cover.

Mechanical/physical weathering processes are therefore dominant and these include, granular disintegration, exfoliation, crystallisation, aridity shrinkage, block disintegration.

The bare grounds accelerate soil erosion which removes the overlying materials from the surface leading to **pressure release** which disintegrates the surface rocks.

Other physical weathering processes in semi – arid areas are due to the action of living organisms for example ; drought resistant plants such as cactus, baobab grow and through the power of their root system, penetrate and breakdown the rocks.

Man through mining, quarrying, construction breaks down the surface rocks.

Animals grazed by pastoralists trample on the surface rocks and break them down.

However, though chemical weathering is limited, it occurs on a small scale due to occasional torrential rains, night dew, moisture drawn to the rock surfaces by capillary action which are sources of water that aids oxidation, hydration, carbonation, hydrolysis, reduction etc to take place.

Montane climate/Mountain climate

In East Africa, montane climate is mostly experienced on the slopes of Mt. Kenya , Mt. Kilimanjaro and Mt. Rwenzori. It is characterised by very low temperatures below 0^0 c that changes water into ice.

Thus, physical weathering in form of frost shattering dominates. Chemical weathering is limited due to low temperatures and relative absence of liquid water. However, carbonation occurs due to carbondioxide being soluble at low temperatures.

THE INTERDEPENDENCE OF CHEMICAL AND PHYSICAL WEATHERING

Physical weathering and chemical weathering operate together rather than in isolation and aid each other.

Physical weathering through exfoliation, block disintegration breaks down rocks into smaller fragments increasing the surface area of the rock for chemical weathering.

Temperature fluctuations cause alternate expansion and contraction of the rock leading to exfoliation, block disintegration, granular disintegration which open up cracks/joints in the rocks through which water and air access the rock to deeper layers, promoting chemical weathering processes.

Pressure release, a form of physical weathering, creates cracks in rocks through which water penetrates the rock to effect chemical reactions such as oxidation, hydrolysis.

Burrowing animals such as rodents physically break down the surface rocks and also create holes in the crust which make it easier for water and air to access the rocks and effect chemical weathering processes like oxidation reduction.

The roots of trees physically force apart joints/cracks in rocks, making it easier for water and air to access the rock and cause chemical weathering.

Physical weathering in form of frost – shattering opens up cracks in the rocks, easening the access of carbondioxide, promoting carbonation.

In all the above ways chemical weathering processes depend on physical disintegration of rocks that provides a larger surface area for chemical reactions to take place as well as creating passages for water and air that aid chemical weathering.

Physical weathering also depends on chemical weathering. Chemical decomposition weakens the rocks opening the way for physical disintegration.

Oxidation , a chemical weathering process turns rocks dark in colour and such rocks absorb a lot of heat causing thermal expansion that breaks down the rocks by processes of exfoliation, block disintegration , granular disintegration.

A chemically weathered rock has weak internal bonds and thus easily penetrated by plant roots that physically disintegrate the rocks. Also, chemically weakened rocks are easily disintegrated by human activities such as quarrying, mining, digging, building and construction. Rocks weakened by carbonation easily break down when subjected to frost shattering.

Hydration a chemical weathering process involving absorption of water by the rock leading to expansion, weakens the rock and thus easily broken down by aridity shrinkage when exposed to high temperatures.

Soluble rocks such as rock salt are dissolved in water and chemically weathered away in solution. When the solution is subjected to high evaporation rates, forms crystals that exert great pressure on the rocks and physically break it down by crystallization process.

In conclusion, physical and chemical weathering processes are inter-dependent and aid one another.

LAND FORMS RESULTING FROM WEATHERING

Weathering through its processes of chemical and physical weathering has contributed to land form evolution and these include;

A) **KARST LANDSCAPE**

This is a type of landscape found in **limestone** areas formed by the chemical weathering processes of **carbonation** and , or **solution**. Carbonation/solution in limestone areas occurs when rain water dissolves carbondioxide from the atmosphere to form a weak carbonic acid that dissolves calcium carbonate from the limestone rock joints to form calcium bicarbonate and carried by the water in solution form.

$$CaCO_3 + CO_2 + H_2O \rightleftharpoons Ca(HCO_3)_2$$

The flow or seeping of the calcium bicarbonate leads into the formation of surface and underground features.

Factors influencing the formation of Karst lands cape include;

- Presence of a soluble under lying rock, preferably limestone.
- Highly jointed and thinly bedded rock for easy penetration of carbonic aicd.
- Hot and humid climate i.e areas receiving moderate to high rainfall to facilitate the solution .
- Deep water table to allow water percolation and erosion to take place.

Features associated with carbonation in limestone areas include ;

1. **Grikes and Clints/Limestone pavement**
   Grikes are deep, narrow and irregular depressions while a **clint** is a flat – topped block of rock or ridge which lies between grikes. Both **grikes** and **clints** are formed by carbonation in limestone areas with rocks of different chemical composition. Limestone is dissolved along joints by a weak carbonic acid to form depressions called **grikes** while undissolves rocks form ridges known as **clints**. Examples include Kambe limestone area along the Kenyan coast, Nyakasura in Forportal, western Uganda.

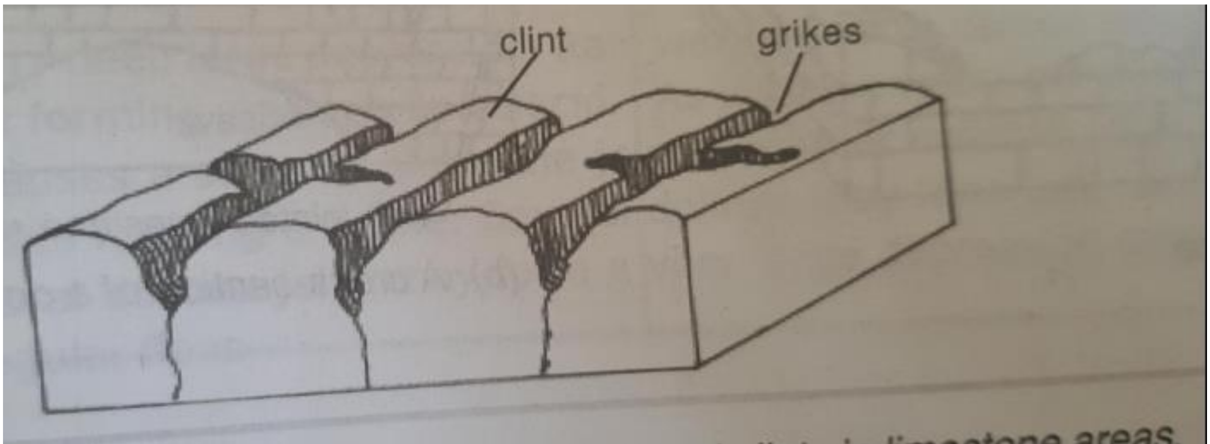


Fig. 10.1: Formation of grikes and clints in limestone areas.

2. **Underground cave**
   This is a large natural underground chamber/cavity in limestone rocks formed by carbonation/solution. Rainwater combines with carbondioxide to form a weak carbonic acid that percolates through limestone rocks along joints/fractures and dissolves out calcium carbonate, leaving behind an underground cavity called a **cave**. Examples are seen at Nyakasura in Western Uganda, Shimoni along the Kenyan coast.

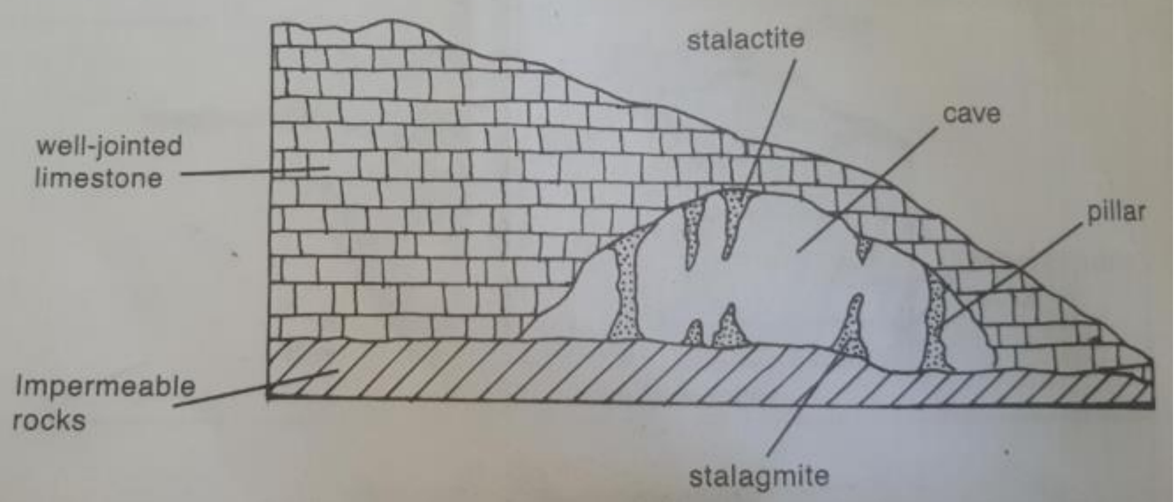


Fig. 10.14: Caves, pillars, stalagmites and stalactites.

3. Stalactites and stalagmites

A **stalactite** is a finger like rock projection or a rock column of calcium carbonate hanging from the **roof** of a limestone cave while a **stalagmite** is a finger like rock projection/a rock column of calcium carbonate at the **floor** of the limestone cave.

They are formed through carbonation. Rain water combines with carbondioxide to form carbonic acid which dissolves calcium carbonate to form calcium bicarbonate (calcium hydrogen carbonate) taken in solution. The calcium hydron carbonate solution percolates through limestone rock joints and drips from the roof of the cave and when water evaporates from it, calcium carbonate deposits form and grow vertically downwards from the roof to form stalactites.

When the calcium hydrogen carbonate drips to the floor of the cave and water evaporates from it, calcium carbonate deposits form and grow vertically upwards from the floor to form the stalagmites. Examples are seen at Nyakasura in Western Uganda, in the Shimoni caves of Kenya.

(As illustrated in the diagram above)

4. **Pillars**

   These are rock columns of calcium carbonate that extend from the roof to the floor of the underground cave. They are formed when stalactites and stalagmites continue to grow towards each other and eventually join. Pillars also form when a stalactite grows and touches the floor of a cave or where a stalagmite grows and touches the roof of a cave. Examples are seen at Nyakasura in Western Uganda, in the Shimoni caves along the Kenya coast.

   (As illustrated in the diagram above)

5. **Sink hole/swallow hole/ponor**

   This is a deep small funnel shaped natural depression with vertical sides in the earth's surface usually leading to an under ground cave. It is formed when carbonic acid/rain water percolates through limestone rock joints and dissolves out soluble rocks, enlarging the joints into vertical holes known as **sink holes.** A sink hole where a river disappears underground and is lost to surface drainage is referred to as a **swallow hole**. Examples can be seen at Nyakasura in western Uganda, at Sipi falls in Eastern Uganda.

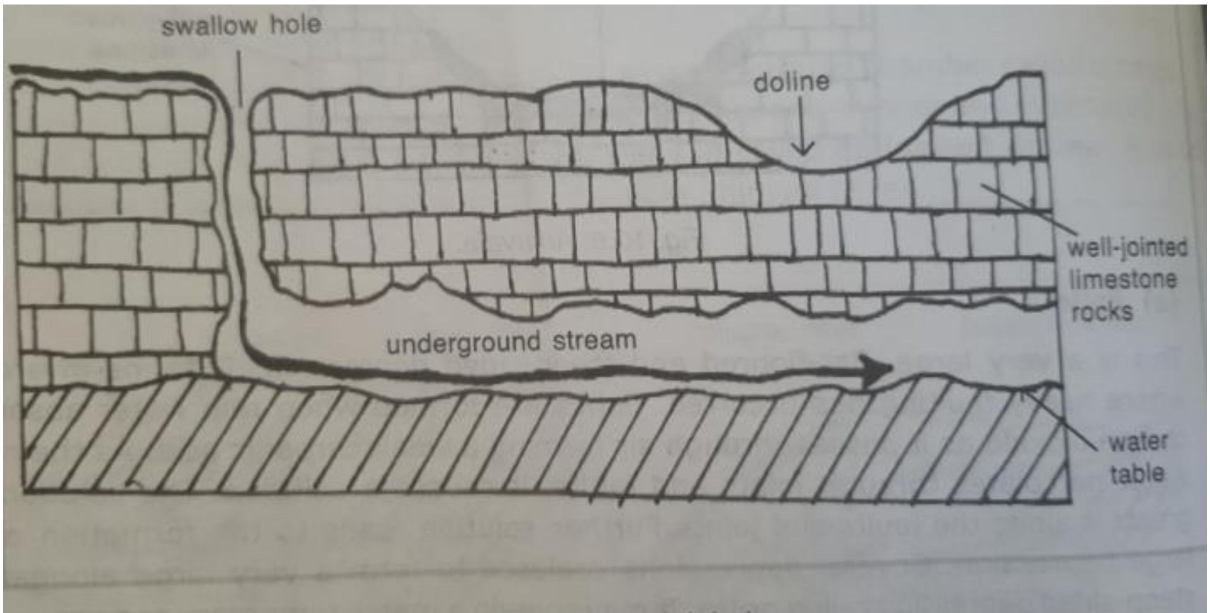


Fig. 10.8: A sink hole.

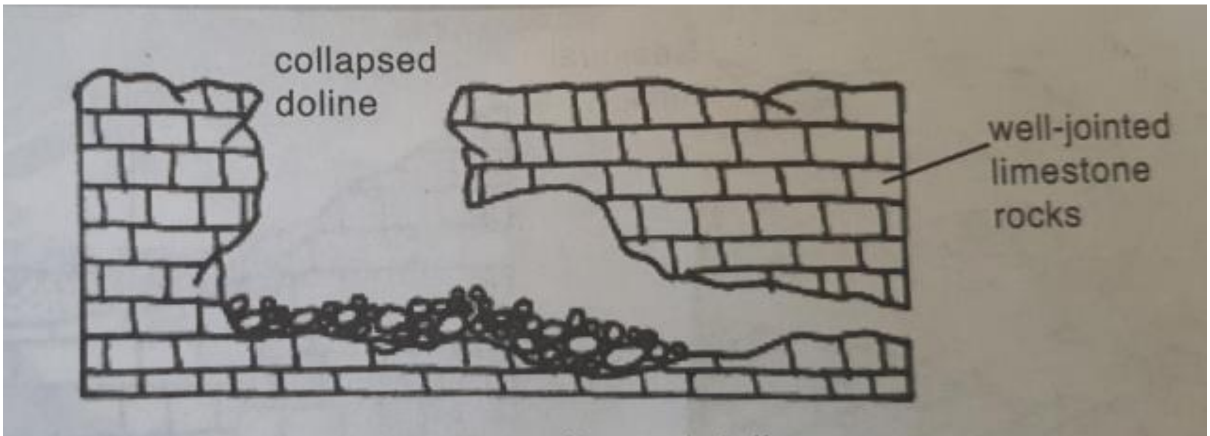
6. **Doline**

This is a shallow circular depression with gently sloping sides and larger than a sink hole. It is formed when carbonic acid/rain water percolating through limestone rocks at the intersection of major joints dissolves out soluble rocks to form a small basin , which is gradually enlarged by further solution weathering into a larger depression called a doline. Examples are at Nyakasura in Western Uganda, at Mt. Muhavura South western Uganda.

(as illustrated in the above diagram)

7. **Collapse doline**

This is a large deep depression with steep sides formed by the collapse of the roof of an underground cave as it becomes thinner due to continued solution weathering . An example is seen in Shimoni caves along the Kenyan coast.



(c) A cross section of a collapsed doline

Fig. 10.4: Stages in the formation of a collapsed doline.

8. **Uvala**

This is a deep large depression, intermediate in size between a doline and a polje, with an irregular floor. It is formed when a doline is enlarged or dolines are joined together due to further solution and carbonation weathering of limestone rocks.

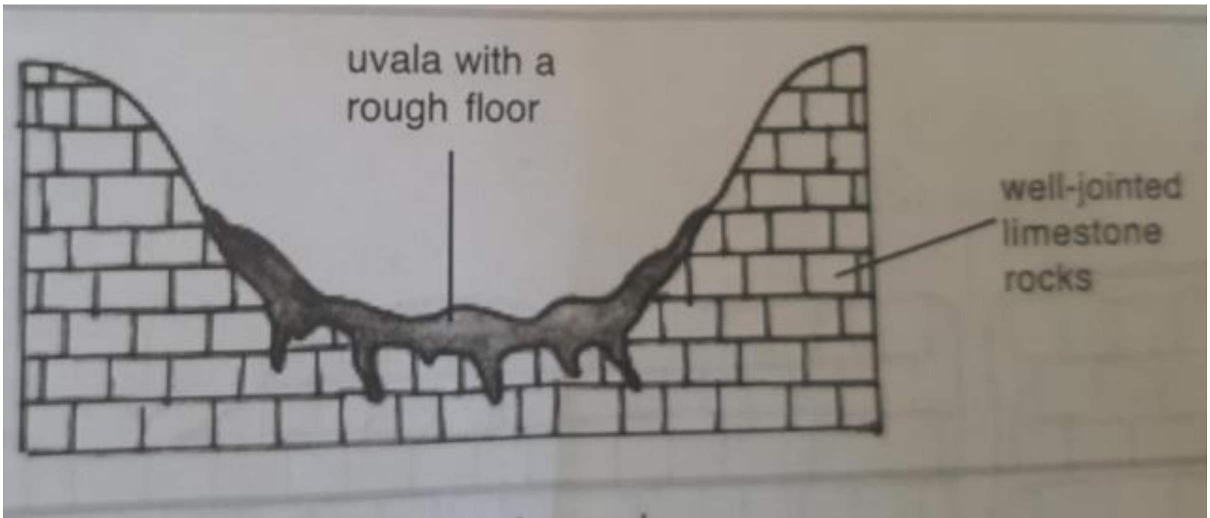
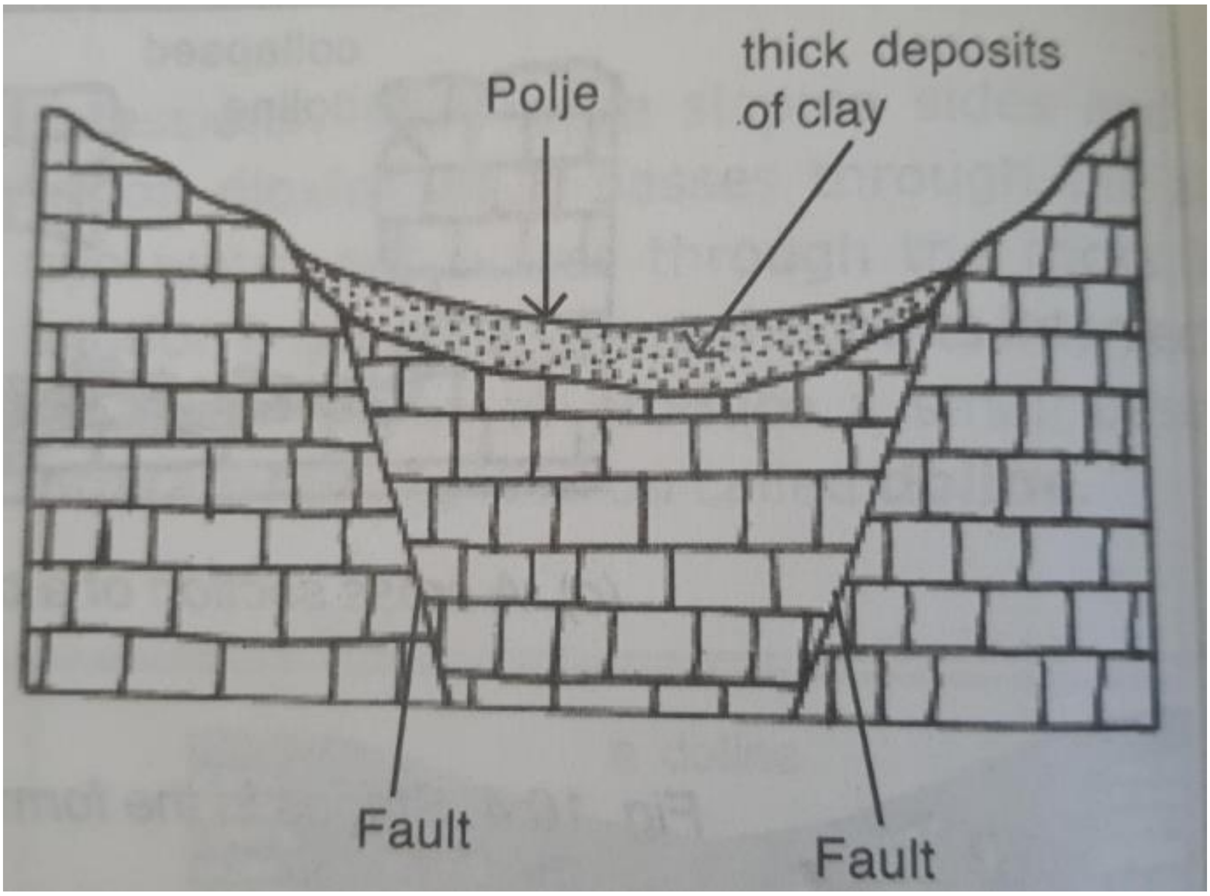


Fig. 10.6: An uvala.

9. **Polje**

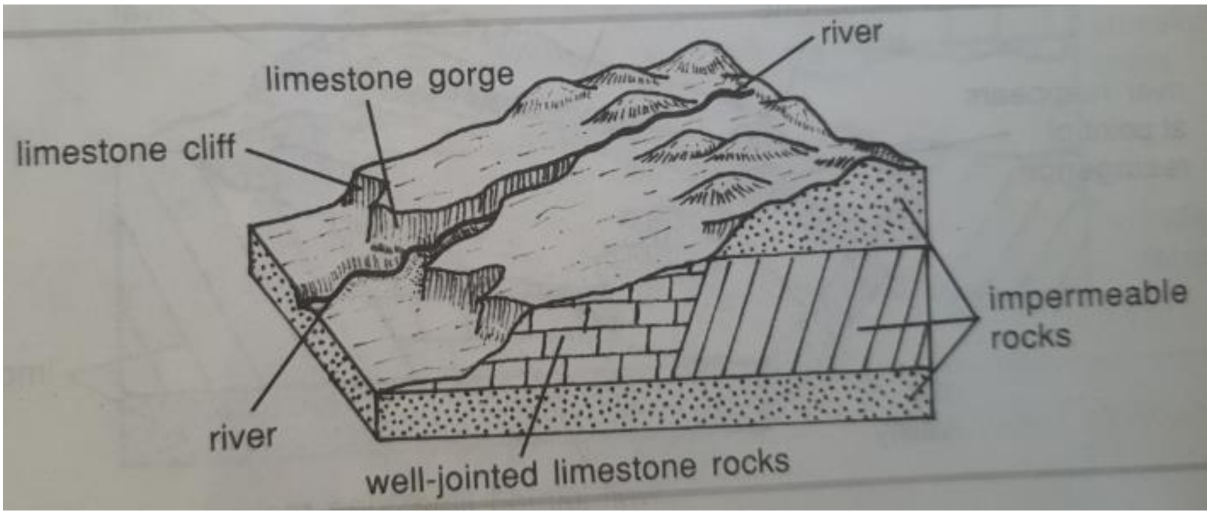
   This is a very wide , steep sided elongated depression with a generally flat foor and it is the largest of all the limestone basins. It is formed by merging of several sink holes or enlarging of an uvala through carbonation and solution weathering of lime stone rocks. Examples are seen around Mt. Muhavura in South western Uganda. A polje may get filled up with water to form solution lakes for example at Nyakasura in Western Uganda.



In some poljes , small residual hills known as **hums** are formed.

10.Limestone gorge

This is a deep step sided river valley found along rivers flowing through a limestone region from a non – limestone area. It is formed when a strong river vertically erodes or weathers the soft limestone rocks by solution and deepens its valley. Examples include Kyambura gorge in Queen Elizabeth National park in Western Uganda , Manambolo gorge in Madagascar.



11.Dry valley

This is a deep steep sided former river valley which no longer contains a stream. When a river originating from a non – limestone area reaches a limestone rock, it flows for a short time and quickly cuts a deep valley. After sometime the river (surface water) rapidly sinks into the limestone rock leaving the valley with no water forming a **dry valley**.

B **OTHER LANDFORMS RESULTING FROM CHEMICAL WEATHERING ;**

These include;

12.Duricrust

This is a hard crust formed at or just below the ground surface as a result of oxidation . The most common in East Africa is lateritic duricrust formed when the weathered layer becomes impregnanted with iron solutions due to leaching. On removal of the top layer, laterite hardens into duricrust due to wetting and drying which washes out clay and crystallises iron. For example on the flat topped hills of Buganda.

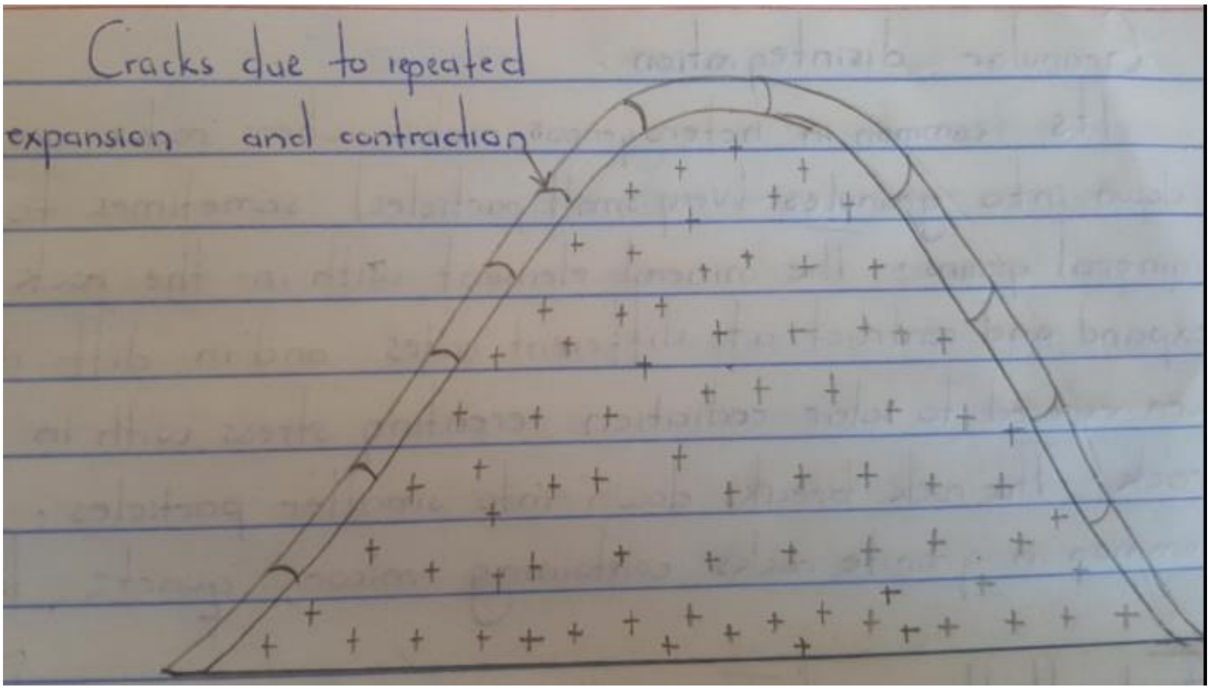
13.Granitic tors/inselbergs

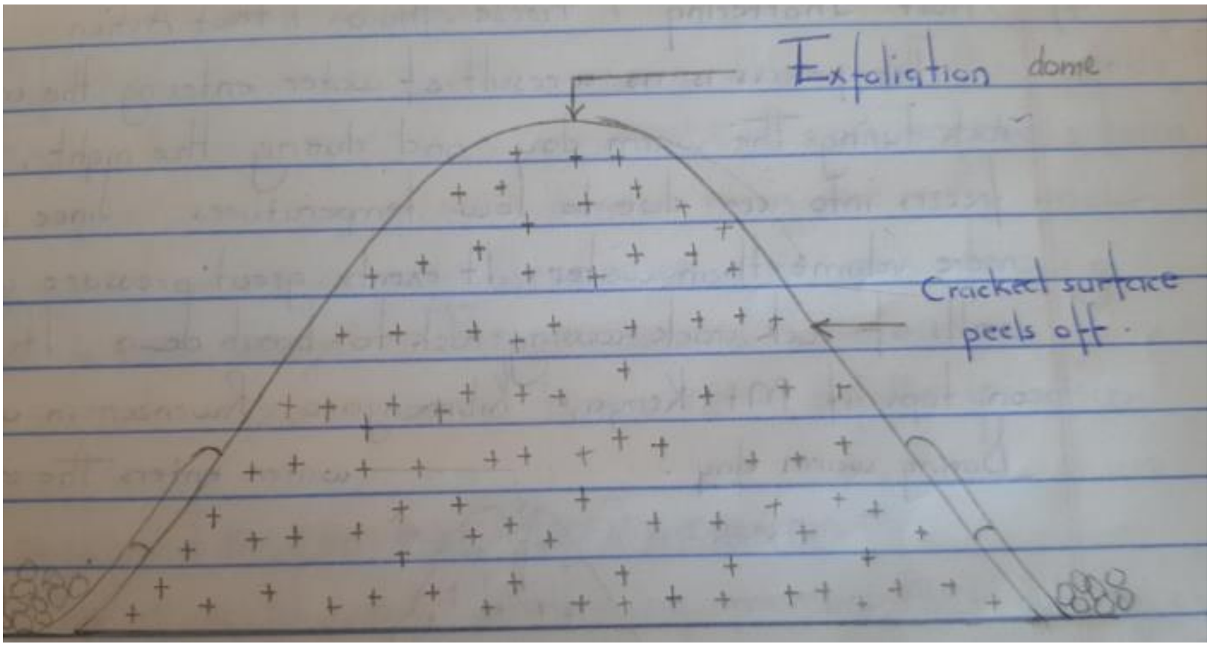
These are residual hills formed due to fast subsurface chemical weathering leading to removal of soft weathered rocks for example in Mubende.

C. LANDFORMS RESULTING FROM PHYSICAL WEATHERING

1. **Exofliation dome.**

This is a smooth and rounded toped hill found in arid and semi – arid areas experiencing extremes of temperature changes. It is formed due to alternating heating up of the rock during the day causing expansion and cooling at night causing contraction. Repeated differential expansion and contraction creates stress and strain that weaken the rock causing the surface rock layers to peel off , leaving behind a smooth rounded dome known as an **exfoliation dome**. For example the Bismarck rock at Mwanza in Tanzania, Nyika plateau in Kenya , Soroti hill near Soroti town, Kachumbala hills of Kumi in Uganda.





2. **Talus slope**
   This is an extensive slope of accumulated angular debris at the base of hill or dome formed when surface rock layers on the hill top are weakened by physical weathering through exfoliation and fall at the base, where they accumulate to higher levels to form a **talus slope**. For example at the base of the Nyika plateau in Kenya.
3. **Granitic Tor**
   This is a large rock outcrop of jointed and broken blocks, piled one upon the other formed by physical weathering process of block disintegration due to temperature changes. Alternate heating and cooling causes expansion and contraction of the rock along the joints. This weakens and widens the rock joints, forming rock blocks termed as granitic tors. For example Mudanda rock in Tsava national park in Kenya.

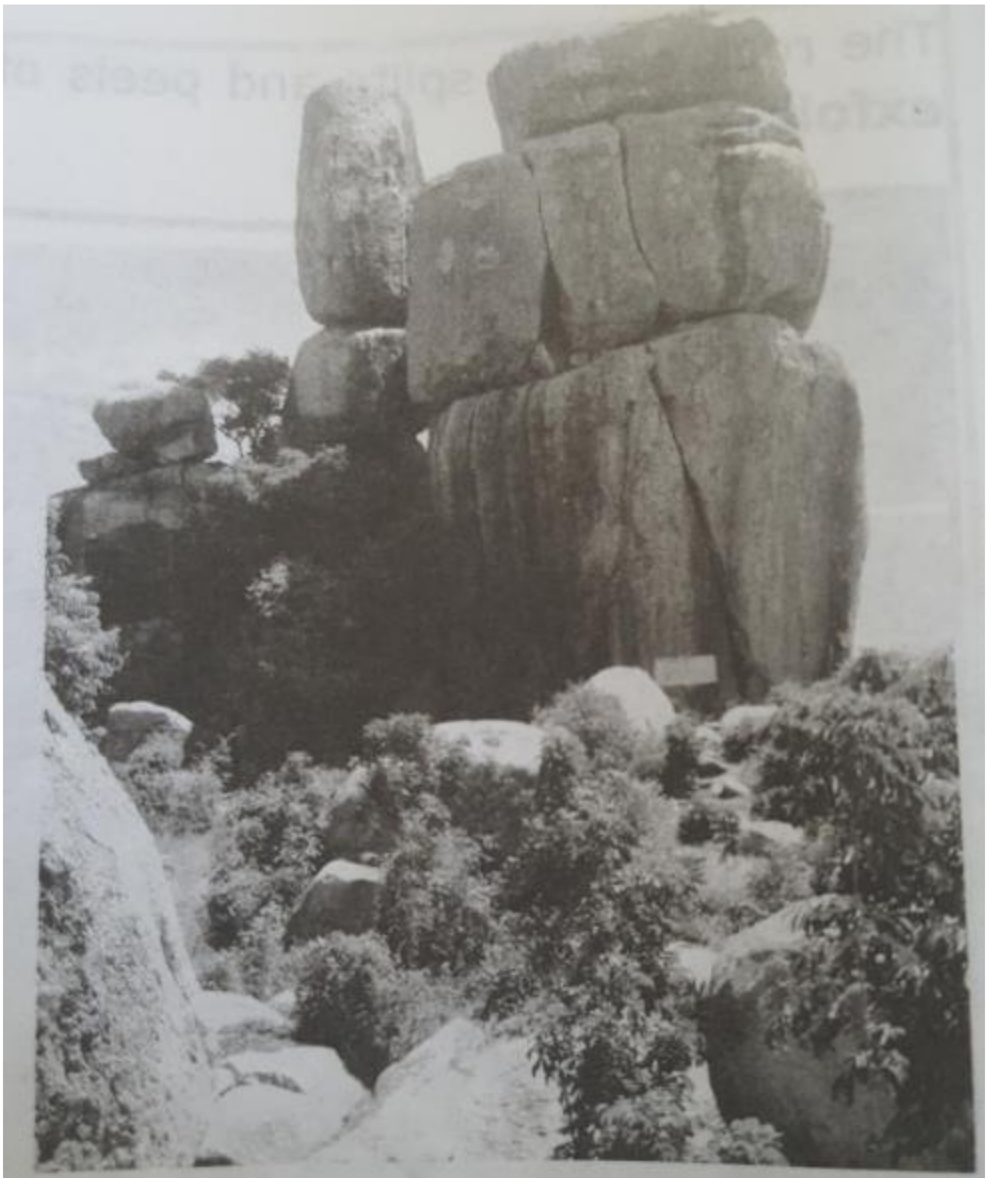


Fig. 3.4: Exposed granite Tors of Kit Mikai in Kisumu.

4. **Inselberg**

   This is a steep – sided isolated residual hill of hard rocks rising from a plain/flat landscape. Inslebergs form when overlying soft rock layers are subjected to physical weathering process due to temperature changes causing alternate expansion and contraction which weakens the rocks and finally removed by erosional process exposing hard rocks as inselbergs. Examples include Nakasongola inselberts, parabong inselbergs in Uganda, Voi inselbergs in Kenya.

ECONOMIC IMPORTANCE OF WEATHERING

Positive

- Weathered limestone rocks are used in the manufacture of cement which is used in building and construction for example at Bamburi, Mombasa in Kenya, Hima cement factory at Kasese in Uganda.
- Land forms resulting from weathering such as caves, pillars, stalagmites, exfoliation domes, granitic tors are great tourist attractions which generates a lot of foreign exchange and revenue to the region. For
- example at Nyakasura in western Uganda, Shimon along the Kenyan coast.
- Weathering breaks down rocks to form fine soil particles which support agriculture for example the fertile volcanic soils of Mt. Elgon used for Arabic coffee and banana growing.
- Soils formed through the process of weathering are used for building and construction. For example sand and mud which are used for plastering of houses.
- The clay which is formed by weathering through the process of hydrolysis is used for making tiles, bricks for example at Kajansi clays industry along Entebbe road in Uganda and these are used in building and construction.
- Clay resulting from the hydrolysis process of weathering is used for pottery work such as pots, flower vases, cups and this earns revenue and income to governments and communities respectively for example at Kajansi along Kampala – Entebbe road in Uganda .
- Weathering weaken and exposes rocks which make it easy for man to carry out quarrying and mining for example at Tororo volcanic plug for cement , diamonds from the Kimberly rocks of the volcanic plug at Mwadui in Tanzania.
- Limestone areas favour the growth of pasture used for animal grazing.
- Land forms resulting from weathering are used for research and study purposes to widen knowledge.
- Metamorphosed limestone (marble) is used for decorating buildings.
  0

Negative

- The high porosity of limestone rocks results into disappearance of surface water hence water scarcity.
- Weathering weakens the rocks within the earth's crust making the construction of houses difficult due to weak foundations.
- The barren and rugged nature of the karst landscape hinders agriculture and settlement for example at Nyakasura in western Uganda.
- Weathering loosens the surface rocks leading to soil erosion, which makes the soil infertile and less productive in terms of agriculture for example along the Kigezi highlands in South western Uganda.
- Deep weathering of rocks on mountain slopes causes landslides which are destructive to man and his property for example along Mt. Elgon slopes in Eastern Uganda.
- Physical weathering through the power of expanding tree roots causes cracks in houses and buildings.

REVISION QUESTIONS

1(a) Distinguish between physical and chemical weathering.

(b)Describe the factors which have favoured chemical weathering in East Africa.

2.(a) Differentiate between block disintegration and exfoliation.

(b).Account for the occurrence of physical weathering in East Africa.

3. Account for the occurrence of mechanical weathering in East Africa.

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

5. To what extent does the character and rate of weathering depend on the climate of an area ?

6."Climate more than other factors determines the rate and ndure of weathering. Discuss

7. Describe the weathering processes taking place in the Lake Victoria basin of East Africa.

8. Account for the dominance f physical weathering in the semi – arid areas of East Africa.

9.(a) What is chemical weathering ?

(b)With reference to specific examples from East Africa, examine the influence of chemical weathering on landform formation.

10. Describe the land forms resulting from, chemical weathering in East Africa.

11. Examine the formation of karst landscape in East Africa.

12. Examine the effect of weathering on landform evolution in East Africa.

13.(a) Describe the processes of chemical weathering

(b) Giving specific examples, outline the effects of weathering on the economic geography of East Africa.