GRADE 11 GEOGRAPHY

UNIT MODULE 1

THE STRUCTURE OF THE EARTH

ACKNOWLEDGEMENT

We acknowledge the contributions of all Secondary Teachers who in one way or another have helped to develop this Course.

Our profound gratitude goes to the former Principal of FODE, Mr. Demas Tongogo for leading FODE team towards this great achievement. Special thanks to the Staff of the Social Science Department of FODE who played an active role in coordinating writing workshops, outsourcing lesson writing and editing processes, involving selected teachers of Central Province and NCD.

We also acknowledge the professional guidance provided by Curriculum and Development Assessment Division throughout the processes of writing, and the services given by member of the Social Science Review and Academic Committees.

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PRINCIPAL

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CONTENT

SECRETARY'S MESSAGE

Achieving a better future by individual students and their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is a part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the national curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The course promotes Papua New Guinea values and beliefs which are found in our Constitution, Government Policies and Reports. It is developed in line with the National Education Plan (2005 - 2014) and addresses an increase in the number of school leavers affected by the lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education curriculum is guided by the Department of Education's Mission which is fivefold:

- to facilitate and promote the integral development of every individual
- to develop and encourage an education system satisfies the requirements of Papua New Guinea and its people
- to establish, preserve and improve standards of education throughout Papua New Guinea
- to make the benefits of such education available as widely as possible to all of the people
- to make the education accessible to the poor and physically, mentally and socially handicapped as well as to those who are educationally disadvantaged.

The college is enhanced to provide alternative and comparable pathways for students and adults to complete their education through a one system, many pathways and same outcomes.

It is our vision that Papua New Guineans' harness all appropriate and affordable technologies to pursue this program.

I commend all those teachers, curriculum writers, university lecturers and many others who have contributed in developing this course.

UKE KOMBRA, PhD

Secretary for Education

Dear Student,

Welcome to the Grade 11 Geography Course Module. This Module consists of four unit modules:

UNIT MODULE 1 : STRUCTURE OF THE EARTH
UNIT MODULE 2 : NATURAL PROCESSES AND DISASTERS
UNIT MODULE 3 : OCEANOGRAPHY
UNIT MODULE 4 : POPULATION STUDIES

The Grade 11 Geography Course is a follow up from what students have studied in Grades 9 and 10. It has been designed using learning outcomes that identify the knowledge, skills, attitude and values that all students achieve or demonstrate by the end of Grade 11. Grade 11 Geography course comprises of four modules.

UNIT 1: STRUCTURE OF THE EARTH

UNIT 2: NATURAL PROCESSES AND DISASTERS

UNIT 3: OCEANOGRAPHY

UNIT 4: POPULATION STUDIES

11.1 The Structures of the Earth, you will cover topics on the components of the earth and the relationship that exists between them and also study the different processes that work within and on the surface of the earth that built and shape the earth's landforms.

11.2 Natural Processes and Disasters, you will study the natural events, activities or happenings that influence our local PNG environment and the World wide environment.

11.3 Oceanography will cover topics on ocean, its uses and management.

11.4 Population Studies, you will learn about factors that influence population, population structures and the effect of increasing population in our communities today.

Grade 11 Geography course modules are focused on the Physical and Human Environment both in PNG and around the world. These modules aim to develop students' awareness of the natural environment and its processes and the interaction that exist between the natural and human environment.

Assessments

- **Activities**
  Each Unit Module has activities for you to do. Answers to the activities will be found at the end of each Unit after the Unit Summary
- **Assignments**
  Each Unit has an Assignment which you will do and then send to FODE Provincial Center for marking. The marked Assignment will be returned to you with comments and advice from your tutor. A mark will be given which will be counted towards your final internal mark.
- **Examinations**
  After the completion of the course, you will sit for an internal exam which will make up 70 % of your total internal mark. You will now be ready for the Grade 12 National Examination which is held in October each year.

Below are the steps to guide you in your course study.

Step 1: Carefully read through each module. In most cases, reading through a lesson once is not enough. It helps to read something over several times until you understand it.

Step 2: There is an instruction below each activity that tells you to check your answers. Turn to the marking guide found at the end of each module and mark your own written answers against those listed under the **Answers to Activities**. Do each activity and mark your answers before moving on to the next part of the module.

Step 3: After reading the summary of the unit module, start doing the Practice Exercise. Refer to the module notes. You must do only one practice exercise at a time.

Step 4: Below each Learning activity, there is an instruction that says:

CHECK YOUR WORK. ANSWERS ARE AT THE END OF COURSE MODULE 1.

Turn to the marking guide at the end of the Module Unit and mark your own written answers against those listed under the Answers to Learning Activity.

Step 5: When you have completed a practice exercise and marked your answers, go back to the module and correct any mistakes you may have made before moving on to the next module.

Step 6: Study the entire module following Steps 1, 2, 3, 4 and 5.

Here is a sample Study Timetable for you to use as a guide. Refer to it as a reminder of your study times.

TIME	MON	TUE	WED	THU	FRI
8:00-10:00	F O D E S T U D Y				
10:00-11:00					
1:00-2:00					
2:00-4:00					
6:00-7:00					
7:00-9:00	Listen to or watch current affairs programmes. Write your diary or read a book.				

A timetable will help you to remember when you should be doing your FODE studies each day.

UNIT MODULE INTRODUCTION

This unit introduces students to the processes and forces that shape the landforms on the earth surface. They also develop an understanding of the nature, functions and complex interactions that exist between the four components: atmosphere, hydrosphere, lithosphere and biosphere. Students develop an understanding of how geomorphic and tectonic processes construct and alter landforms and the human and natural environments.

Objectives or aims

On successful completion of this module, students will be able to:

- Identify and describe the internal and external processes and their interactions with the four components: lithosphere, biosphere, hydrosphere and atmosphere.
- Investigate geomorphic processes and the resulting landforms
- Describe and interpret geographical information about plate tectonics and their boundaries from a number of sources.
- Plan field work and assess the impact of humans on weathering, erosion, and mass movement.
- Identify, collect and record data about erosion, weathering, mass movement and tectonic activities.
- Construct and interpret flow charts and diagrams describing the key biophysical processes operating within a given area.
- Interpret and identify plate boundaries and major landforms from maps and diagrams.
- Examine landforms resulting from geomorphic processes and tectonic activities through fieldwork.
- Record findings using maps, diagrams, field notes, sketches and so on.

Time Frame

This unit should be completed within 10 weeks.

If you set an average of 3 hours per day, you should be able to complete the unit comfortably by the end of the assigned week.

Try to do all the learning activities and compare your answers with the ones provided at the end of the unit. If you do not get a particular exercise right in the first attempt, you should not get discouraged but instead, go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor. Do not pass any question without solving it first.

11.1.1 : COMPOSITION OF THE EARTH

This topic mainly provides you with the information about the composition of the earth, specifically looking at the difference between the internal and external processes that shape the surface of the earth. You will also discover that when looking at the earth's composition, we are basically looking at the physical elements of the environment. The physical elements of the environment includes all those things that occur naturally in an area, for example, air, water, soil, plants and animals. There are several processes that affect the physical elements of the environment which we will also identify in our lessons.

Objectives or aims

On successful completion of this module, you will be able to:

- Define important key terms; spheres, lithosphere, biosphere, hydrosphere, atmosphere, soil and rocks
- Explain the relationship that exists between the different components of the earth.
- Label and describe the different layers of the earth.
- Identify the different types of rocks and explain the soil-forming processes.

Time Frame

This unit should be completed within 4 weeks.

If you set an average of 3 hours per day, you should be able to complete the topic comfortably by the end of the assigned week.

11.1.1.1 : The Interaction of the four Spheres

The earth's surface is a vast area of 500 million square kilometres where four immense open systems interact. Each system loosely occupies a shell around the Earth so each is called a **sphere**. The spheres are again further divided into two main groups called **Biotic and Abiotic Environmental Spheres.**

The abiotic (non-living) spheres are the atmosphere, hydrosphere and the lithosphere

The biotic (living) sphere is called the biosphere. Because these four systems are not independent units in nature, their boundaries must be understood.

The **Earth's spheres** relates to the division of the Earth into broadly four interacting spheres sometimes referred to as the Biophysical environment: These are

- Hydrosphere
- Biosphere (ecosphere)
- Lithosphere
- Atmosphere

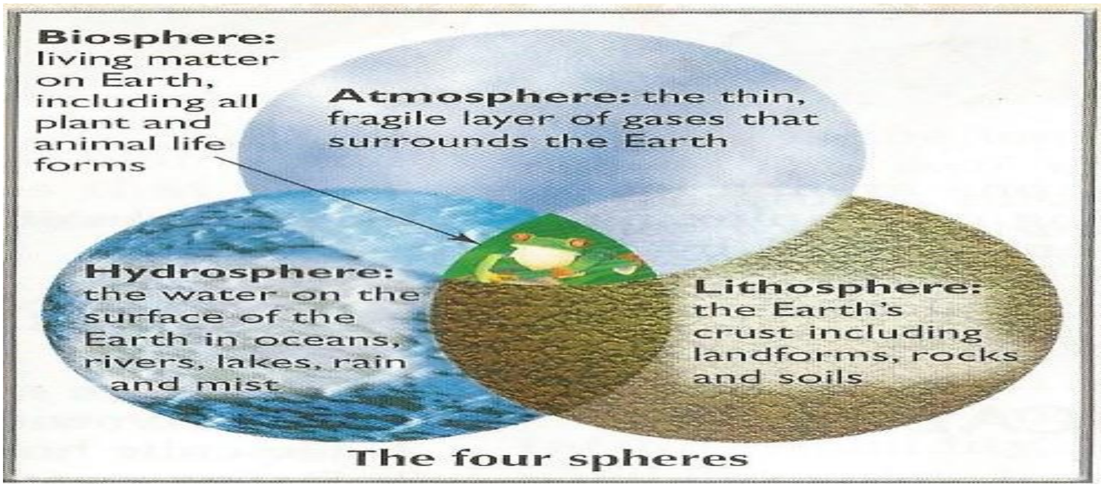
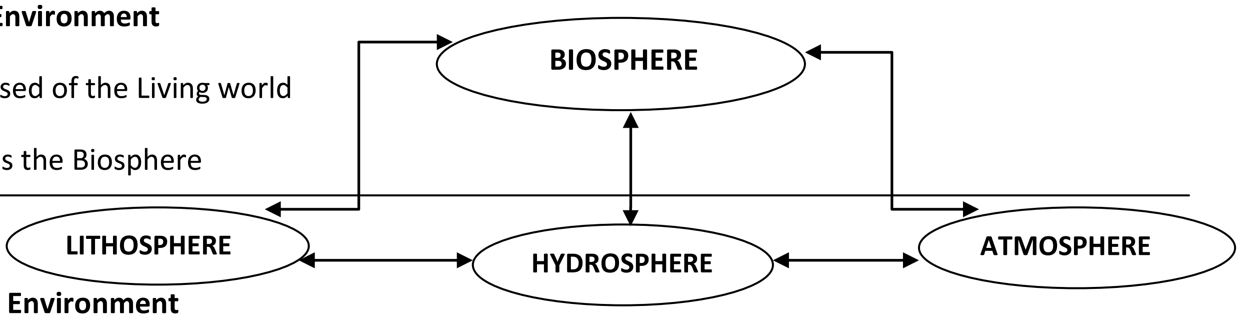


Figure 1.1: The four spheres

Biotic Environment

Composed of the Living world

Includes the Biosphere



Abiotic Environment

Composed of the Non-Living World and it includes the Lithosphere, Hydrosphere, and Atmosphere.

Student Learning Activity 1

1. The four spheres are divided in to two main groups. What are these two groups?

   i) ____________________________ ii) ___________________________

2. The Biotic environment is made up of the ________________________________

3. The Table below list the four spheres. Choose from this list the correct examples of things found in each sphere and correctly place them under the correct sphere.

   bear, pencil, sand, sea, orchid, pear, lakes, stamp pad, methane, stars, dogs, pebbles, oxygen, troposphere, gravel, rocks, rivers, streams.

SPHERES	EXAMPLES OF THINGS FOUND IN THE SPHERES			
1.BIOSPHERE	i)	ii)	iii)	iv)
2.ATMOSPHERE	i)	ii)	iii)	iv)
3.LITHOSPHERE	i)	ii)	iii)	iv)
4.HYDROSPHERE	i)	ii)	iii)	iv)

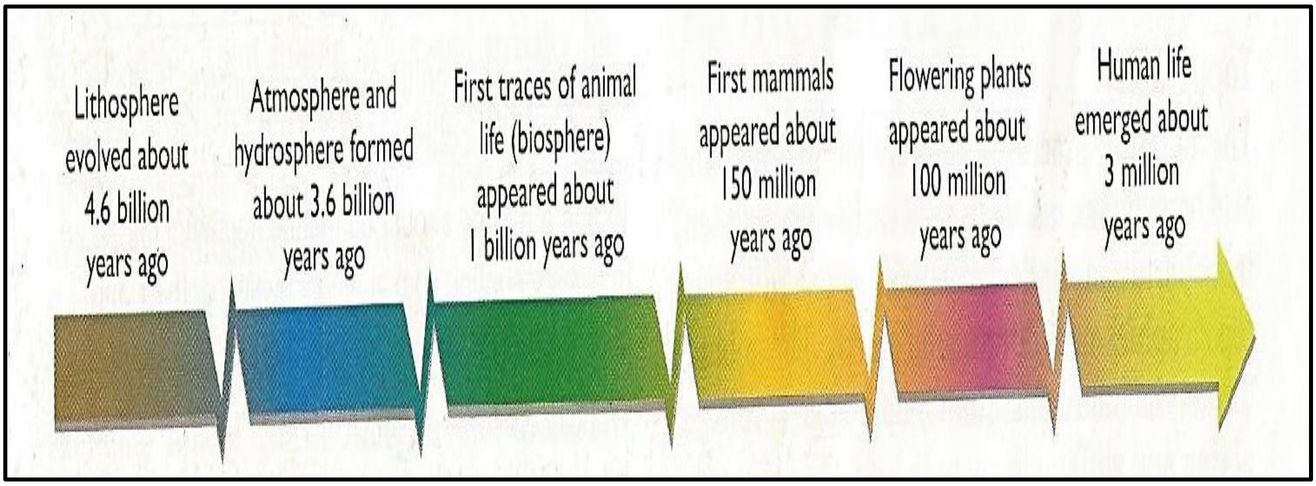


Figure 1.2: Formation of the spheres

Use the timeline on Figure 1.2 above to answer the following questions.

4. When did the lithosphere atmosphere, hydrosphere and biosphere form?

   ____

   ____

5. Identify the four (4) spheres of the biophysical environment.

i)________________________ ii) ___________________________

iii) _______________________ iv) __________________________

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.2 : The Atmosphere

Atmosphere

The Atmosphere of our planet is the thin envelope of life sustaining gases surrounding the earth and is also the key to the life development of this planet. The atmosphere of the earth extends nearly 563 km (350 miles out) from the solid surface of the Earth. It is made up of a mixture of different gases that combine to allow life to exist on the planet. In the lower layer atmosphere, nitrogen is found in the greatest amount, 78% followed by oxygen at 21%., and Carbon dioxide which is vital to the growth of plants.

The atmosphere is divided into layers according to the mixing of gases and their chemical properties as well as temperature .The atmosphere of the earth exist as four distinct layers, beginning with the closest layers to the ground of which are:

a. Troposphere b. Stratosphere c. Mesosphere d. Thermosphere

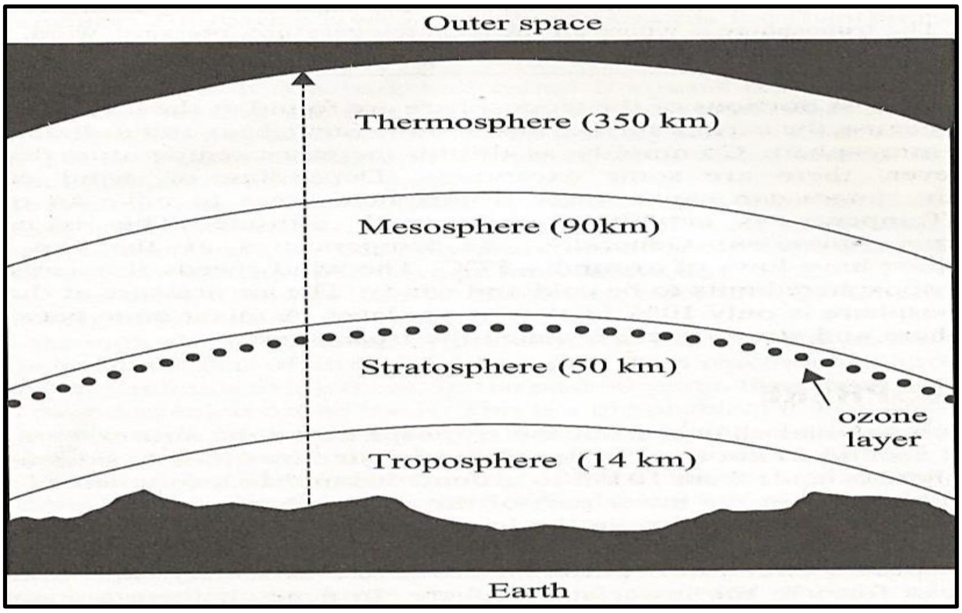


Figure: 1.3: The Four major layers that make up the Earth's atmosphere

I) **Troposphere** (means the region where air turns over)

- The lowest of the atmospheric layers and extents from the earth's surface up to about 14 km in altitude.
- It extends to about 17km above the sea level at the equator and about 8km over the poles.
- Holds
- The thickness of the troposphere varies with altitude and the seasons. The outer boundary of the troposphere is the tropopause.
- All human activities occur in the troposphere.
- It is the layer where all weather we experience takes place.

II) Stratosphere

Beyond the tropopause is the stratosphere.

- Temperature remains constant to a height of about 20 km and then begins a gradual increase that continues until the stratopause.
- Temperatures increase in the stratosphere because it is in this layer that the atmosphere's ozone is concentrated.
- The ozone absorbs ultraviolet radiation from the sun as a result, the stratosphere is heated.
- Most commercial aircraft travel takes place in the lower part of the stratosphere.

3. Ozone

- The ozone layer is contained within the stratosphere. it is mainly located in the lower portion of the stratosphere from about 15–35 km, though the thickness varies seasonally and geographically.
- This ozone layer is largely responsible for absorbing most of the sun's ultraviolet radiation, most importantly, it absorbs the fraction of ultraviolet light called UVB.

III) Mesosphere

- Above the stratosphere is the Mesosphere, the third layer or a middle layer separating the lower stratosphere from the Thermosphere, extending from 80 to 90 km
- Military aircraft travel at much higher altitude with some classified stealth aircraft.

IV) Thermosphere

- The change over from the Mesosphere to the Thermosphere layer begins at the height of 80km.
- The temperature in this layer is very high due to gases in the thermosphere moving at very high speeds.

The Aurora Borealis (*northern lights*) and Aurora Australis (*southern lights).*

V) Ionosphere

- Part of the atmosphere that is ionized by solar radiation
- Overlaps both the exosphere and the thermosphere.
- It forms the inner edge of the magnetosphere.
- It has practical importance because it influences, for example, radio propagation on the earth
- It is responsible for auroras

Now do the activity on the next page.

Student Learning Activity 2

1. List the four (4) spheres of the atmosphere.

   i)___________________ ii) ______________________

   iii) __________________ iv) ______________________

2. Of the four main Spheres or Layers that make up the atmosphere, which one is responsible for all the earth's weathers? _________________________________.

3. Commercial aircrafts would be found flying in which sphere? ________________.

4. The Ozone gas is found within which sphere? _____________________________.

5. In which layer of the atmosphere is Australis Aurora found?

   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.3 : The Hydrosphere

In the last sub-topic, we looked at the four layers that make up the Atmosphere. Let us now take a look at the third Layer that makes up the Atmosphere which is the Hydrosphere.

Hydrosphere

The **hydrosphere** in physical geography describes the combined mass of water found on, under, and over the surface of the earth.

Water is the most distinctive substance found on earth. It set the stage for the evolution of life and is still an essential ingredient of all life today. It is the most abundant substance on the face of earth with surface water occupying 97% of the surface area of the earth. The water of the earth is found naturally in three stages; as a liquid (seas, rivers), as a solid (ice) and as a gas (water vapour). The great majority of the world's moisture is in the form of liquid.

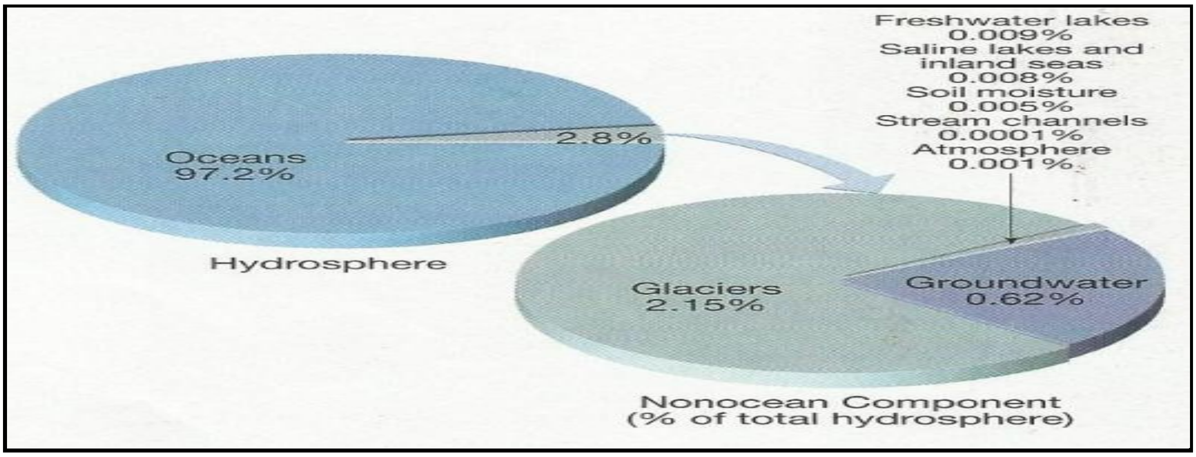


Figure 1.4: Distribution of the earth's water

- The Global oceans, the earth's most noticeable feature form space makes up the largest single part of the planets total covering.
- The Pacific Ocean is the largest of the Earth's oceans that the landmass of all the continents could fit into it. The combined water of the oceans make up nearly 97% of the Earth's water.

The Water Cycle

The **water cycle** is the circulation system which carries water from the oceans, through the atmosphere, to the land and back to the sea and is also a key process of the **hydrosphere**. Water is transferred between various storages, such as oceans and the atmosphere; however, no water actually leaves the circulation system and so on a world scale it is recognized as a closed system. The water cycle is powered by the energy from the sun. This energy passes into, through and out of the system, and in doing so, transfers water from the various stores.

Water is a renewable resource. This means that if water is used and managed properly it can be replaced or renewed. Water moves through the atmosphere, land, rivers and oceans in the water (or hydrological) cycle. It involves the processes such as **condensation, precipitation, infiltration and runoff, evaporation and transpiration**.

Evaporation is the process by which water changes from a liquid into a gas and becomes water vapour. The oceans are by far the most important source of water vapour. From them comes almost all of the water vapour contained in the air.

Condensation is the reverse of evaporation. It occurs when water vapour changes from a gas to a liquid. This results in water appearing as visible droplets in the atmosphere.

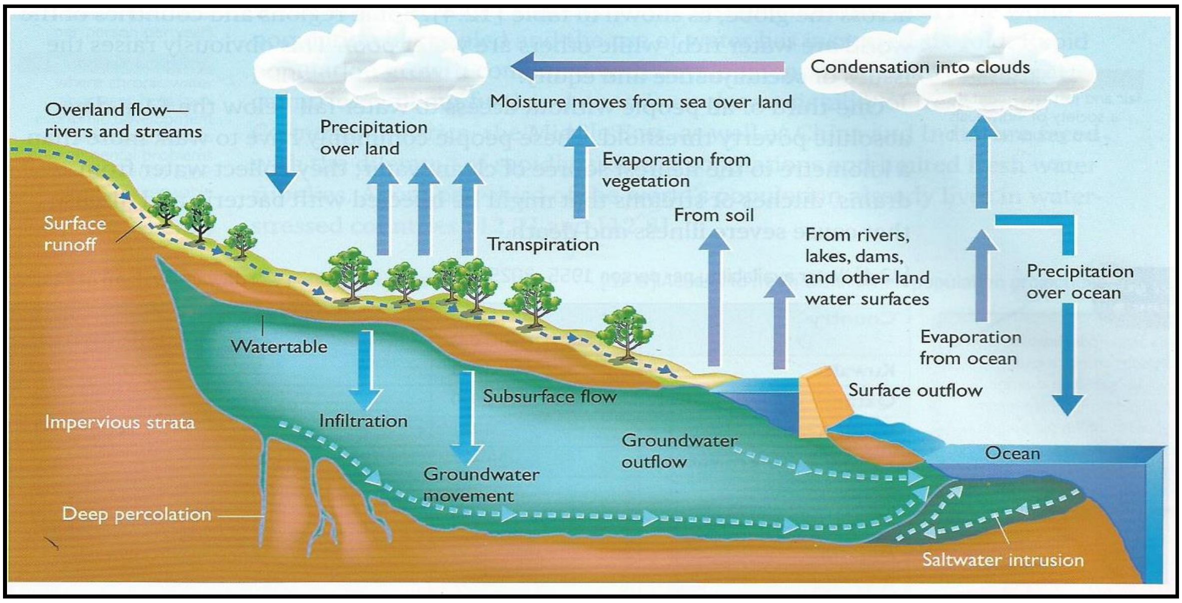


Figure: 1.5 The water cycle

Plants also discharge water vapour into the atmosphere. This is called **transpiration**. The combined water loss into the atmosphere from evaporation and transpiration is called evapotranspiration

Precipitation is the descent of some form of water (hail, hail, fog or dew) through the air to the ground. For precipitation to occur, the very small water droplets have to increase in size to the point where the air can no longer support them.

Since humans are dependent upon water for their survival, the section of the atmosphere which is most important to them is the troposphere, for it is this portion which contains practically all of the water vapour present in the atmosphere. The capacity of air to hold water vapour depends upon the air’s pressure and temperature, the higher the air temperature, the greater is the capacity of air to hold water vapour.

Student Learning Activities 3

1. The main energy source for the water cycle is the ___________________________________.

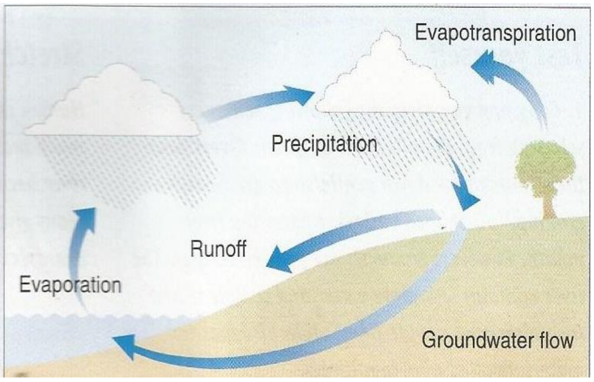
2. Water actually moves in a system known as the ____________________________________.

3. Water is said to be a renewable resource. Explain
____
____
____

4. Define the water cycle
____
____

5. What are main processes in the water cycle
____
____

6. Identify the process that is missing from the water cycle below.



____

Figure 1.6: The water cycle

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.4 : The Lithosphere

Lithosphere

The crust and the very top part of the mantle are known as the Lithosphere. This layer of the crust is rigid and brittle acting as an insulator over the mantle layer below. It is the coolest of all the earth's layers and though to float or glide over the layers beneath it.

The Earth's Lithosphere

- the lithosphere includes the crust and the uppermost mantle, which constitute the hard and rigid outer layer of the earth.
- is underlain by the asthenosphere, the weaker, hotter, and deeper part of the upper mantle.
- the boundary between the lithosphere and the underlying asthenosphere is defined by a difference in response to stress.
- the lithosphere is broken into tectonic plates.

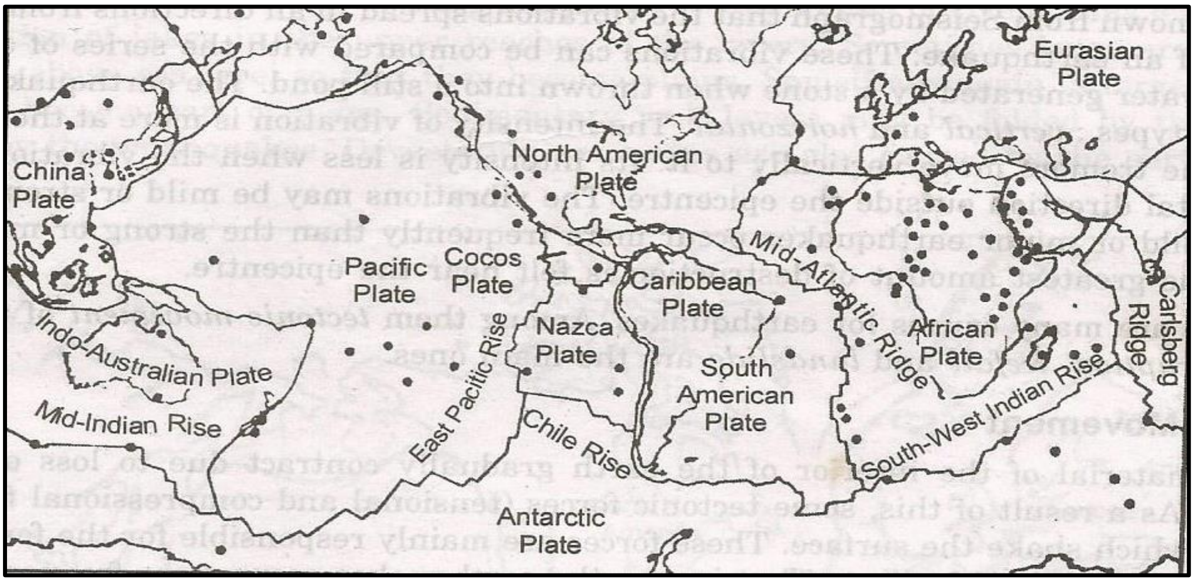


Figure 1.7 The tectonic plates of the lithosphere on earth

The lithosphere provides a conductive lid atop the convecting mantle; as such, it affects heat transport through the Earth. The crust is distinguished from the upper mantle by the change in chemical composition that takes place at the Mohorovicic discontinuity.

There are two types of lithosphere:

- oceanic lithosphere, is associated with Oceanic crust and exists in the ocean basins
- continental lithosphere, is associated with continental crust

Student Learning Activities 4

1. What are the two main types of Lithosphere?

   i).________________________________ ii).______________________________

2. What is the difference between the continental crust and the oceanic crust?

   ____

   ____

3. Make a list of the 7 major tectonic plates.

   a) _________________________ b) ________________________

   c) _________________________ d) ________________________

   e) _________________________ f) _________________________

   g) _________________________

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.5 : The Biosphere

The Biosphere includes the hydrosphere, crust, and atmosphere. It is located above the deeper layers of the earth.

Of the four principal components of our earthly environment, the biosphere has the boundaries that are hardest to pin down. From the view point of physical geography, the surface of the earth comprises a complex interface of four distinct components of the environment, namely, atmosphere consists of the envelope of air that surrounds the earth and the lithosphere is the solid portion. The waters of the earth consisting of rivers, lakes, oceans and glaciers form the hydrosphere. All living things, plants and animals, collectively comprise the biosphere. The four important components meet together and interact collectively.

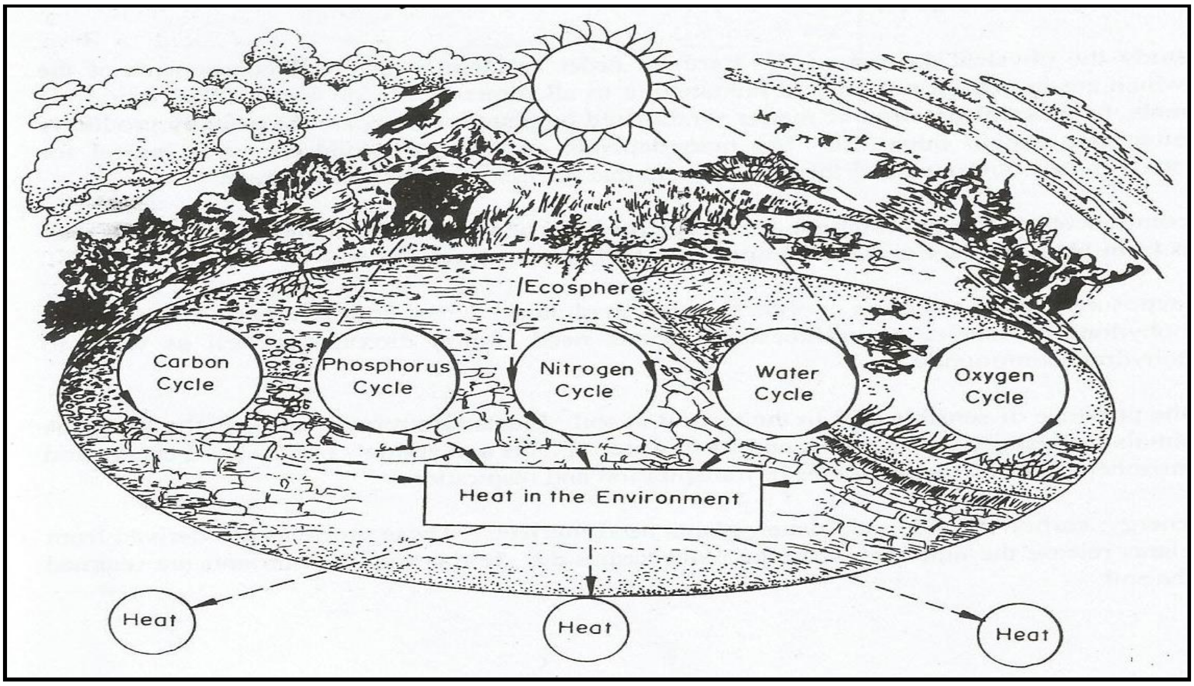


Figure 1.8: Simplified summary of the biosphere

Biosphere is that part of the earth where life exists. The geographical distribution of living organisms reveals that living creatures are found in different sets of environmental conditions.

- all of life on earth is contained in the biosphere. All the plants and animals of the earth live in this layer which is measured from the ocean floor to the top of the atmosphere.
- it includes all living things, large and small, grouped into species or separate types.
- the main compounds that make up the biosphere contain **hydrogen**, **carbon** and **oxygen**. These elements interact with other earth systems.

1. The Hydrological Cycle

The most abundant single substance in the biosphere by far is water. It is the medium of life processes and the source of their hydrogen. Most organisms contain considerably more water in their mass than anything else. Every living thing depends on keeping its water supply within a narrow range. For example, humans can survive without food for 2 months or more, but they cannot live without water for only about a week.

All living things require water to carry out their life processes. Watery solutions dissolve nutrients and carry them to all parts of an organism. Through chemical reactions that take place in a watery solution, the organism converts nutrients to energy or to materials it needs to grow or to repair itself. In addition, the organism needs water to carry away waste products. There are two ways water is found in the biosphere; with its hydrogen chemically bound into plants and animals tissues and as part of the transpiration-respiration stream.

2. The Carbon Cycle

Carbon is one of the basic elements of life and part of all living things. The biosphere contains a complex mixture of carbon compounds. The main component of the carbon cycle is a conversion of carbon dioxide to living matter.

Ecosystems and Biomes

Understanding of the biosphere demands us to understand two main concepts namely ecosystems and biomes.

Ecosystem

An ecosystem is a collection of living things and the environment in which they live in. So an ecosystem can be a large rainforest or a small pond and a large ecosystem can be broken down into number of smaller ones. The important thing is that ecosystems are produced by living organisms interacting with each other and the physical environment.

Biome

A world distribution pattern of ecosystems can be understood in terms of a biome. A biome is a large recognizable community of plants and animals interacting with its environment. Most biomes are named for their dominant vegetation as well as fauna and their interrelationships with soil, climate and topography.

Student Learning Activities 5

1. Define the following terms

   i) biosphere:

   ____

   ____

   ii) Ecosystem:

   ____

   ____

2. List the environmental controls in Figure 1.9?

   ____

   ____

   ____

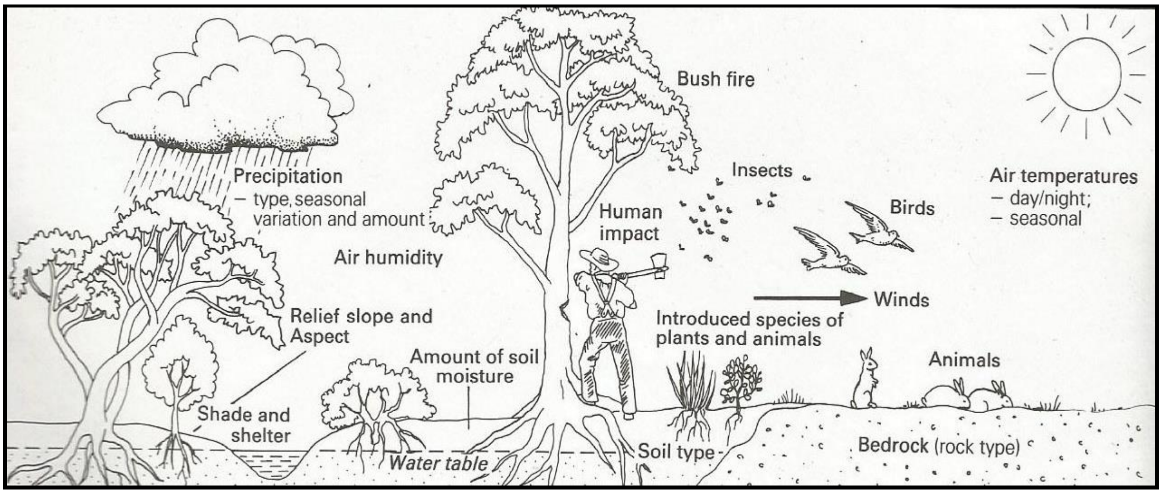


Figure 1.9: Some environmental factors affecting plan growth

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.6 : The Earth's Structure

The earth is made up of three main parts or Layers:

1. Cores (Barysphere) 2. Mantle (Mesosphere) 3. Crust (Lithosphere)

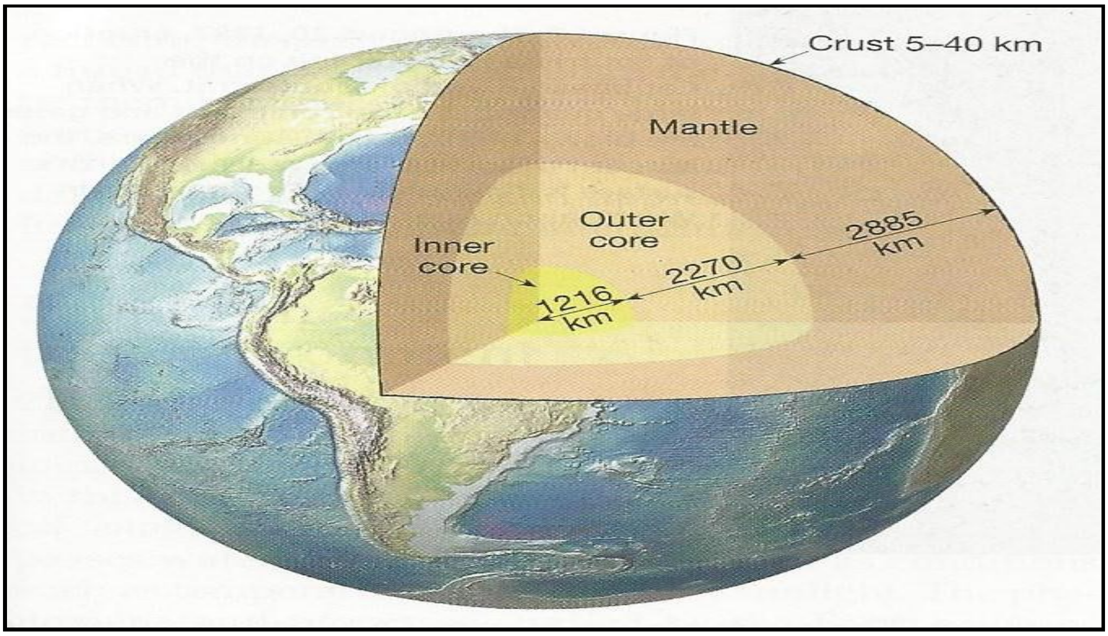


Figure 1.10 Veiw of the earth's layered structure

The Crust

- is the outer skin of the earth
- relatively speaking this is as thin as the skin of an apple is to its flesh
- consist of **basalt** rocks and it floats on the mantle
- it is in constant motion moving only 1 or 2 cm horizontally or vertically a year
- forms a continuous covering to the mantle but it's thickness varies from 5 to 7 km under the oceans to 20 to 75 km under the continents
- geologists know more about the crust than other zones of the earth because they can collect samples from it.

The types of Crust :

1. **Oceanic Crust (Sima)**
    - consist of much younger and denser rock of basaltic composition. it's dominant minerals are silica and magnesium
    - it's thickness is from 6 to 7 km on an average
    - weight of the rocks is much heavier
    - the rocks are darker in colour
    - it is weaker and it is here that new crust is form and old ones are destroyed.
    - the crust under the oceans is much thinner.

- mostly extrusive or volcanic rocks

2. Continental crust (Sial)

- Composed of much older, lighter rock of granitic type. It is dominated by minerals rich in silica and aluminium from which the term is derived.
- The thickness of the rock is from 35 to 40 km on an average reaching 60 to 70 km under chain mountains
- Weight of rocks is much lighter and is mostly intrusive or plutonic rocks

Plutonic rock is an igneous rock formed at the depth of the earth's crust. E.g. Granite (intrusive)

Volcanic rock is a category of igneous rock which comprises those rocks formed from magma which has reached the earth's surface .E.g. basalt. The Crust is separated from the mantle by the mohorovicic discontinuity (MOHO) and beneath the MOHO is the mantle.

Moho is the boundary between the upper mantle and the crust is referred to as the mohorovicic discontinuity or Moho. This is the area where seismic waves are modified.

Mantle

- volumetrically, the mantle is by far the largest of the four shells
- the earth scientist now believe that there are three zones in the mantle
- is semi-molten

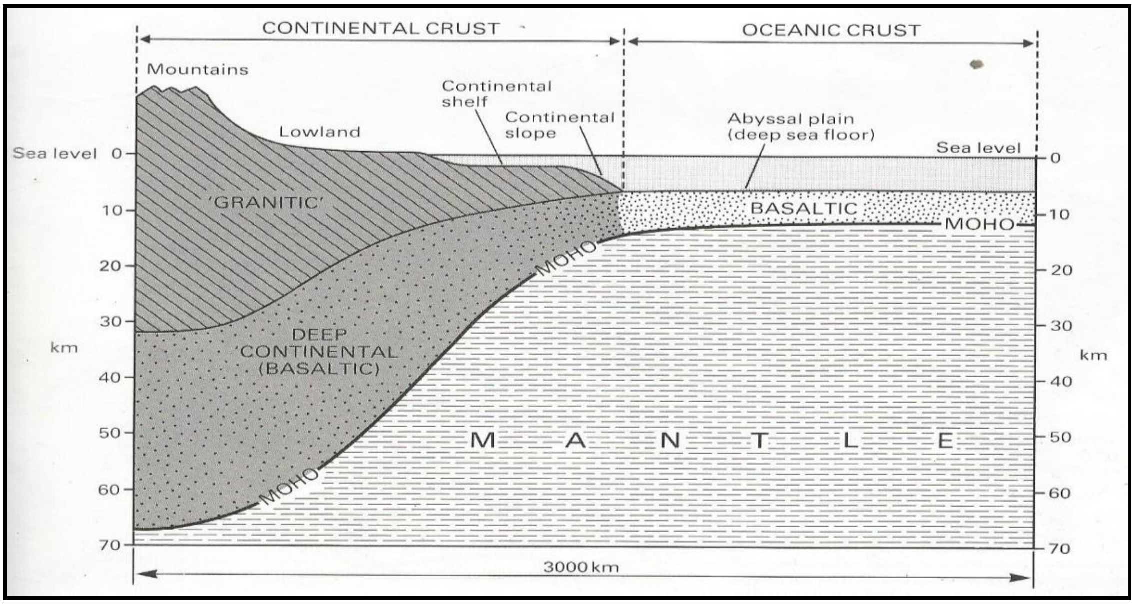


Figure 1.11 Section through part of the earth's crust and upper mantle.

Beneath this rigid zone extending downwards to a depth of 350 km is a zone in which the rocks are so hot that they lose much of their strength and are much easily formed like tar. This is called the **asthenospher**e (weak sphere).

The Uppermost zone is relatively thin but hard and rigid extending down to about 40 kilometers beneath the oceanic crust and about 80 kilometers below the continental crust. This uppermost zone plus the crust are together called the **Lithosphere.**

Asthenosphere

Is the semi-molten part that acts as a lubricant to allow the plates on the lithosphere to move.

- Is the upper mantle, is soft and therefore flows easily
- Beneath the asthenosphere is the deep mantle, the MESOSPHERE where the rocks are believed to be rigid .

Mesosphere

- this is the solid region of high temperature but also high relatively high strength.
- it is the intermediate mantle (middle)

It is important to remember that despite the fact that the crust and the mantle differ in composition it is rock strength, not rock composition that differentiates the lithosphere from the asthenosphere.

The Cores

Outer Core

- it is made of liquid iron and nickel
- beneath the mantle is where the outer core is
- thought to be molten (liquid) and extending to a depth of about 5000km
- outer core is hot electrically conducting liquid-mainly iron and nickel.
- this is the zone where temperature and pressure are so balanced that the iron is molten and exist as a liquid.

This conductive layer combines with earth's rotation to create a Dynamo effect that maintains a system of electrical current creating the earth's magnetic field. Also responsible for subtle jerking of the earth's rotation

Inner Core

- inner most portion of the earth
- a supposedly solid and very dense mass
- the inner core is made of solid iron and nickel and is unattached to the mantle. it is solid due to massive pressure.

The main difference between the inner and the outer core is not the composition instead it is in the physical state of which one being solid whilst the other being liquid.The lithosphere is the outer zone of the solid rock which is found above the asthenosphe

Student Learning Activities 6

1. The boundary that separates the crust from the mantle beneath it is called ___________________________________

2. The earth's crust and the upper most mantle together forms the ________________

3. Study Figure 1.11 and complete the table that follows below.

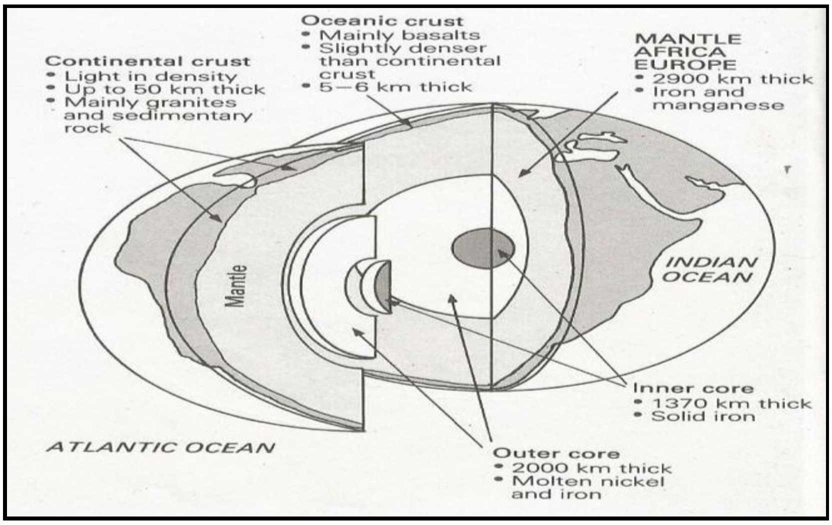


Figure 1.11: The earth's structure

EARTH STRUCTURE	MATERIAL	THICKNESS
OCEANIC CRUST		
CONTINENTAL CRUST		
MANTLE		
OUTER CORE		
INNER CORE		

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.7 : Rocks

A **rock** is an assemblage of minerals made up of minerals cemented together (such as granite, a rock containing three minerals) or sometimes a mass of single material (such as rock salt).

Unlike plants and animals, most rocks have long histories. They seem ancient and never changing because within our lifetimes they don't change much. A rock is continuously formed through the rock cycle.

Rocks are divided into three main groups:

1. Igneous rocks **2. Sedimentary rocks** **3. Metamorphic rocks**

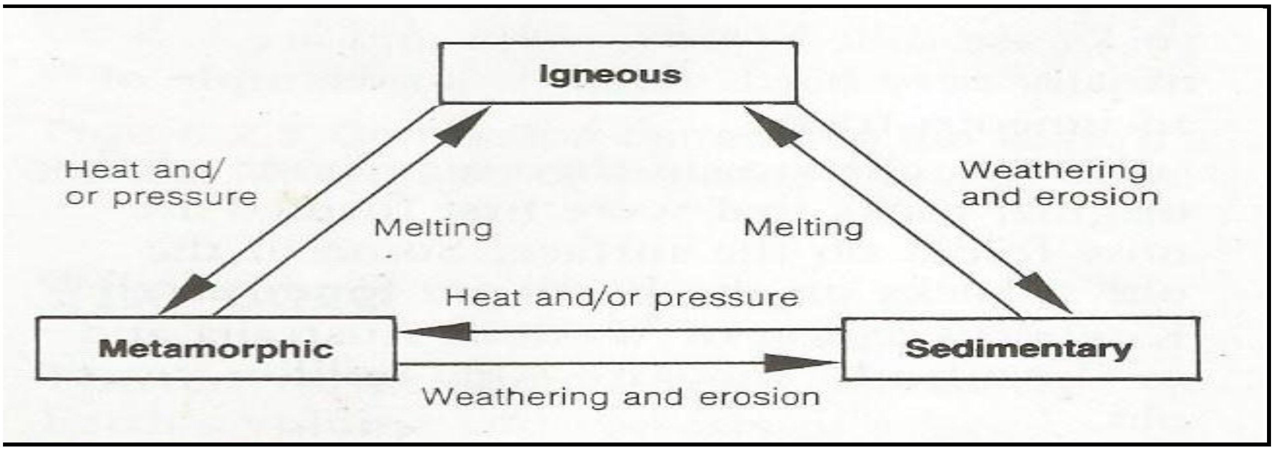


Figure 1.13 The rock cycle

1. Igneous Rocks

Igneous rocks are formed when magma cools and solidifies. The name comes from the latin word ***ignis*** meaning fire.

Rocks formed by the hardening of molten rock (magma) whether deep in the earth or blasted out during an eruption are called igneous rock.

Igneous rocks are probably the only rocks that give us a window into rock formation. Igneous rocks are formed from magma that is sent through volcanic activity to the surface. Depending on the speed and the way magma reaches the surface, the hardened igneous rock that is formed can look very different. There are three main types that come from magma: igneous, sedimentary and metamorphic. Of these three, igneous is probably the most active and exciting. Igneous rock is created by exploding volcanoes and boiling undersea fissures.

Explanation:
Magma is molten rock

- Magma is formed in the crust and upper mantle where there is sufficient heat to partially or completely melt rocks.

- Once formed, magma tends to rise upwards. If it reaches the earth's surface it is then called lava.
- As magma cools, mineral crystals begin to grow (especially crystals of silicate minerals)

Six minerals make up nearly all of igneous rock. These are quartz, feldspar, pyroxene, olivine, amphibole and mica

Igneous rocks can be divided into two main groups:

1. **Extrusive igneous rocks**: Are formed from magma (that is Lava) which has solidified on the earth's surface. Another name for this group is ***Volcanic rocks.*** *Examples, basalt granite pumice.*

2. **Intrusive igneous rocks**: Intrusive igneous rocks are those produced where magma cools and hardens underground or are rocks which are formed from magma which has solidified within the earth's crust. The three main types of intrusion are: Dykes, Sills, Batholiths.


Figure 1.14 Basaltic lava flow

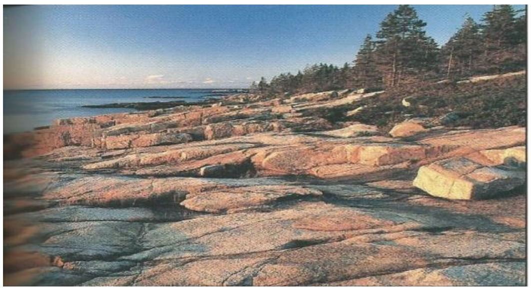


Figure 1.15 Exposed granite


Figure 1.16 Obsidian


Figure 1.17 Pumice

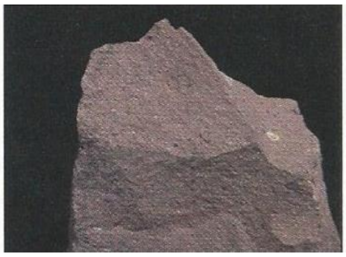


Figure 1.18 Rhyolite

Plutonic rocks are those that crystallized deep within the earth. Rocks of this type generally have large crystals, having cooled very slowly. Granite is a typical example.

2. Sedimentary Rocks

Sedimentary rocks are formed from the deposits of material which has originally come from older rocks or living organisms.

Explanation:

- All rocks exposed at the earth's surface are **denuded** (worn away) by weathering and erosion.

- The material worn away from these rocks is **transported** (carried away) by gravity, wind, ice, sea and rivers.
- The transported material may be fragments of rocks and minerals (for example, pebbles and sand grains) or it may be dissolved in water.
- Eventually the transported material is **deposited** (laid down) as a layer or bed of sediment (for example, in a desert or on a sea shore)
- Some beds of sediments are made from the remains of living organisms (for example, coal formed from trees)
- The beds of sediments, however formed are slowly compacted (pressed together) as other material continues to be deposited above. Eventually the separated pieces of loose sediments become **lithified** (joined together and turning into stone) into a solid sedimentary rock.

At the time of deposition these sediments are described as being unconsolidated (a loose mixture of separate fragments). Given time and the right geological conditions, they will become lithified (compressed and cemented) into solid sedimentary rocks.

Sedimentary rocks are classified (divided into groups) according to how they are formed. Two major groups are recognized.

i). CLASTIC Sedimentary Rocks:
These are formed from material which has been transported as actual pieces of rocks and minerals, for example, pebbles, sand grains, clay minerals etc. This type of material is described as "visible load" carried by water, wind or ice. Clastic rocks contain pieces which have been broken from other older rocks.

ii) CHEMICAL and ORGANIC Sedimentary Rocks: (sometimes called non-clastic)
These are mainly formed from material which was transported as a solution dissolved in water (i.e. invisible load)

EXAMPLES:

Conglomerate, Sandstone, Mudstone, Limestone, Clay, Coal, Shale, Chalk


Figure 1.19: Limestone rocks


Figure 1.20: Conglomerate

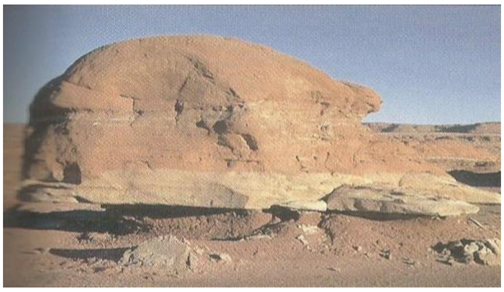


Figure 1.21: Sandstone

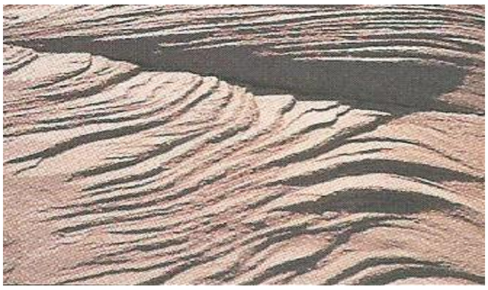


Figure 1.22: Shale

3. Metamorphic Rocks

Metamorphic rocks are rocks which have been changed by heat and pressure. Remember too, that metamorphic changes take place while the rock remains essentially solid. If melting occurs, then magma is produced. Any rocks formed from these would be classified as igneous. Let us start our study by seeing where heat and pressure are likely to occur.

HEAT:

- rocks close to an intrusion of magma will become heated
- rocks buried deep in the crust will be heated.

PRESSURE:

- rocks within the active zones of the earth, where plates are moving together are subject to tremendous pressure. this is particularly true where continental edges are being deformed and uplifted into mountain chains.
- rocks buried deep in the crust will be affected by pressure, for example, at a depth of 3km , each square cm of rock will have to bear the weight of over a tonne of overlying material.

Heat and Pressure cause metamorphic change in two ways;

1. The mineralogy is changed; although no elements are added to or taken from the original rock, its mineral will react and re-crystallize to suit the new condition.
2. The texture is changed; as new minerals develop, their size shape and their arrangement will depend on the conditions under which they form.

When molten rock at a temperature of several hundred degrees centigrade, is forced upwards, the surrounding rock becomes baked and hot gases are given off. Remember too that metamorphic changes take place while the rock remains essentially solid. If melting occurs then magma is produced and any rock that is formed from this would be classified as magma.

EXPLANATION:

- As conditions within the earth change, rocks are also forced to change.

- heat and pressure may cause the chemical elements in the original rock to react and re-form into new minerals.
- the new metamorphic minerals are often aligned (arranged) in a parallel pattern because they have been formed under pressure.
- during metamorphism, no elements are taken away from the original rock and no elements are added; the original elements are simply rearranged to suit new conditions.
- although metamorphism may involve great heat the rock does not melt as it changes; if it did, a magma would be formed and the new rock would be classified as igneous

What is a Rock Cycle?

Rocks are constantly exposed to various physical and chemical conditions that can change them overtime. The interaction of processes that change rocks from one type to another is called the **rock cycle**.

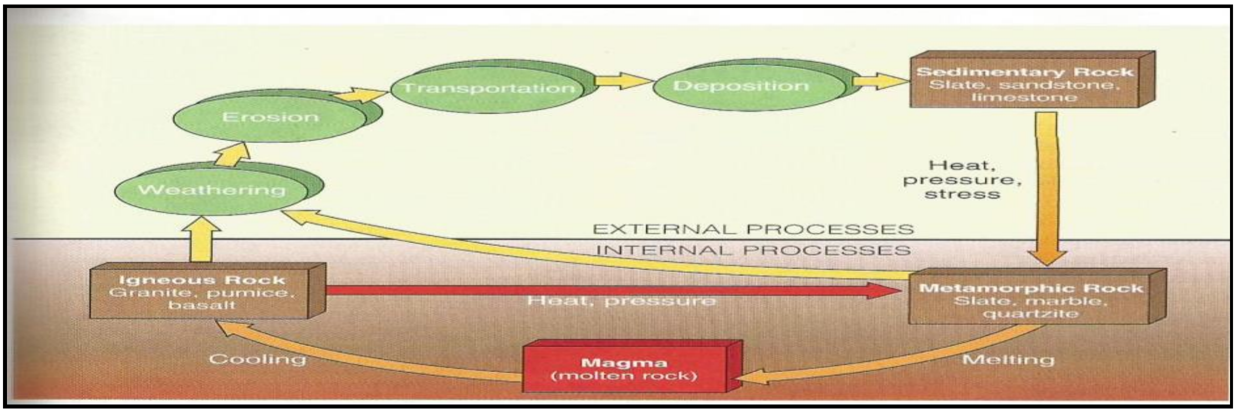


Figure 1.23: Showing the rock cycle

The slowest of the earth's cycle processes, the rock cycle recycles material over millions of years. It is responsible for concentrating the planet's non-renewable mineral resources on which humans depend.

Now do activity 7 on the next page.

Student Learning Activities 7

1. What are the three main groups rocks are grouped into according to how they were formed?

   a) _________________ b) __________________ c) _________________

2. What is the difference between intrusive and extrusive rocks? Explain

   ____

   ____

3. Why are metamorphic rocks formed in a parallel pattern? Explain

   ____

   ____

4. Heat and Pressure can cause metamorphic change in two ways.

   i) ____

   ____

   ii) ____

   ____

5. Rearrange these terms into correct order so that they list the processes which form sedimentary rocks.

   Lithifaction /denudation /transportation /deposition

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.1.8 : Soils

What Is Soil?

Soil refers to the loose material or the upper layer of the Mantle Rock, made up of very small particles. It is penetrated by the roots of plants that derive from its nutrients and moisture.. The bulk of most soils are inorganic material and so soil's development begins with the physical and chemical disintegration of rock which is called weathering.

Figure 1.24: Soil –our greatest resource

Soil makes up the top layer of the earth's crust. Rocks on the earth's surface are ground down over time in to smaller fragments by the erosive power of the rain, wind and the sun, and combine with the rotten remains of plants and animals. Living things and the rock type each play a vital role in the formation of the soil.

Soil is what plants grow in. Soil consists of mineral particles, organic matter, water and air. There is a great variety of mineral particles. Among the most common are coarse-grained silica or quartz which resist chemical break down and finer particles of clay- like material known as silicates.

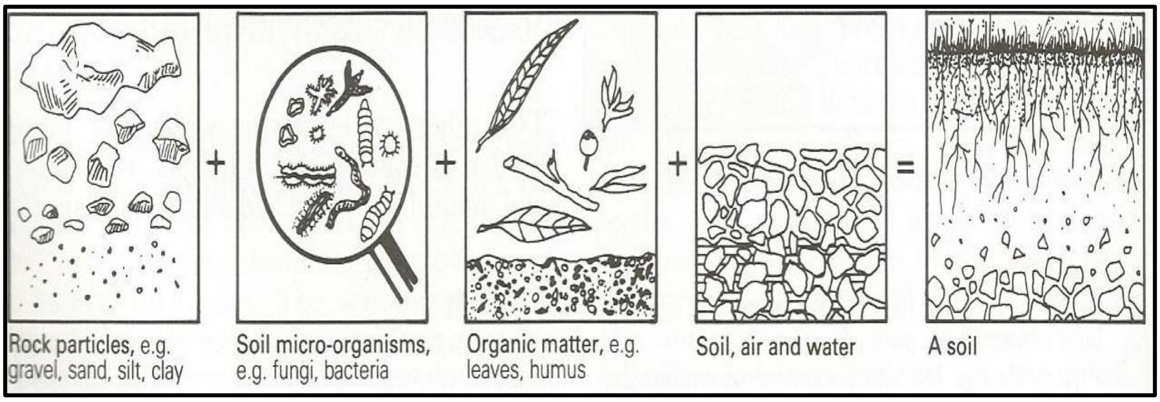


Figure 1.25: Composition of the soil

Soils that are made up of coarse grains are called **sandy soils**. Soils that are made of smaller particles are known as **silts** and finer grain soils are **clay.** A mixture of sand, silt and clay is known as a **loam soil**. The size difference of the particles is known as **soil texture**.

Pedologists have identified five main factors involved in the soil formation. All these factors are interconnected and are interdependent.

1. **Parent material**: In most soils the inorganic material of the soil consists of fine particles of mineral matter. The term parent material describes all forms of mineral matter that are suitable for transformation into soil.
2. **Climate**: Climate determines the type of soil at a global scale. The distribution of world soil types corresponds closely to patterns of climate and vegetation. Climate affects the rate of weathering of the parent rock, with the most rapid breakdown being in hot, humid environments.
3. **Topography** (relief): As the height of the land increases, so too do amounts of precipitation, cloud cover and wind, while temperatures and the length of the growing season both decrease. Aspect is an important local factor in mid- latitudes with south facing slopes in the northern hemisphere being warmer and drier than those facing north. The angle of the slope affects drainage and soil depth.
4. **Organisms (biota)**: Plants, micro - organisms such as bacteria and fungi, and animals all interact in the nutrient cycle. Plants take up mineral nutrients in the soil and return them to it after they die. This recycling of plants nutrients is achieved by the activity of micro-organisms, which include worms and termites.
5. **Time**: Soils usually take a long time to form, perhaps up to 400 years for 10 mm.

Soil Profile and Soil Horizon

There are many different types of soil. Each individual soil can be identified and described by looking at its **soil profile.** Soil Profile is a vertical column of the soil that may be exposed at a pit or may be extracted from the ground. The soil profile consists of different layers of materials called **horizons.**

Each horizon has a different *color and texture* but it is important to remember that not all three horizons are found in all soils. The different horizons are parallel to the ground surface and lie above the bedrock.

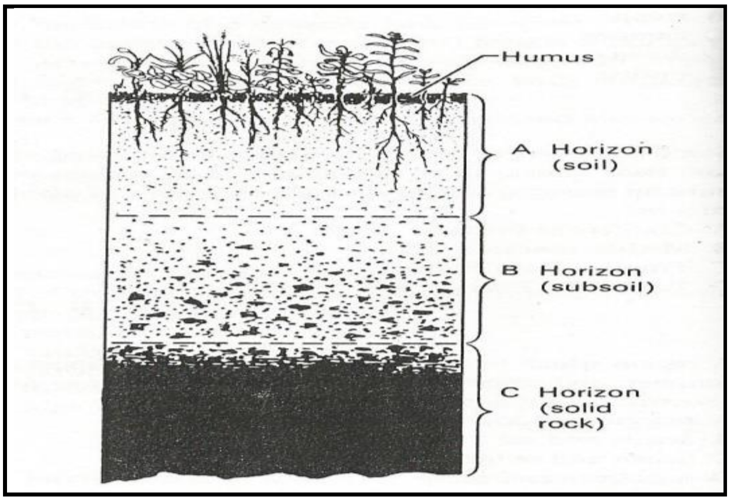


Figure 1.26 The top part of A horizon is often rich in humus.

Soil Profile

A soil profile is a vertical section through the soil to the underlying solid rock. Most soil profile consists of three layers which are called horizons.
These are lettered A,B and C
A- Horizon the proper soil
B -horizon the subsoil
C-horizon the solid rock

Soil Composition

- mineral particles (inorganic material)
- humus (organic material)
- water
- air

- living organisms

The actual amounts of each of these depend upon the type of soil rock. Many soil profiles deficient in one or more of these.

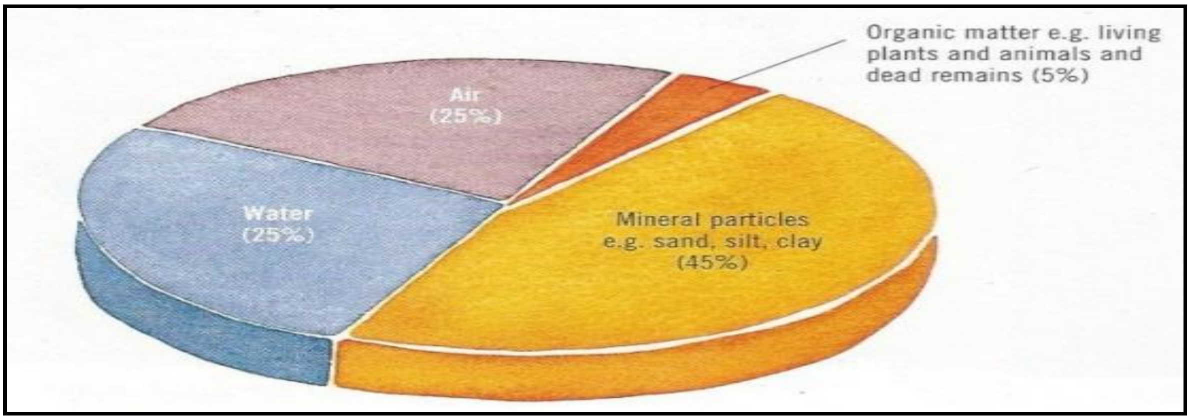


Figure 1.27: Soil Composition

Classification of Soil Types

There are numerous ways of classifying the many soil types of the world. Some soil types develop from the effects of climate and vegetation belt. Some soils develop from the effects of climate where there are no extremes of weathering, relief or drainage (Zonal). Others result from local factors (intrazonal) such as a limestone parent rock, a continuous presence of water, or high altitude. Some soil types are mature having a long time to develop, whereas others are still young (azonal) and soil forming processes have not had time to operate fully.

- **Zonal Soils:** Zonal soils are mature soils. They result from the maximum effects of climate and living matter (vegetation) upon parent rock in areas where there are no extremes of weathering, relief or drainage and where the climate has not been stable for a very long time.
- **Azonal Soils:** Azonal soils have a more recent origin and occur where soil forming processes have had insufficient time to operate fully.
- **Intrazonal Soils:** Intrazonal soils reflect the dominance of a single local factor, such as parent rock or extremes of drainage. As they are not related to general climatic controls, they are not found in zones.

Properties of Soil

All soils are composed of the same basic materials, although the proportions of each vary greatly from one soil type to another. Individual soils are made up of four main components, mineral particles, organic matter, air and water

The four main soil components are intermixed with one another to give three important soil properties.

- soil texture, which is the amount of sand, silt and clay in the soil. Texture influences the soils capacity to retain moisture, air and nutrients.
- soil structure, which is the size and shape of individual particles (or peds) within the soil.
- soil fertility; which how suitable the soil is for crop growth.

Soil Characteristics

Rotting vegetation and animal matter break down to form humus. This is a mixture of decomposed material. It is found in the soil just below the surface layer of plant material known as the leaf litter. The dark colour in the upper layer or soil horizons of some soils is often an indication that soil particles are coated by humus. Humus plays an important role in helping to retain minerals in the soil.

Classification of Soil Types

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Climate plays the greatest part in the formation of a soil, and any classification of major soil types soil will always corresponds with a specific climate. These types are called zonal soils. They are also mature soil.

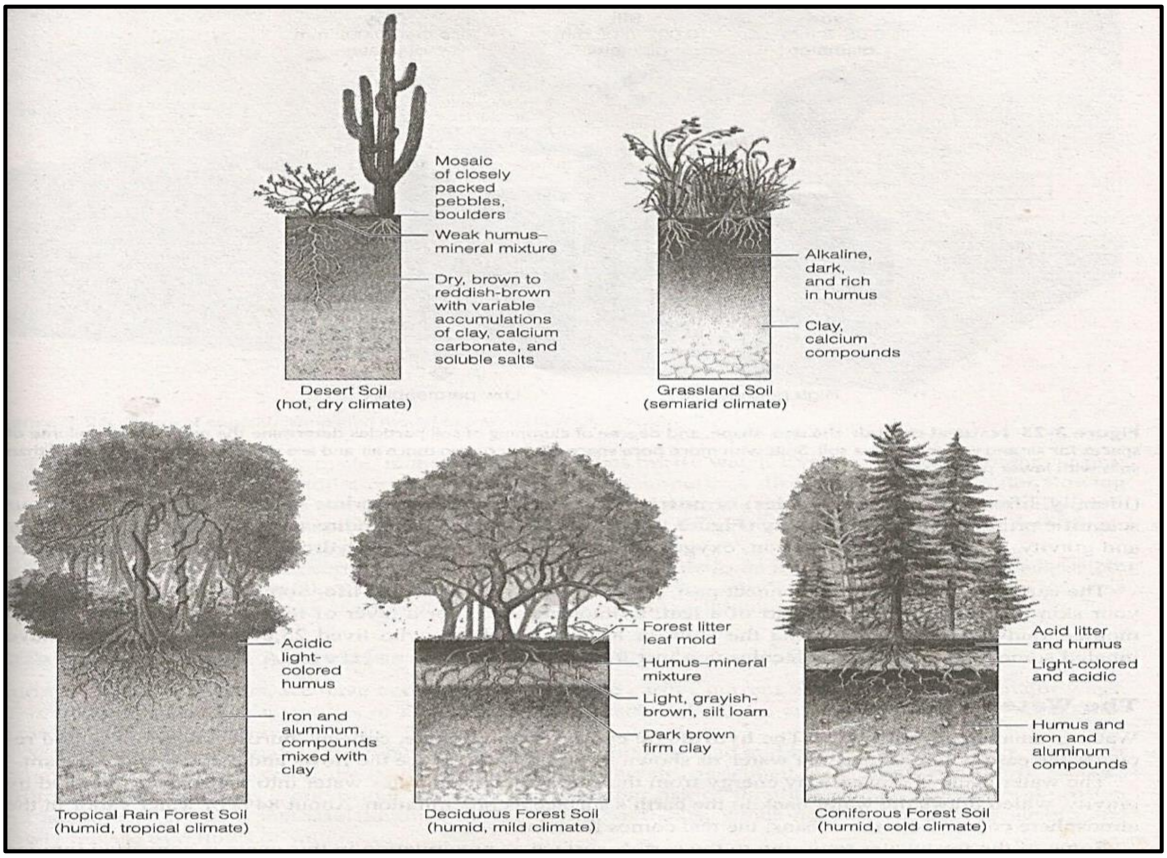


Figure 1.28: Soil profiles of the principal soil types

Zonal Soils

A: Tropical

i) laterite
ii) red soil
iii) black soil
iv) desert soil

B: Temperate Soil

i) podzols
ii) chernozems (black soil)
iii) brown soil
iv) desert soil

Tropical Black Soil

- develops in humid tropical regions which have volcanic rocks
- soil is rich in calcium carbonate and other mineral
- when wet becomes very sticky

Chernozems

- probably the richest soils in the world
- formed under natural vegetation of grass in temperate latitudes
- rich in humus due to very little leaching
- world's wheat is grown on this soil

Temperate Brown Soil

- formed in climatic regions which has natural vegetation of deciduous forest
- soil is rich in humus

Temperate Desert Soil

- soil of arid temperate regions have not been leached
- rich in plant food
- when irrigated often very fertile

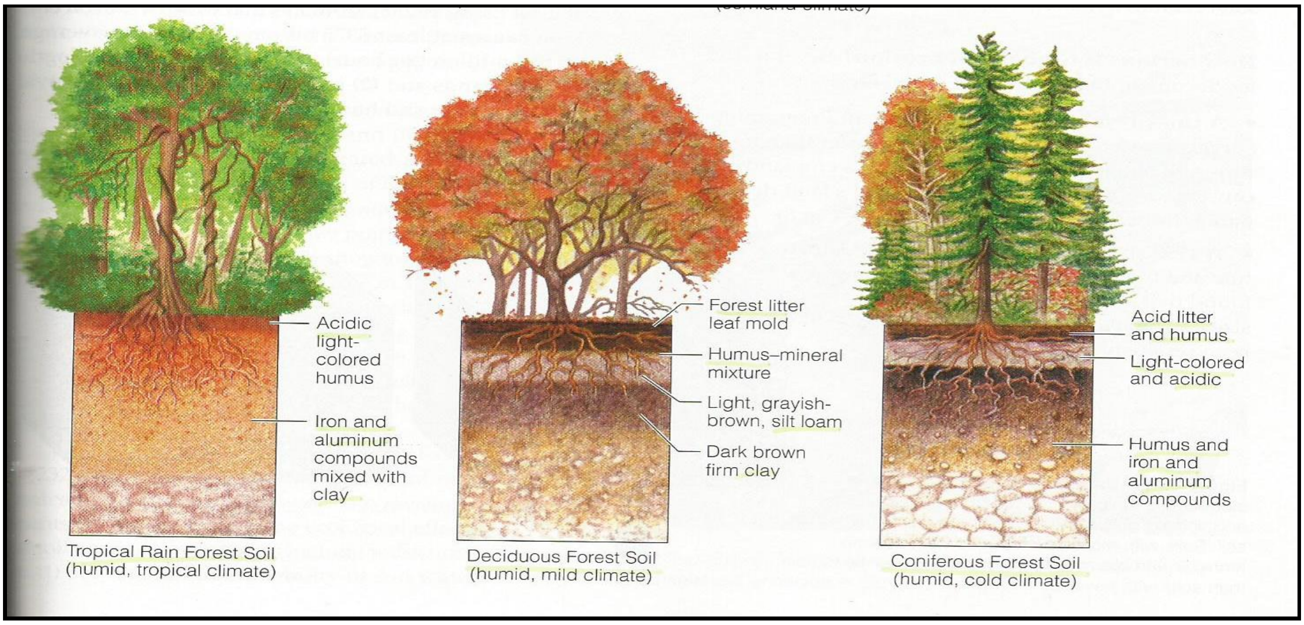


Figure 1.29: The types of forest

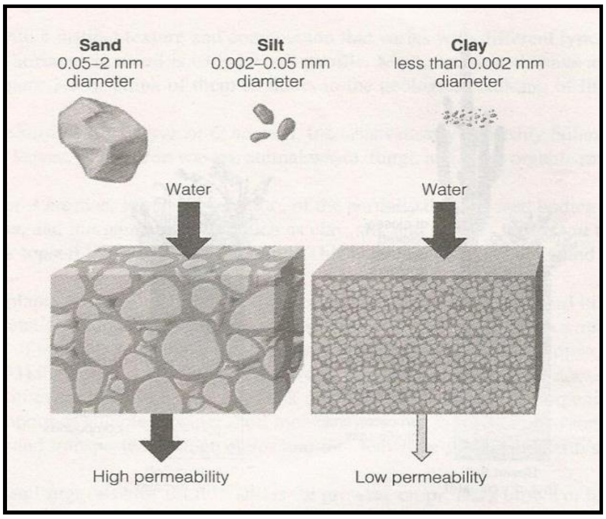
Factors Influencing Soil Profile

i) Water movement in the soil

When rainfall is greater than evaporation, water moves downward in the soil and mineral matter is removed from the top layer **(A Horizon)** and is deposited in the layer beneath **(B horizon**. Very often these deposits give rise to a hard layer which is often called a **hardpan** and this can cause drainage to be poor. When this takes place in a soil the soil is said to be leached. In cold wet regions leaching helps to produce grey soil which is known as a **podzol,** in hot wet regions it may produce a red brown soil known as **laterite**.

ii) Laterite

Is found in tropical and sub-tropical climates and is high in organic matter. Because of high equatorial rainfall in very wet climates, there is widespread leaching of silica and all soluble nutrients.



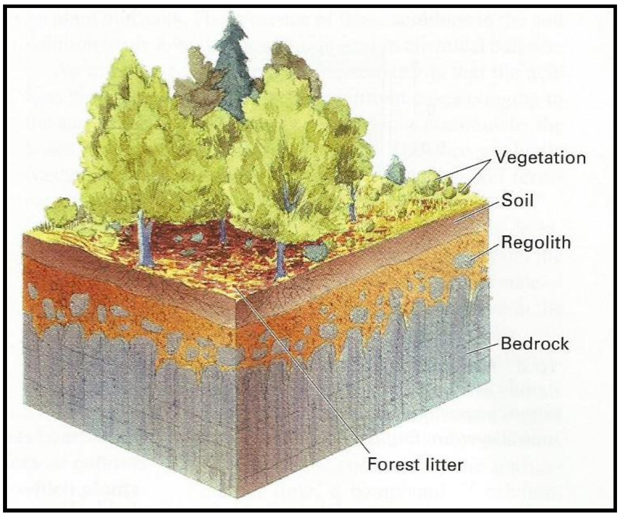


Figure 1.30: A cross section through the land surface

Soil Texture

The term soil texture refers to the proposition of the particles that fall into each of three size grades-sand silt and clay. Soil texture is described by a series of names that emphasized the dominant particle size, whether sand, silt or clay. A loam is a mixture containing a substantial proportion of each of the three grades. Loams are classified as sandy, silt or clay when one of these grades is dominant.

Soils vary in their content of

- Clay (very fine particles)
- Silt (fine particles)
- Sand(medium sized)
- Gravel (coarse to very coarse particles)
- Soils with roughly equal mixtures of clay sand silt and humus are called loams.

Loams are the best soils for growing most crops because they had lots of water, but not too tightly for plants roots to absorb. Sandy soils are easy to work, but water flows rapidly through them. The particles in clay soils are very small and easily compacted. When these soils get wet, they form large dense clumps, which is why wet clays can be molded into bricks and pottery. Clay soils are more porous and have a greater water holding capacity than sandy soils, but the pore spaces are so small that these soils have a low permeability.

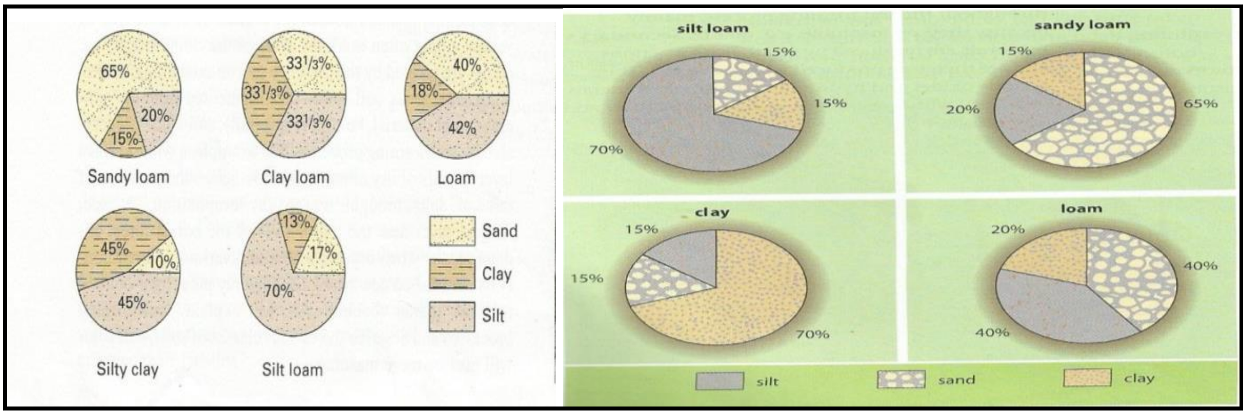


Figure 1.31: The texture of different soil types

Soil Structure

Soil structure refers to the way in which soil grains are grouped together into larger masses called peds. Peds range in size from small grains to large blocks.

Type of structure (ped)	Size of structure (mm)	Description of peds	Shape of peds	Location (horizon: texture) and formation	Agricultural value
crumb	1–5	small individual particles similar to breadcrumbs; porous		*A* horizon: loam soil; formed by action of soil fauna (e.g. earthworms, mites and termites), high content of fibrous roots (grasses) and excretion of micro-organisms	the most productive; well aerated and drained – good for roots
granular	1–5	small individual particles; usually non-porous		*A* horizon: clay soil; formation as for crumb structure	fairly productive; problems with drainage and aeration
platy	1–10	vertical axis much shorter than horizontal, like overlapping plates; restrict flow of water		*B* horizon: silts and clays; formed by contraction by tree roots, especially when trees (e.g. Scots pine) sway in wind. Also due to ice lens, and compaction due to farm machinery	the least productive; hinders water and air movement; restricts roots
blocky	10–75	irregular shape with horizontal and vertical axes about equal; may be rounded or angular but closely fitting		*B* horizon: clay-loam soils; formation associated with wetting–drying and freeze–thaw processes	productive: usually well drained and aerated
prismatic	20–100	vertical axis much larger than horizontal; angular caps and sides to columns		*B* and *C* horizons: often limestones or clays; formation associated with wetting–drying and freeze–thaw processes	usually quite productive: formed by wetting and drying; adequate water movement and root development
columnar	20–100	vertical axis much larger than horizontal; rounded caps and sides to columns		*B* and *C* horizons; alkaline soils; formation associated with accumulation of sodium	quite productive (if water available)

Figure 1.32: Soil structure

Mineral of the Soil

Two classes of minerals are usually recognized, Primary minerals and Secondary minerals. The Primary minerals are compounds present in unaltered rock. They are mostly silicate minerals- compound of silicon and oxygen.

In terms of the properties of soil, the most important secondary minerals are clay minerals. They form the majority of fine mineral particles in soils.

Soil Moisture

Besides providing nutrients for plant growth, the soil layer serves as a reservoir for the moisture that plants require. Soil moisture is a key factor in determining how the soils of a region support vegetation and crops. The soil receives water from rain and from melting snow.

Soil Organism

Soil organism includes bacteria, fungi and earthworms. They are more active and most plentiful in warmer, well drained and aerated soils than they are in colder.

Soil Nutrients

Nutrient is the term given to chemical elements found in the soil which are essential for plant growth and maintenance of the fertility of the soil. The main sources of nutrients are:

1. The weathering of minerals in the soil
2. Release of nutrients during the decomposition of organic matter and humus by soil organisms
3. Rainwater
4. Artificial application of fertilizer

Numerous processes are involved in the formation of soil and creation of the profile, structures and other features described below. Soil forming processes depend on all the five factors

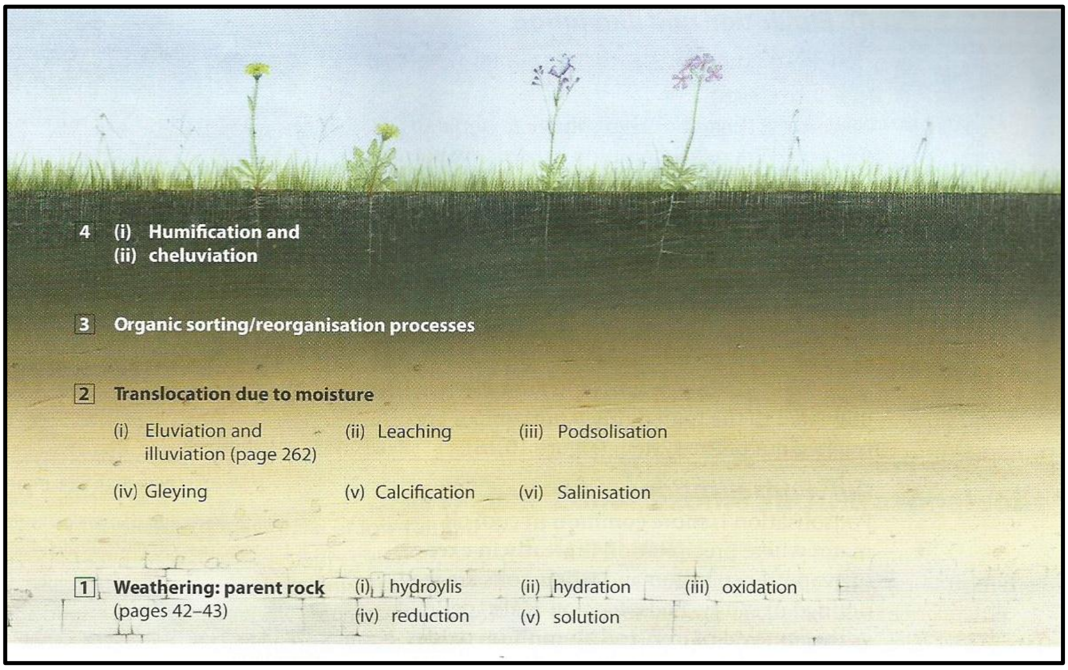


Figure 1.33: Some of the main important soil forming processes

1. Humification

Humification is the process by which organic matter is decomposed to form humus-a task performed by soil organisms. Humification is most active in the H horizon of the soil profile or the upper A horizon.

2. Leaching

Leaching is the removal of soluble material in solution. Where precipitation exceeds evaporation and soil drainage is good, rainwater (containing oxygen, carbonic acids and organic acids) causes chemical weathering.

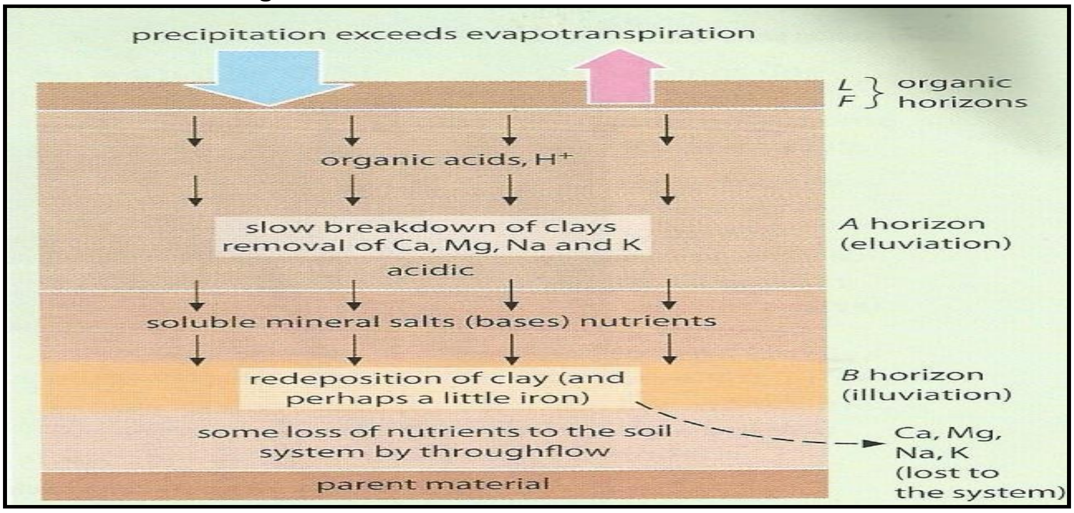


Figure 1.34: The processes of leaching

3. Podzolization

Podsolisation is more common in cool climates where precipitation is greatly in excess of evapotranspiration and where soils are well drained or sandy. Podsolisation is also defined as the removal of iron and aluminiumoxides , together with humus.

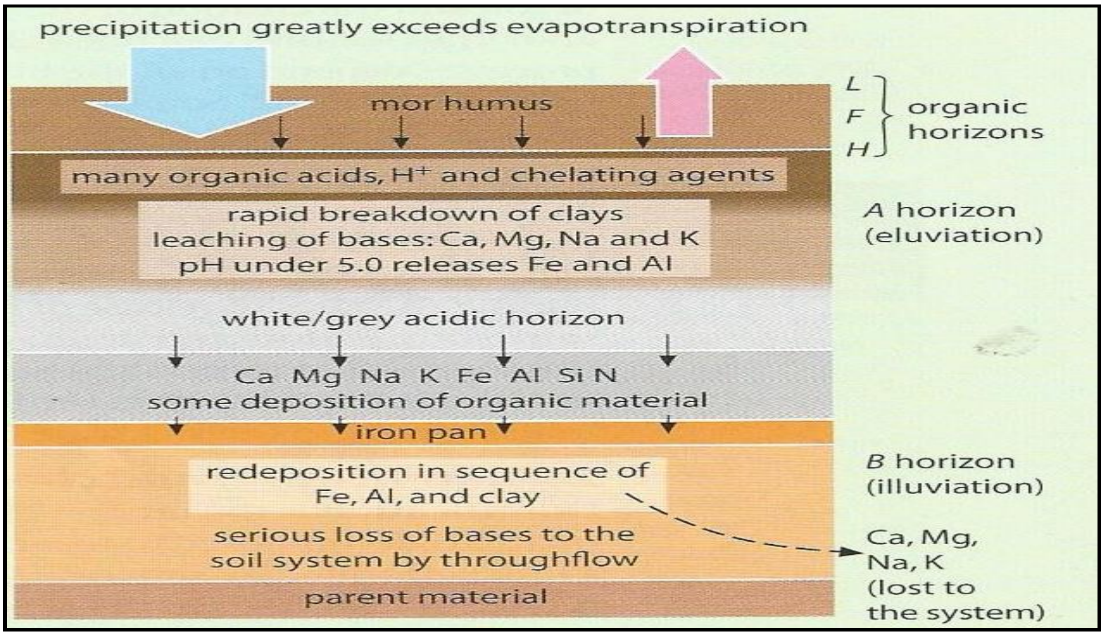


Figure 1.35: The process of podsolization

4. Gleying

This occurs when the output of water in the soil system is restricted giving anaerobic or waterlogged conditions. This is most likely to occur in gentle slopes, in depressions where the underlying rock is impermeable, where the water table is high enough to enter the soil profile or in areas with very high rainfall and poor drainage.

A process that includes an accumulation of humus and a thick, water saturated gray layer or clay beneath, usually in cold, wet climates and poor drainage conditions.

Figure 1.36: Gleying a hydromorphic soil

5. Salination

This is the process that concentrates salts in soils in climates with excessive potential evapotranspiration.

This occurs when evapotranspiration is greater than precipitation in places where the water table is near to the surface. It is therefore found locally in drier climates and is not a characteristics of desert soils. As moisture is evaporated from the surface, salts are drawn upwards in solution by capillary action, Further evaporation results in the deposition of salt as hard crust.

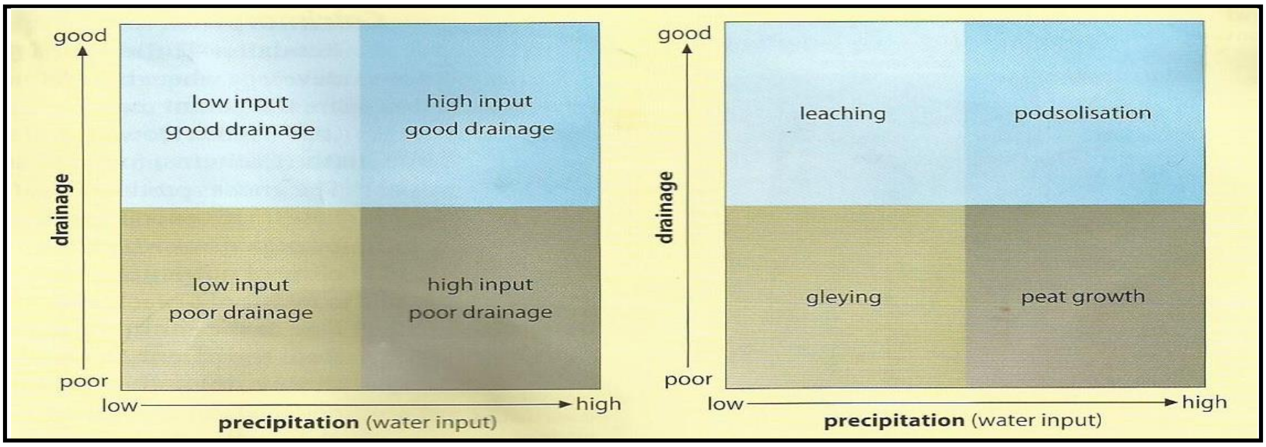


Figure 1.37: Soil forming Processes and the water balance

Student Learning Activities 8

1. What is soil? Explain

____

____

____

2. What are the two main factors influencing the soil profile?

i) _____________________________ ii) ______________________________

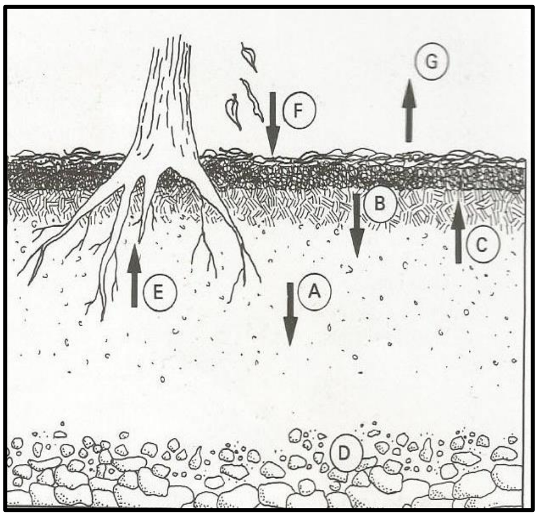
3. List the 5 (five) main factors influencing the soil formation according to Pedologists?

i) _____________________________ iv) ______________________________

ii) _____________________________ v) ______________________________

iii) ______________________________

4. Study the diagram and match the following labels with the arrows (A – G)



I. Leaves accumulate on the soil: ___________
II. Rock weathering: ________
III. Soil moisture loss by evaporation: ___________
IV. Leaching takes clay into B horizon: ______________
V. Soil moisture drawn upwards by capillary action: ___________
VI. Humus washed through A horizon. ________________
VII. Roots take up water and minerals. ________________

5. What is leaching?

____

____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2. : Geomorphic Processes

Introduction

Geomorphology is the science that studies landforms. In this topic, you will be provided with in-depth information on the shape of landforms and furthermore the processes that make them the shape they are and also how their shape has changed through time. Geomorphic processes modify the earth's crust and the shape of the land surface.

This topic will introduce you to the different types of land forming processes. Landscapes are the result of two major sets of processes acting on the surface of the earth. First group of processes are those that add new material to the earth's crust and the second, are those processes which destroy or wear away the rocks and landforms of the earth's surface. These are called the processes of denudation.

Denudation is accomplished by the interaction of three types of activities.

- Weathering
- Mass wasting
- Erosion

Rocks on the earth's surface are in contact with air and water, and it is water that is primarily responsible for denudation. Rocks decay in the presence of air and water, valleys are cut back by running water and by glacier ice, and the coast is worn away by the actions of waves

Objectives or aims

On successful completion of this module, students will be able to:

- Identify the geomorphic processes that wear and reshape landforms
- Discuss erosion, transportation and deposition as processes involved in reshaping land features
- Define mass movement, identify and explain the different types of mass movement.
- Define weathering and explain the different types of weathering.

Time Frame

This unit should be completed within 3 weeks.

11.1.2.1 : Erosion, Transportation and Deposition

Weathering produces rock, mineral and chemical debris at the place where the original rock was exposed. This material is usually moved or transported to a different site before being deposited as sediment.

Erosion can be defined as the process of the wearing away of the land surface by natural agents (running water, ice wave action, wind).

Erosion can happen in three ways;

1. If water moves across the soil, the force of the water will be enough to pick up some particles of soil.
2. These particles in turn will help to break off more particles. Sand which is blown along by the wind does the same thing. Weathered material which is being transported by water, ice or wind acts like hammers to wear away the land
3. Sometimes also a river may dissolve its bed and banks.

Transportation

Transportation is the carrying of the material from one place to another. This material is usually moved or transported to a different site before being deposited as a sediment. The material can be moved in several different ways:

- By gravity
- By water in rivers and streams
- By water in the sea
- By glacial ice
- By wind

Often several of these agents of transportation may move one sediment.

Deposition

Deposition is the dropping of materials which have been picked up and transported by wind, water, or ice.

The action of laying down of material, especially of the debris transported by wind, running water, waves and ice.

The photograph on the right shows a stream that has deposited larger materials like gravel and pebbles along the inside curve of a meander.

Figure 2.1: A meander

Student Learning Activities 1

1. What is the term that refers to the disintegration or braking down of rocks, minerals and chemical debris?

____

2. Of these processes, what is the order of which they appear?

____

____

____

3. What is the difference between erosion and deposition?

____

____

____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.2 : Coastal Processes and Landform

The sea shapes the coastal landscape. Coastal erosion is the wearing away and breaking up of rock along the coast. **Destructive waves** erode the coastline in a number of ways:

- **Hydraulic action**. Air may become trapped in joints and cracks on a cliff face. When a wave breaks, the trapped air is compressed which weakens the cliff and causes erosion.
- **Abrasion**. Bits of rock and sand in waves grind down cliff surfaces like sandpaper.
- **Attrition**. Waves smash rocks and pebbles on the shore into each other, and they break and become smoother.
- **Solution**. Acids contained in sea water will dissolve some types of rock such as chalk or limestone.

Ocean waves are energy traveling through water. They form when wind blows over the surface of the ocean. Wind energy is transferred to the sea surface. Then, the energy is carried through the water by the waves. Ocean waves transfer energy from the wind through the water. This gives waves the energy to erode the shore.

Three factors determine the size of ocean waves:

i) The speed of the wind.
ii) The length of time the wind blows.
iii) The distance the wind blows.

The faster, longer, and farther the wind blows, the bigger the waves are. Bigger waves have more energy. Runoff, streams, and rivers carry sediment to the oceans. The sediment in ocean water acts like sandpaper. Over time, they erode the shore. The bigger the waves are and the more sediment they carry, the more erosion they cause.

Types of Waves

1. **Constructive waves-flat waves** that are thrown on the beach, travels longer distances up the beach (swash) at an oblique angle and deposits sediments it has carried.

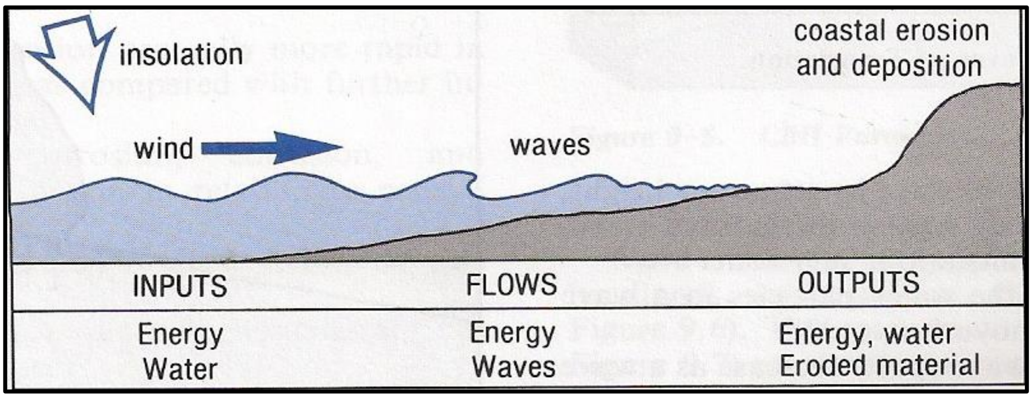


Figure: 2.2: The Coastal systems

2. **Destructive waves-steep or high waves** are those that retreat back to the sea as the backwash. It removes sediments from the beach and carries more sediments than swash into the open waters, it travels at right angles due to force of gravity.
Some of the important terms to get to know are:

Wave Crest Is the highest point of a wave

T**rough** Is the lowest point of a wave

Wave Height Is the difference between the two.

Fetch Is the distance of open water over which the wind blows.

Coastal Landforms of Erosion

1. **Headlands and Bays**
   - Headlands receive high energy waves and more vulnerable to erosion
   - Found at areas of alternating and less alternating rocks (hard or soft rocks)

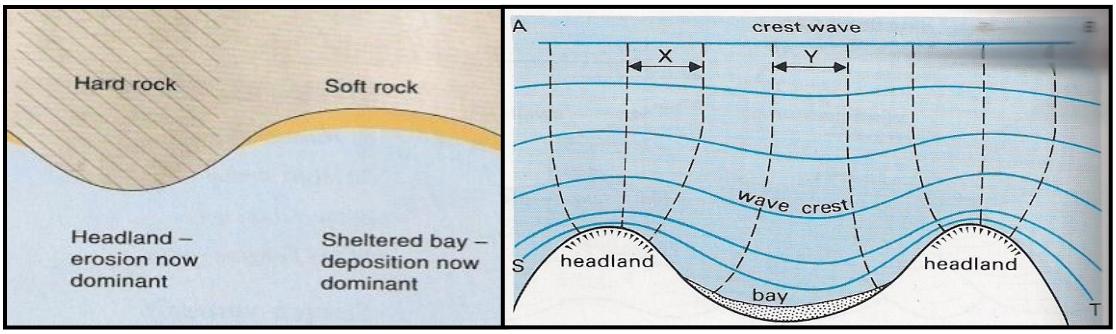


Figure 2.3: Headlands and bays

How waves cause Erosion around the headland
Wave Refraction
Wave refraction along a bay and the headland coast
Wave AB approaches the shore at right angles to it. It's crest line is straight, Segments X and Y are of same width and same amount of energy. Both are in deep waters in position AB.

As they move towards the shore, segment X reaches shallower water first and it slows down. Segment Y which is approaching the bay is not slowed down, the wave length of X is reduced and height is increased. At position ST segment X breaks on the headland-energy of segment X is concentrated over a smaller length of coast than that of segment Y.

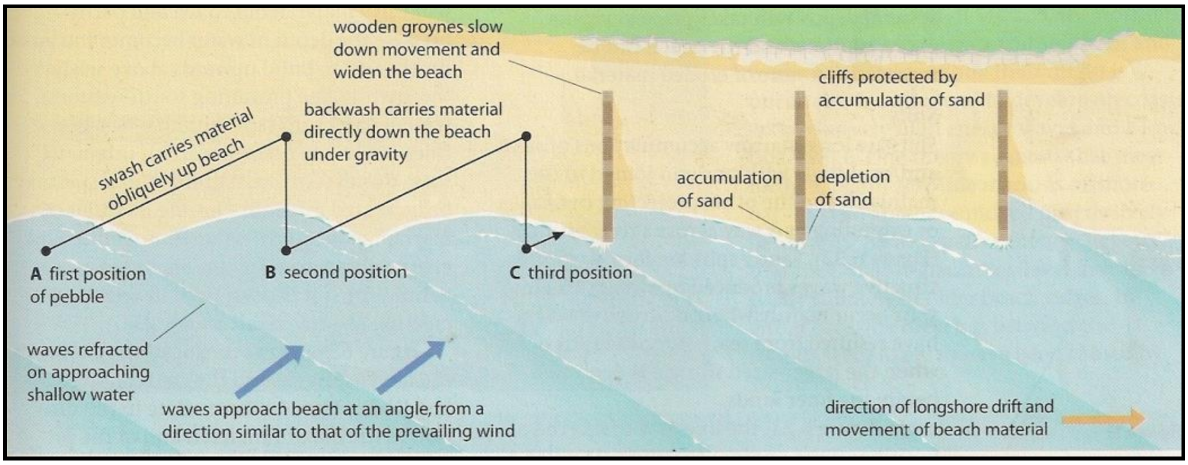


Figure 2.4: Formation of the long shore drift current

In deep waters wave crest move forward at right angles to the wind direction. When they reach shallow water, the waves are slowed by friction at the base . This may cause a bend to develop in the wav e crest. The effect is to spread the energy around the headland. This bending is **called wave refraction.**

2. Caves

Wave attack on the sides of a headland sometimes lead to the formation of caves especially where there are vertical faults or joints.

3. Blowhole

Joints and bedding planes are opened under wave attack both by abrasion and hydraulic action. Breaking waves puts enormous pressure on the rocks at the base of the cliff. Breaking waves compress air trapped in cracks and crevices but when waves retreat the pressure is released and the air expands.

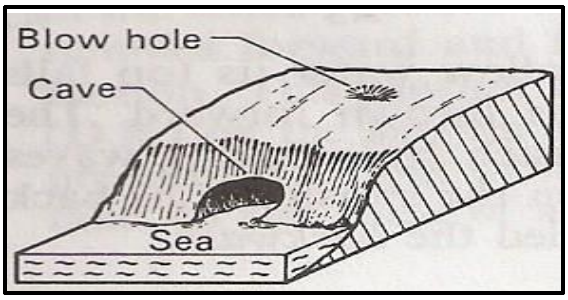


Figure 2.5: Blow hole

When a joint is extended to the top of the cliff, it becomes enlarged by alternate compression and expansion of air in the joint, and in time the joint may be opened right up to the top of the cliff. This forms the blow hole

4. Inlets

Inlets are formed when the water breaches the island during a large storm, such as a hurricane or northeaster accompanied by high storm surges and high waves. Inlets are often carved from a surge of water flowing from behind the barrier towards the ocean.

5. Arches

Sometimes a cave in a headland or similar feature is eroded right through to form a natural arch.

6. Stack
When the roof of the arch collapses, a stack is formed. The diagram on the next page shows the different features formed by movement of waves.

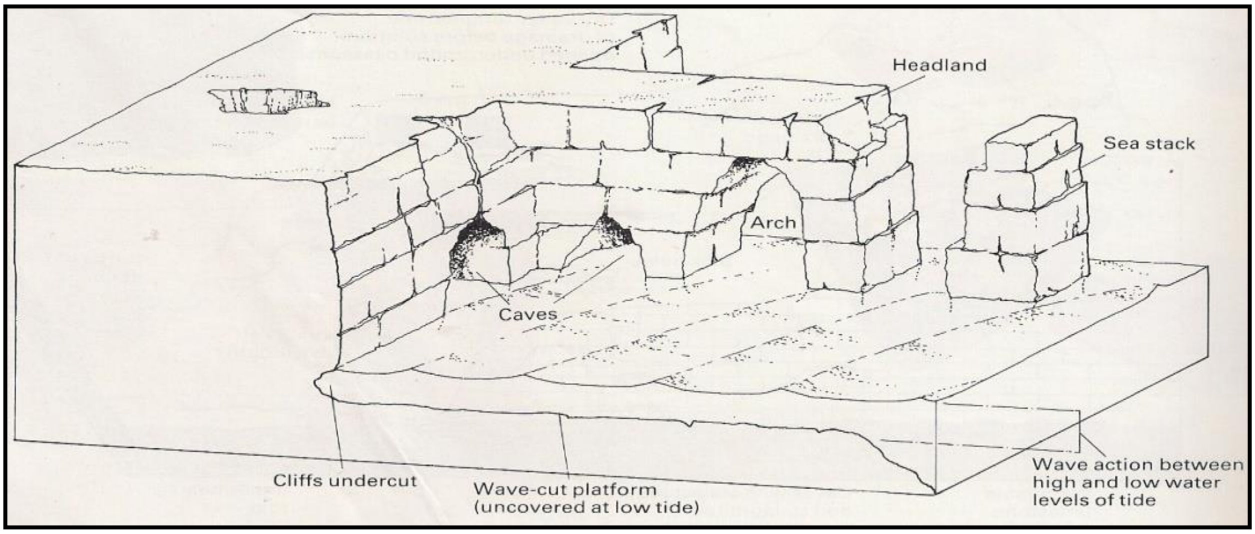
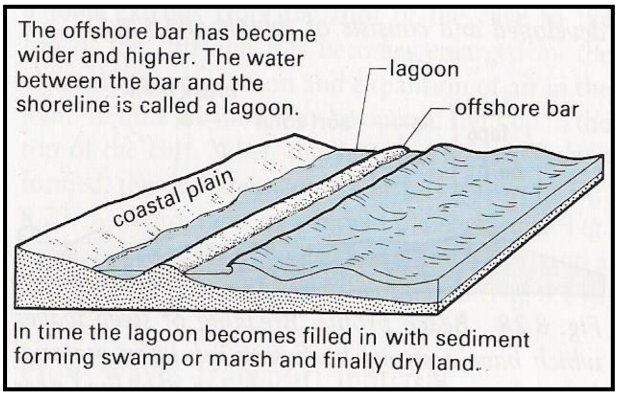


Figure 2.6: Coastal erosional landforms

Landforms Produced by Wave Deposition

1. **Beach:** made of sand shingle, boulders or mud.
   - Material comes from eroded headlands, rivers and other beaches through the action of longshore drift and all of this is sorted by the action of swash and backwash.
2. **Spit**
   - Long narrow ridge of pebbles or sand joined to the land or island at one end with the other end terminating out into the sea.
   - Formed by longshore drift.

3. **Bar**
   - Ridge of sediment which is parallel to the coast , may be exposed at both high or low tides or only at low tides or not at all.
   - A bar often develops in to a barrier.



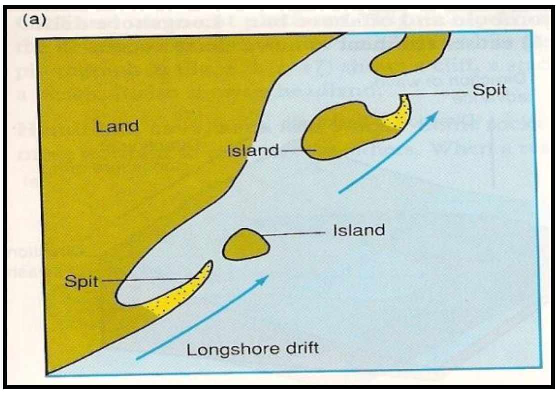


Figure 2.7: Formation of a Barrier island

4. **Barrier Island**

- It is a long ridge of sand parallel to the coast and separated from it by a lagoon.
- A Barrier island often develops from an underwater offshore bar as the latter moves towards the land.
- It is called a barrier island when its surface appears above water.

5. **Tombolo**

When a bar joins an island to the mainland it becomes a Tombolo.

Fiord/ Fjord: Drowned glaciated valleys are called fiords

- When coast of a glaciated highland is submerged, lower part of the glaciated trough is drowned to form a fiord.
- Sides of fiords are very steep and the depth of water it may have exceed 1000m
- Fiords's great depths resulted from glacial erosion, often to below sea level
- Water depth at seaward end of fiord is shallower than is inside the fiord

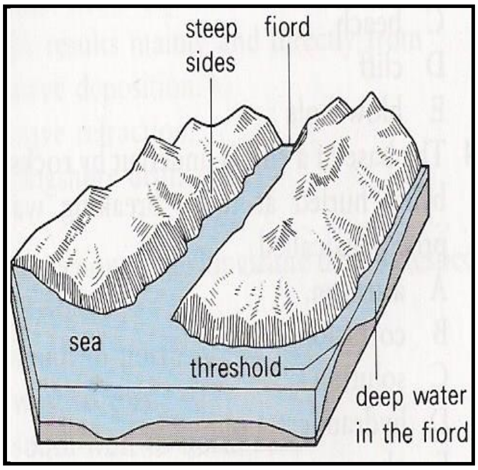
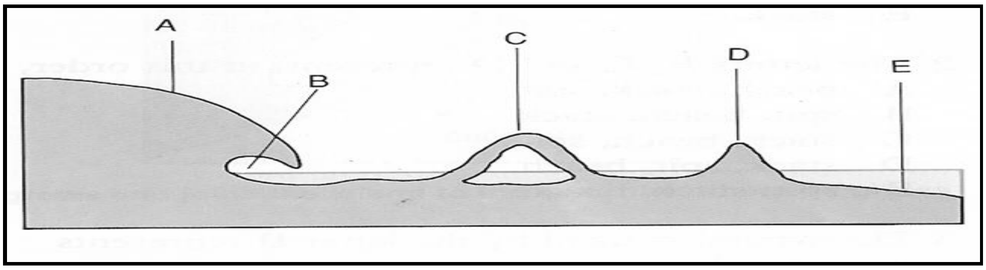


Figure 2.8: Formation of a fiord

Now do the activity on the next page.

Student Learning Activities 2

The diagram below shows a cross section through part of a coast.



1. Name the features ;

   A: __________________ B: ___________________ C: _________________

   D: _________________ E:___________________

2. Explain how feature D was formed?

   ____

   ____

3. Explain how the action of the waves can cause materials to move along a shoreline?

   ____

   ____

   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.3 : Desert Processes and Landforms

Desert Landscape

Wind the fourth agent of erosion produces a variety of interesting landforms, both erosional and depositional. The work of the wind-erosion, transportation, and deposition is called eolian (also spelled Aeolian)

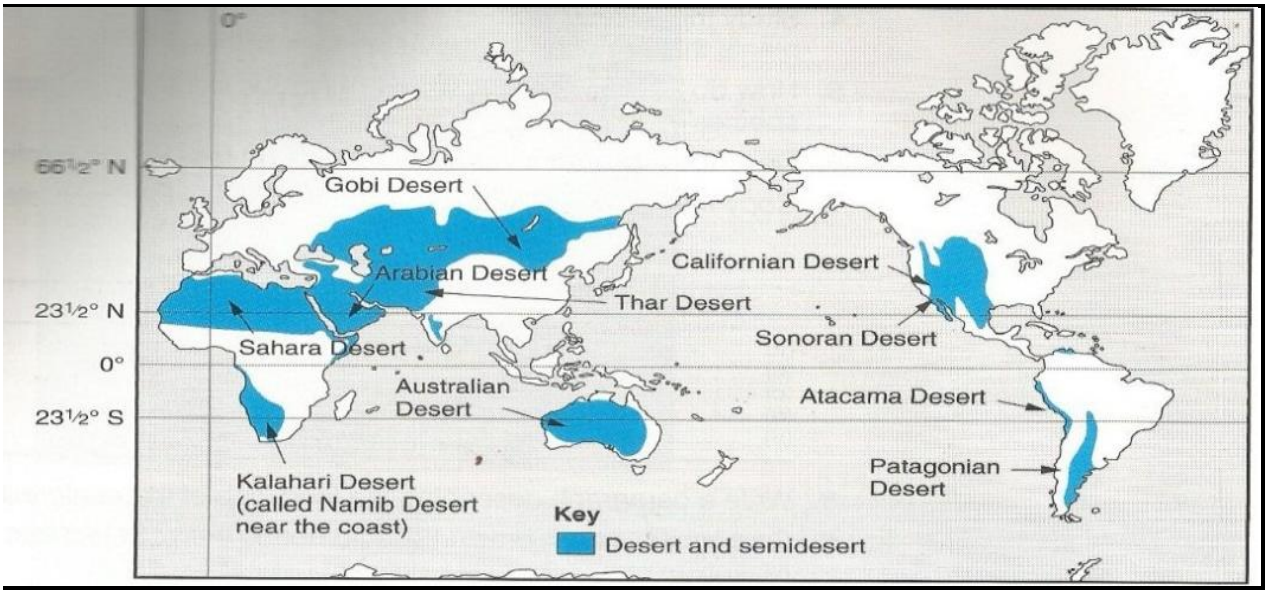


Figure 2.9: World deserts

Why Deserts Occur

Aridity (caused by low rainfall and high evaporation) is the main characteristic of a **desert. Arid deserts** rarely receive more than an average rainfall of 250 mm a year, but a semi-arid deserts such as the Kalahari, receive at least 500 mm a year.

World Deserts

Most of the world's deserts are located in latitudinal belts of 15 to 30 north and south of the equator. Most of the world's deserts have a tropical latitude. Although the role of prevailing winds from dry land and the presence of rain shadow areas is important, it is latitude which best explains the desert climate.

- **Hot deserts**, including the Sahara, lie in Subtropical zones. The **Sahara** is the largest of the world's deserts. Its land area is larger than the continent of Australia. Some hot deserts are along coasts, for example the Namib Desert.

- **Cold deserts** lie far from the sea in the higher latitudes-between the subtropical hot deserts and the polar regions. High Latitude cold deserts include the Gobi Desert of Central Asia and the Patagonian Desert of South America.

- Most but not all deserts are hot, but the Gobi desert in winter is one of the coldest places on earth.

HOT & COLD DESERTS **There are ten major deserts regions. Cold deserts have hot summers and relatively cold winters. Hot deserts are hot during the day all year around**	
HOT	**COLD**
Sahara	Gobi
Namib-Kalahari	Turkestan
Arabian	Patagonian
Iranian	
Atacama (Chile)	
Australian	
Thar (India-Pakistan)	
Mojave (S. Western USA)	
Chihuahuan (Mexico)	
Sonoran (S. Western USA)	

Figure 2.10: Table showing World Hot and Cold Deserts

Characteristics of World's Great Deserts Are:

- Rare clouds
- Little rain
- Very hot days
- Extremely cold nights

Geographical Processes Operating In Hot Deserts

There are several main atmospheric influences that contribute to the formation of hot deserts. Atmospheric processes are those that take place in the gaseous layer surrounding the earth. These include

- Global air circulation
- Rainshadow effect
- Cold ocean currents

LARGEST DESERTS

DESERT	LOCATION	SIZE km^2
1. Sahara	North Africa	8 400 000
2. Australia	Australia	1 550 000
3. Arabian	South-West Asia	1 300 000
4. Gobi	Central Asia	1040 000
5. Patagonian	South America	670 000
6. Kalahari	Southern Africa	520 000
7. Turkestan	Central Asia	450 000
8. TaklaMakan	China	320 000
9. Sonoran	USA Mexico	310 000
10. Namib	South West Africa	310 000

Figure 2.11: Table showing World's largest deserts

Hot deserts at night

At night in hot deserts, it is cool after a long hot day. There is a large diurnal (daily) range in temperature. Deserts cool down rapidly after sunset because there is not enough vegetation to retain the heat through the night, nor is there insulation from clouds. For this reason, deserts warm up quickly once the sun rises.

Diurnal Range is the difference between the highest and the lowest temperature in one day.

Insulation refers to the cover that acts like blanket to trap heat in the atmosphere.

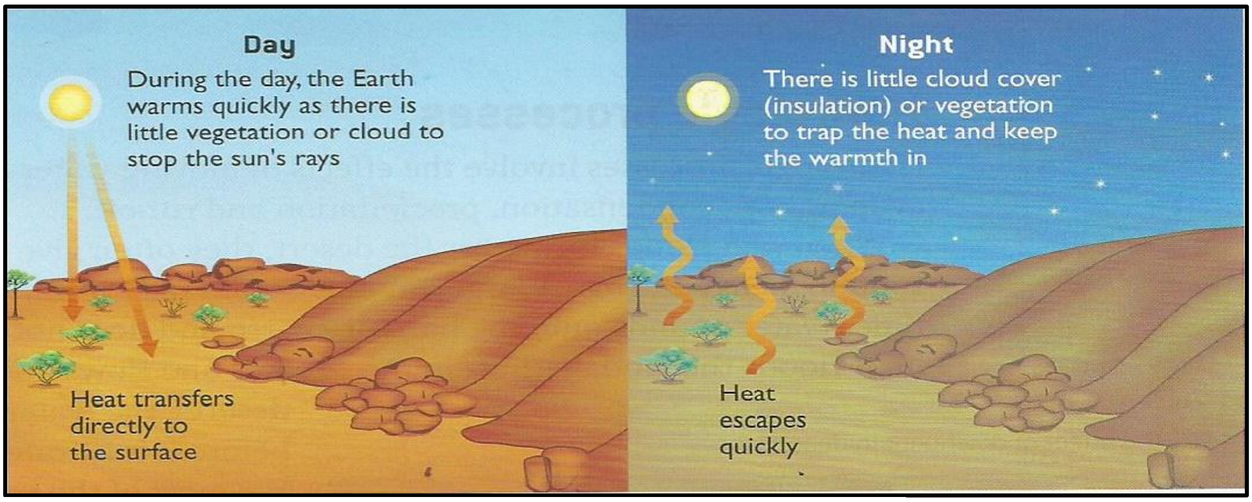


Figure 2.12: The change between day and night temperatures in hot deserts

Global distribution of major hot deserts

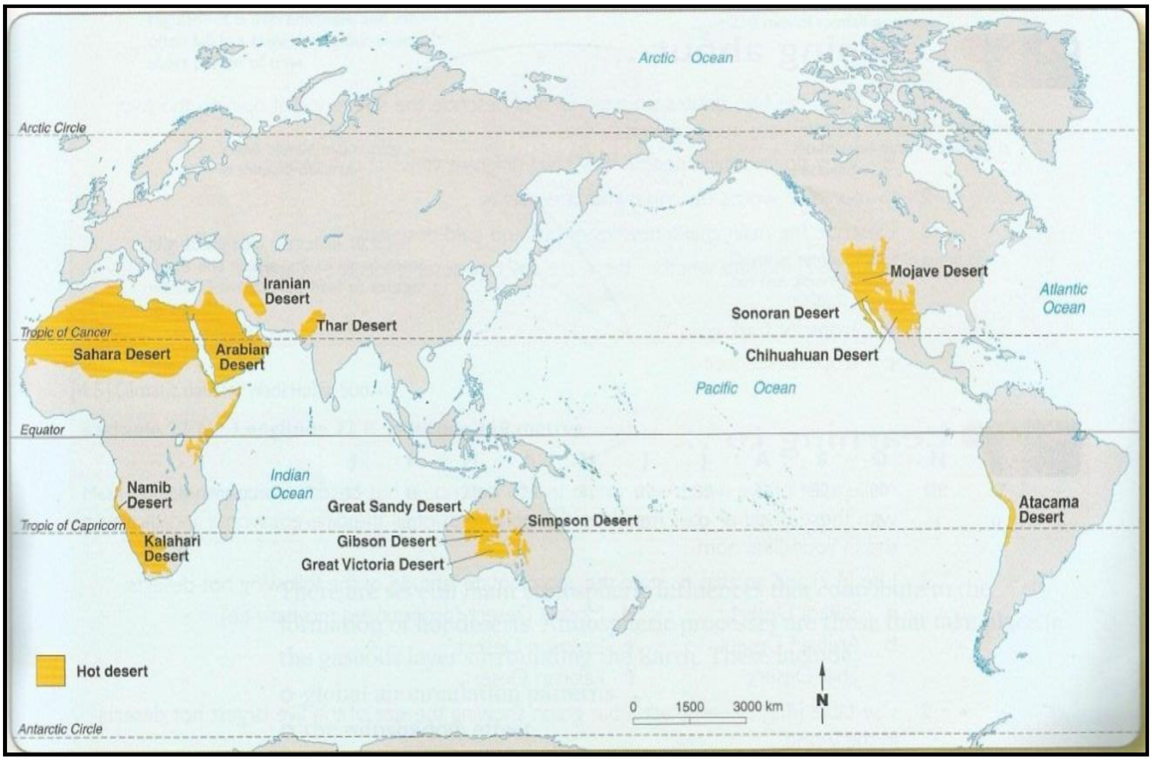


Figure 2.13: Map showing Hot Deserts

Global Air Circulation

Most hot deserts occur along two bands that circle the globe at latitudes about 20^0 N to 30 ^{0}N and 20^0 S and 30^0 S. Deserts tend to be at these latitudes due to the motion of air within the atmosphere. At the Equatorial regions, warm moist air rises, producing much of the rainfall that occurs in these areas. Much of the moisture in the air is left behind at the equator. This warm air cools and expands, as it rises and moves north and south away from the equator.

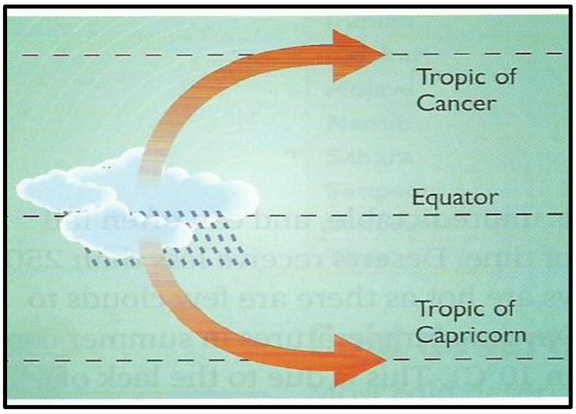


Figure 2.14: Dry air flows out of equatorial

As it descends back towards the ground, it heats up, permitting more moisture to be absorbed. This warm dry air sinks back to the surface at about 30^0 N and 30^0 S, and is so dry it soaks moisture from the ground. The regions 30^0N and 30^0S generally have clear skies, low rainfall and high evaporation. Persistent high pressure systems tend to block incoming storms or push them into other regions. All these are prime characters of deserts.

Cold Ocean Currents

Cold ocean currents lie off the west coast of all continents with deserts. Air over cold oceans becomes cool. Cool air is less likely to absorb moisture than warm air. If this cool dry air moves over dry land, it becomes warmer and dry.

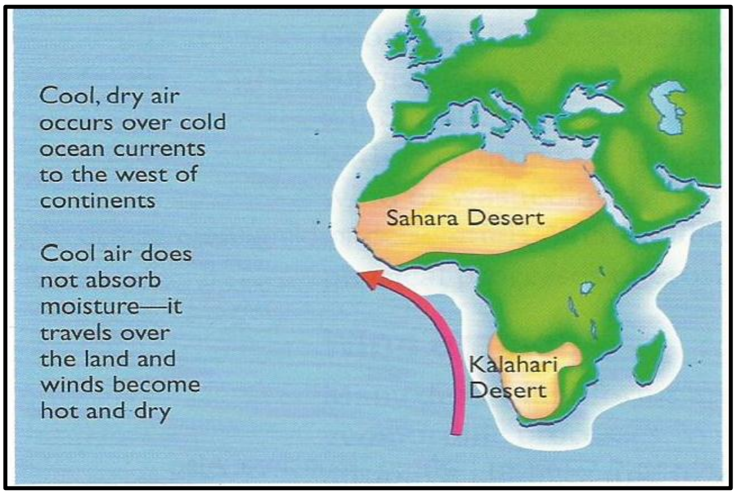


Figure 2.15: Cold ocean currents

Such cold ocean currents influence the Atacama (Chile) and Kalahari (S. Africa) deserts. Cold oceans currents inhibit the formation of rain clouds. Evaporation is a function of heat, so cold oceans do not provide the moisture that warm oceans

Rain shadow effect

Another atmospheric process influencing some deserts, is the rain shadow effect. Deserts created by the rainshadow effect from behind mountain ranges. Air rises to pass over the mountain ranges, causing rain to fall on the ocean side of the mountain-the windward side.

On the other side-the leeward side, it becomes dry and deserts are in **rainshadow**. This means they are blocked from the rain by the mountain barriers. Examples of this type of desert include the Gobi desert in China,Pantagonia Desert in Argentina and the Mojave Desrt in South-Western United States.

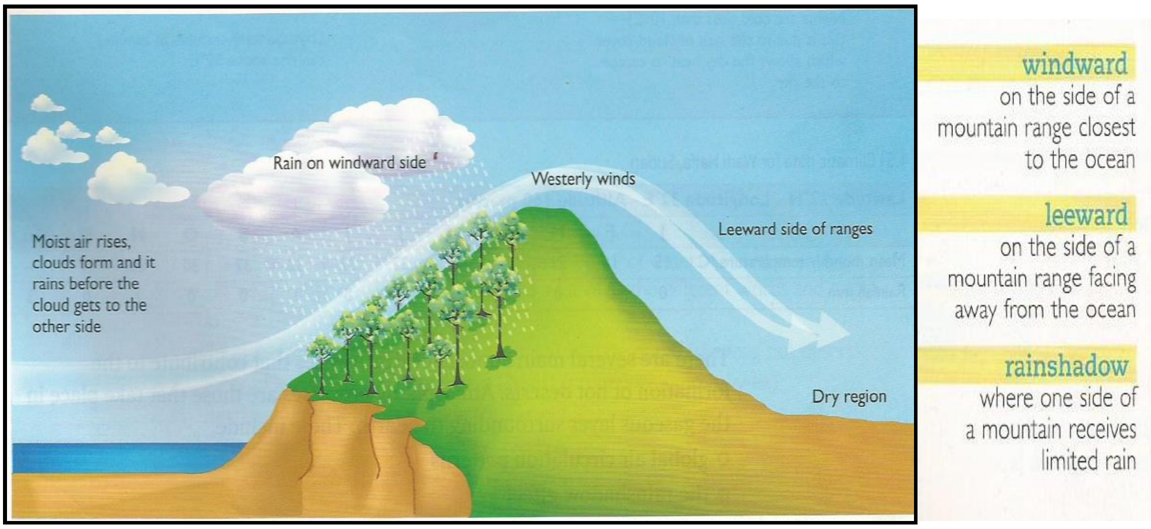


Figure 2.16 : The rain shadow effect

Types of Deserts

The combined action of wind and water produces four main types of deserts landscape.

1. **ERG or sandy desert: (also called sand sea)**
   - Sandy desert called erg in the sahara and koun in Turkestan.
   - Erg is a sandy desert with large areas of moving sand dunes. Sand is shaped into dunes by the wind.
   - This consists of undulating plain of sand, the surface of which is blown into ripples and sand dunes.

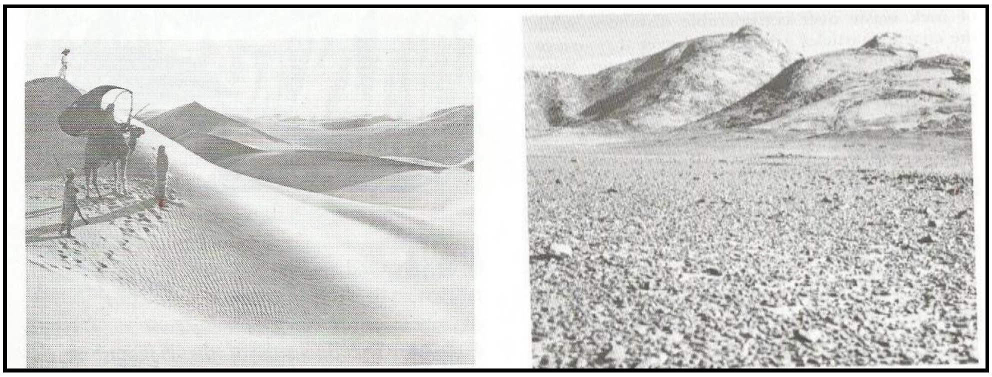


Figure 2.17 : Sandy desert or erg in Sahara

2. REG or stony desert:

- Stony desert called ***reg*** in Algeria and ***serir*** in Libya and Egypt
- Is a gravel desert, usually the most inhospitable of the desert environments.
- The surface is covered with boulders angular pebbles and gravels which have been produced by daily temperature changes.

3. **Hamada or rocky desert**:

- Called Hamada in Sahara.
- Hamada is a flat rocky desert, swept clear of sand by wind.
- This consist of extensive areas of bare rocks from which all fine materials have been removed by deflation while abrasion polishes and smooths the rock surfaces.

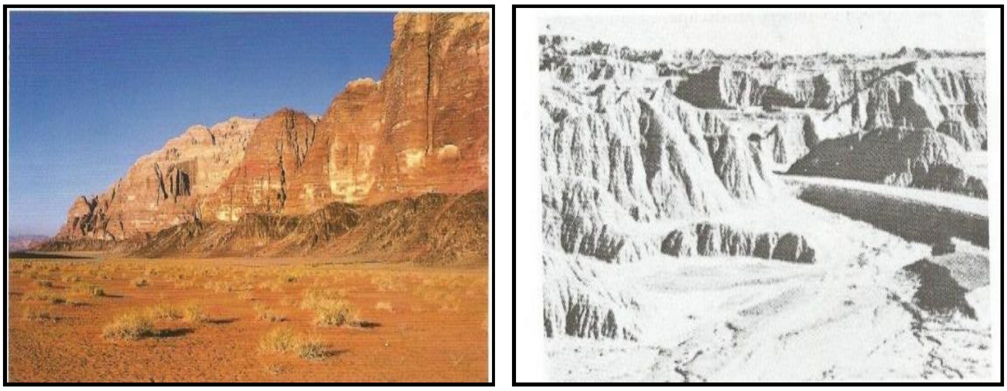


Figure 2.18: The Badlands

4. **Badlands**: This type of desert is quite different from the three in that it develops in semi-deserts regions which experience sudden violent rainstorms

Water in the Desert

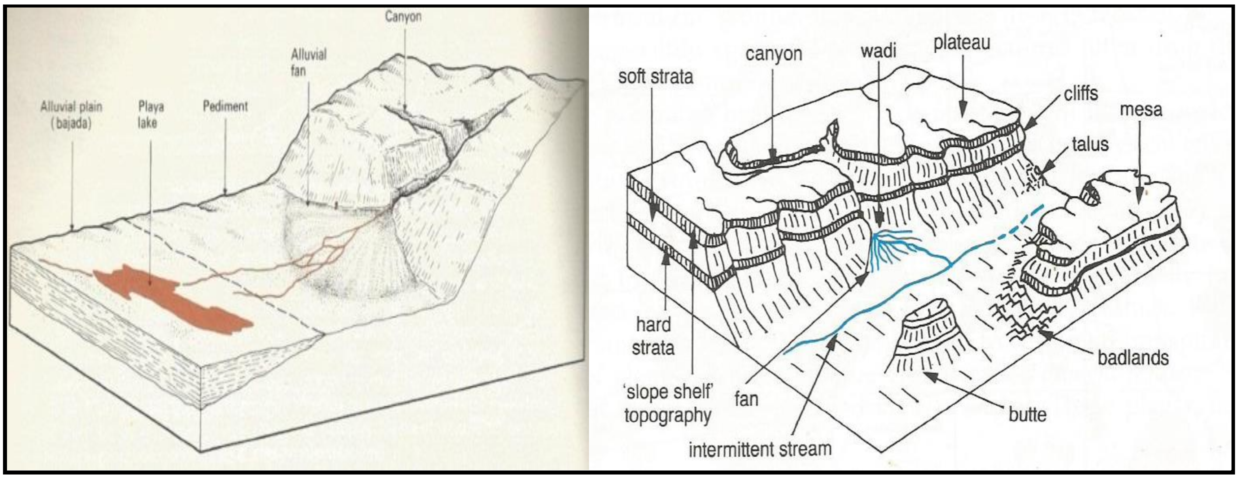


Figure 2.19: showing the main water eroded desert landscape

Water also helps to shape the desert environment, when rare heavy downpours cause floods. The flood water picks up loose rock, ranging from dust to large boulders and sweeps them along valleys, deepening and broadening them as it surges along.

These normally dry valleys are called **wadis.** The water deposits the loose rocks on the beds of temporary lakes called **playas.** At the bottom of some of some slopes loose stones pile up in heaps called **alluvial fans** or cones. A **bajadas** is formed when several alluvial fans merge.

Canyons are also desert features that have been formed by water. A **canyon** is a narrow, deep steep –sided gorge or valley. It is formed by a river cutting down through soft rocks in a arid region.

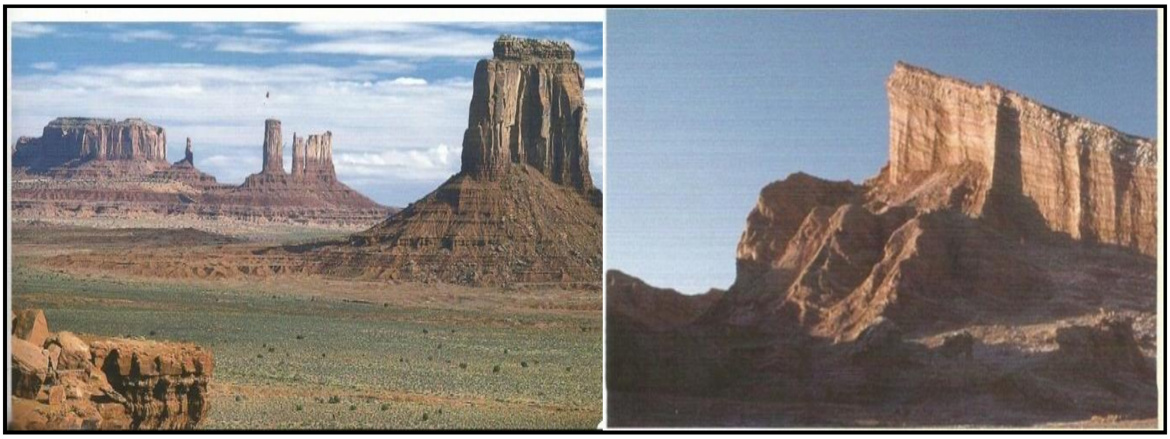


Figure 2.20: Showing Pediments

Pediments: Is a broad relatively flat surface eroded across the bedrock. Although from a distance a pediment may resemble a bajada, it is a bedrock surface rather than a thick alluvial fill. Is one of the most characteristic landforms of the dry regions.

Desert Landforms Shaped By Water

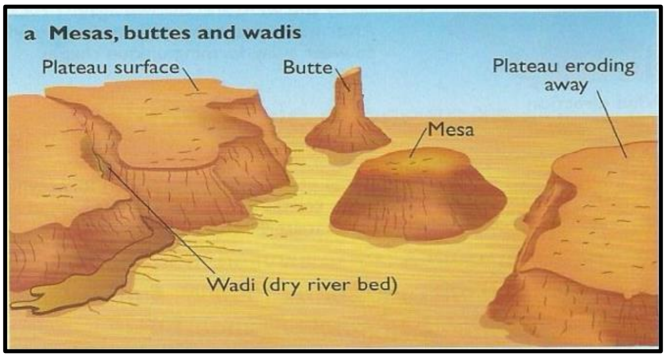


Figure 2.21: Desert mesas. Buttes and wadis

Plateau lands that become heavily eroded by the action of the running water, produce a landscape of mesas and buttes. These are the remains of the more resistant former plateaus. Wadis are dry river beds or dry river course that have been shaped by flash flood

When hilly or mountainous country is severely chopped up by heavy storms and flash floods, a landscape known as badlands is formed. The landscape was called this because it provided shelter for robbers on horseback.

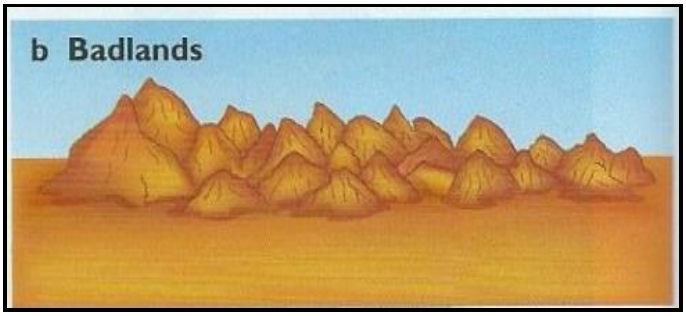


Figure 2.22: Badlands

The streams that flow after rain, carry loads of sand and rock fragments as they cut through narrow gorges and gullies. When these streams hit flatter lands they tend to spray their loads out in fan like way forming alluvial fans and playa lakes.

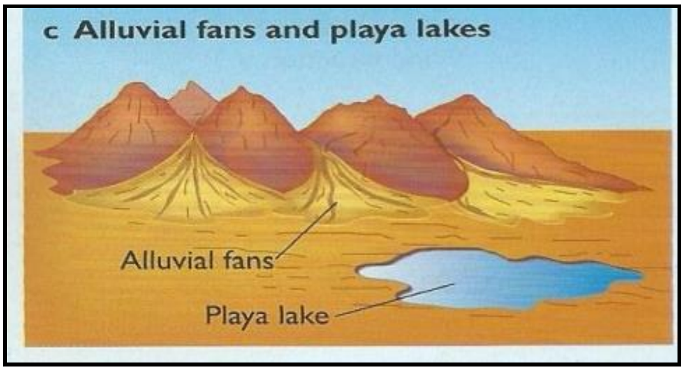


Figure 2.23: Alluvial fans and playa lakes

When the land surface is very flat and low, rainwater often collects in holes to form playa lakesOther desert features such as mesas (flat-topped mountains) and buttes (jagged columns of rocks) are made by running water, although they are also the work of wind erosion.

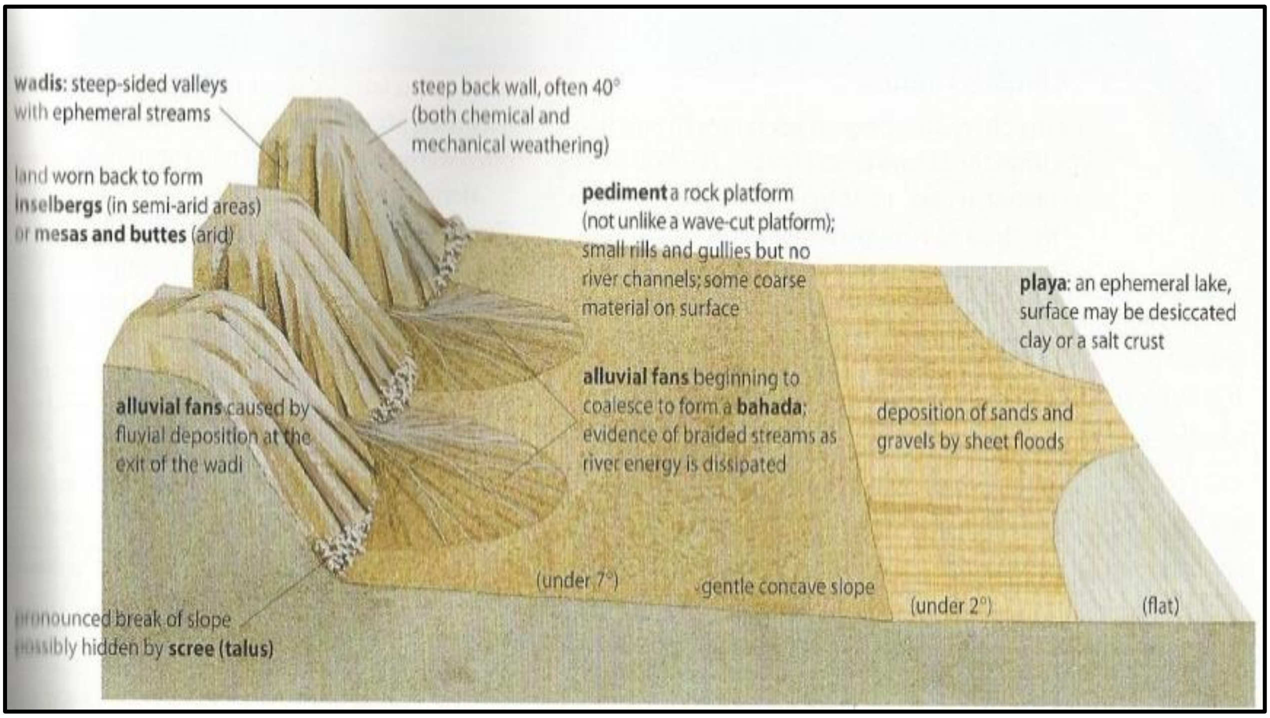


Figure 2.24: Water forming desert features

Erosion by Wind

Winds perform two kinds of erosional work;

1. **Deflation** which blows away rock waste and thus lowers the desert surface producing depression.
2. **Abrasion** which breaks up rocks and produces rock pedestal, zuegens, yandangs and inselberges.

1. **Deflation (Latin meaning to blow away)**

- Deflation is the picking up and removal of loose rock fragments, sand, and dust by the wind.

- Loose particles lying upon the ground surface may be lifted into the air or rolled along the ground or is simply the removal and lifting of individual loose particles by the wind. Deflation acts whenever the ground surface is thoroughly dried out and is littered with small loose particles derived by rock weathering or previously deposited by running water, ice or waves.
- Literally blows away loose or non- cohesive sediments. Fine materials are eroded away by wind deflation and moving water, leaving behind a concentration of pebbles and gravel called desert pavement. Water is an important factor in the formation of a desert pavement.

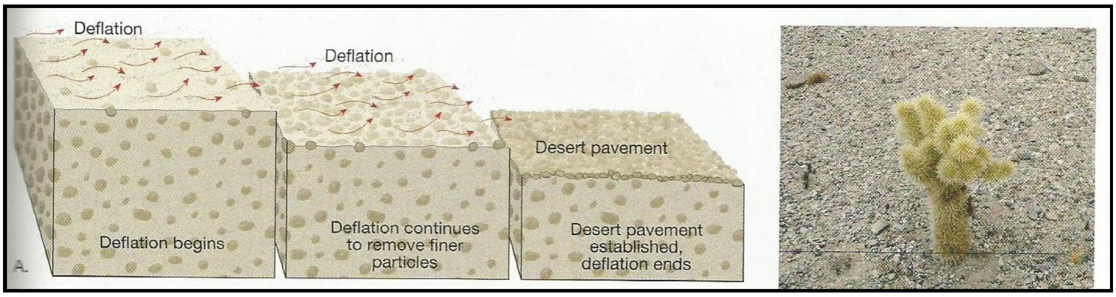


Figure 2.25: Process of deflation

Wherever wind encounters loose sediments, deflation may remove enough material to form basins called blowout depressions.

2 Abrasion

- results when rock is impacted by wind-driven grains of sediments.
- is where the wind drives sand and dust particles against an exposed rock or soil surface causing it to be worn away by the impact of the particles.
- the grinding of rock surfaces with a sandblasting action by particles captured in the air.
- requires cutting tools carried by the wind.
- is sandblasting action effected by materials as they are moved by saltation. this process smooths, pits, polishes and wears away rock close to the ground.
- produces a number of distinctive landforms which include **ventifacts, yardangs and zeugens, rock pedestals and inselberges**

Features Produced By Abrasion

Wind abrasion attacks rock masses and sculptures them into strange shapes. Some of these, because of their shape are called rock pedestals

Rock Pedestal: The weaker strata in the mass of rocks are shaped by wind abrasion and weathering to give the tower like structures of various shapes.

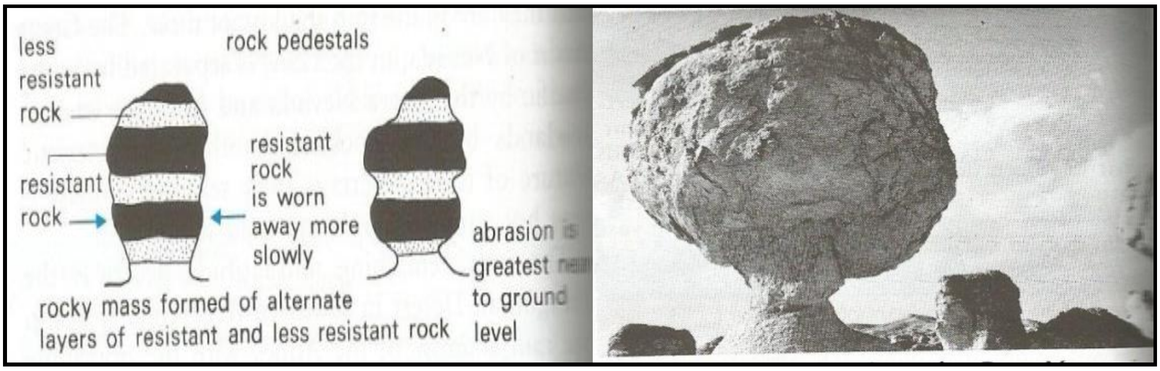


Figure 2.26: Formation of a rock pedestal in Saudi Arabia

Ventifacts are individual rocks with sharp edges and due to abrasion, smooth sides.

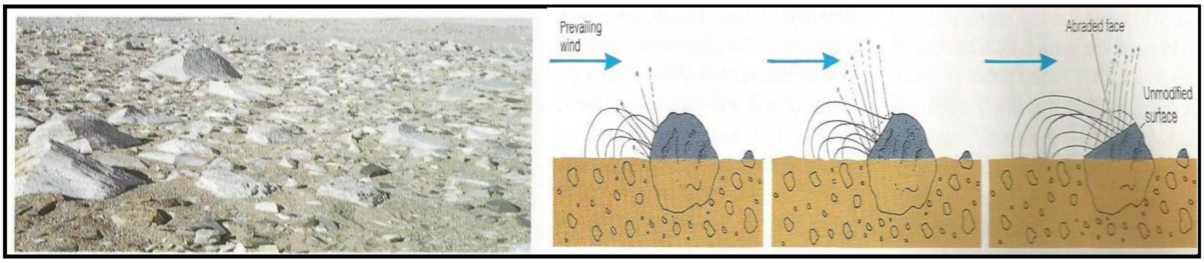


Figure 2.27: Formation of Yandangs

Yardangs: Bands of hard and soft rocks which lie parallel to the prevailing winds in a desert region are turned into another type of 'ridge and furrow' landscape by wind and abrasion. Yardangs are very common in the central Asian and Atacama deserts.

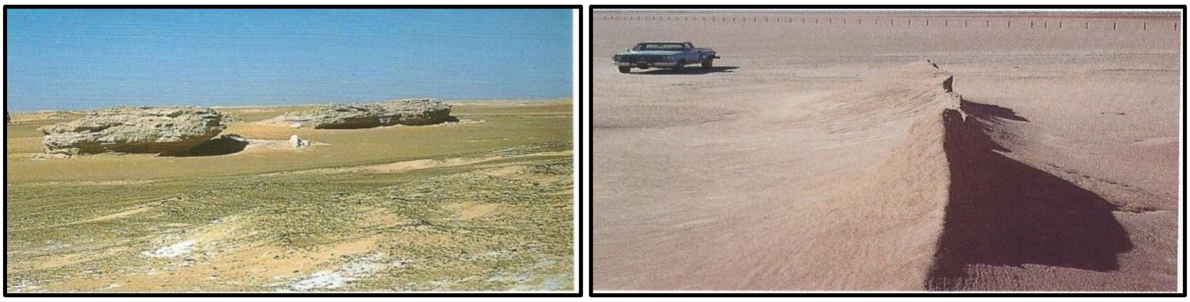


Figure 2.28: Yardangs in Western Desert Egypt

Zeugens: are tabular masses of resistant rock separated by trenches where the wind has cut vertically through the cap into underlying softer rock. Eventually they are undercut and worn away.

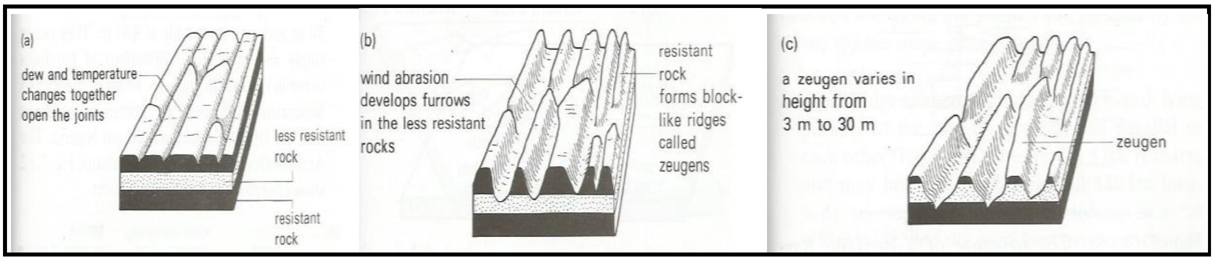


Figure 2.29: Stages in development of a zeugens

Inselberges: In some desert regions erosion has removed the entire original surface except for isolated pieces which stand up as rounded-topped masses called inselberges. These features are common in the Kalahari Dessert.

Wind Transportation

Wind transport causes fine particles of rock waste called desert dust to be carried great distances. Coarser particles called sand are bounced over the surface for short distances. Wind can move material by three processes; **suspension, saltation and surface creep**.

1. **Suspension**: Where material is very fine (less than 0.15mm in diameter) and it can be picked up by the wind, raised to considerable heights and carried great distances. Visibility in deserts is sometimes very difficult and this is called **dust storms.**

2. **Saltation**: This occurs when wind speeds move particles by skipping and bouncing action. Saltation: describes movement of particles by water. The term also describes the wind transport of grains along the ground. This process is accomplished by this skipping and bouncing action.

3. **Surface Creep**: Every time a sand particle transported by saltation lands, it may dislodge and push forward larger particles which are too heavy to be uplifted. This constant bombardment gradually moves small stones and pebbles over the desert surface.

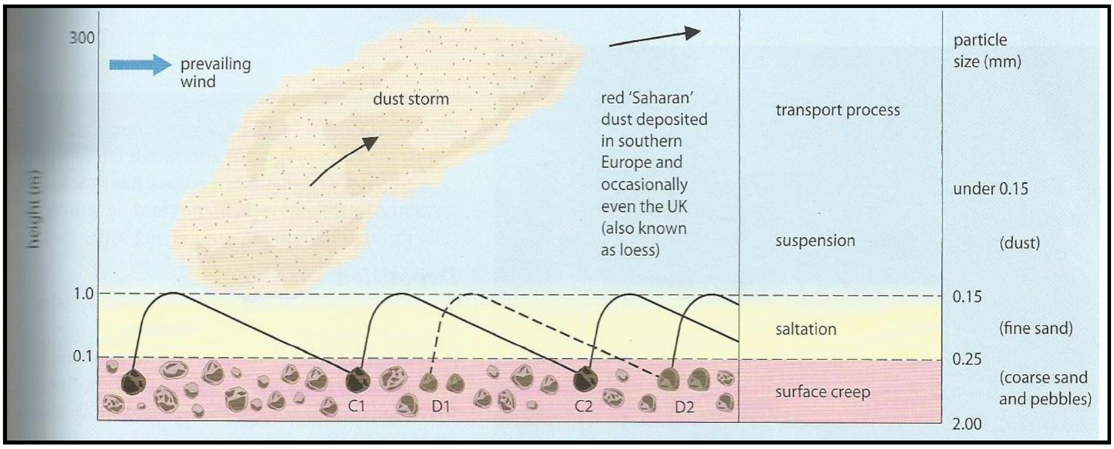


Figure 2.30: Processes of wind transportation

Deposition

Wind deposition gives rise to dunes which are made of sand and **loess** (German for loose) which is made of desert dust.

Strong winds occasionally blow across desert surfaces, and when they occur they carry vast amounts of desert dust (very find sand particles). This movement produces dust storms and in time, it results in the transport of enormous quantities of fine material from one part to another part of the desert or from a desert to a neighboring region. Slight movements of air called wind ***eddies***, bound grains of sand forward which when deposited may form gentle ripples or sandy ridges called dunes.

Dunes develop when sand grains moved by saltation and surface creep are deposited.

Sand Dunes

- is any hill of loose sand or accumulation of sand shaped by the wind.
- form where there is a source of sand
- must be free of vegetation cover in order to form and move.
- constantly change form under wind currents.
- develop when sand grains, moved by saltation are deposited. Although large areas of dunes, known as ergs cover about 25 percent of arid regions, they are mainly confined to the Sahara and Arabian deserts.

There are different types of dunes but the common ones are:

1. **Crescentic Dunes or Barchan**

- It is an isolated heap of free sand.
- The broadly rounded ends of the crescent point downwind and indicate the direction of dune motion and prevailing winds.
- Where sand is abundant that it completely covers the ground, dunes take the form of wavelike ridges separated by trough like burrows. These sand dunes are called Transverse dunes because their crest trend at right angles to the direction of the wind.

The entire area may be called a sand sea. Large areas of dunes, known as erg do exist, but they cover only about one quarter of the world’s desert. Most deserts consist of bare rocks, known as Hamada, or stone covered plains, called reg.

2. **Transverse Dunes**

- They occur in regions where the prevailing winds are steady, sand is plentiful, and vegetation is sparse or absent,
- The dunes form a series of long ridges that are separated by troughs.
- Typically many coastal dunes are of this type.

3. **Longitudinal Dunes**

- They are long ridges of sand that form more or less parallel to the prevailing wind and where sand supplies are limited.

4. **Parabolic Dunes**

- Unlike the other dunes that have been described thus far parabolic dunes form where vegetation partially covers the sand.
- The shape of these dunes resembles the shape of barchans except that their tips point into the wind rather than downwind. Parabolic dunes often form along coast where there are strong onshore winds and abundant sand.

5. **Star Dunes**

- Confirmed largely to parts of Sahara and Arabian deserts, star dunes are isolated hills of sand that exhibit a complex form.
- Their name is derived from the fact that the bases of these dunes resemble multipoint stars.

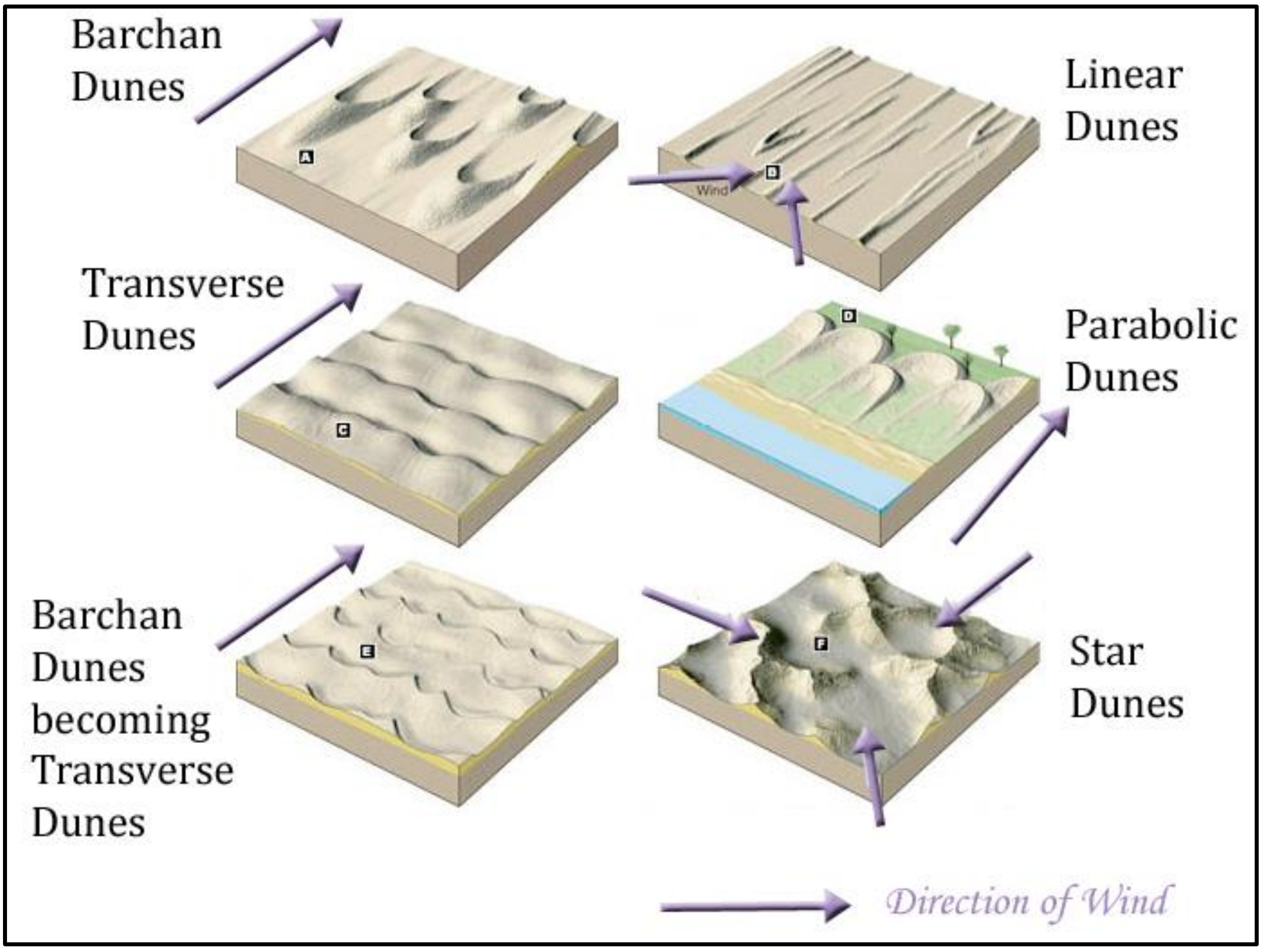


Figure 2. 31: Different types of dunes

Student Learning Activities 3

1. What are two desert erosional processes?

   i) ____________________________ ii) .______________________

2. What are three desert transportational processes?

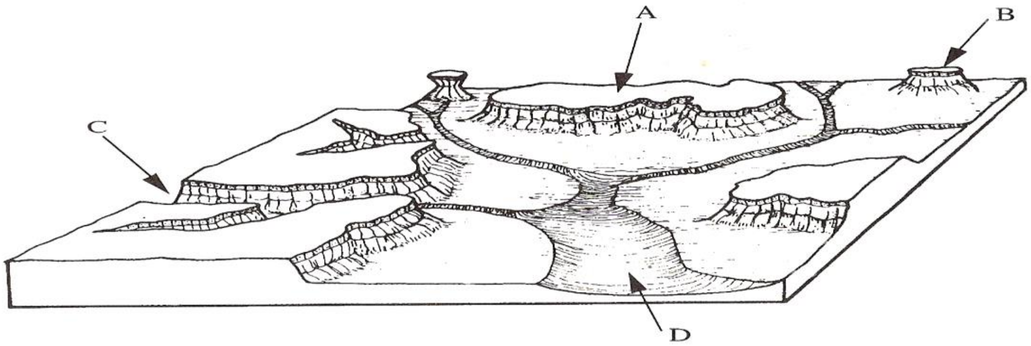
   i) ______________ ii) _________________ iii) __________________

3. Explain the process of saltation.

   ____

   ____

4. Below is a cross section of a Desert Landform. Label the features marked A – D.



A: __________________ B: ______________ C: ________________ D: _______________

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.4: Glacial Processes and Landforms

When the temperature falls below 0^0 C, some of the water vapour condenses and freezes into ice crystals that fall to the earth as **snow**. Some of this snow melts in summer for areas in high latitudes but sometimes this snow does not melt, then a permanent snow covering results. This happens in Greenland, Antarctica and tops of mountains that are high enough. The area where there is permanent snow covering is called a **snowline**.

- When the accumulation of snow in a region increases yearly, the snow gradually turns to ice by its own weight. (snow consist of small ice crystals separated by air spaces but as depth of snow increases, the pressure exerted on the bottom layers causes some of the ice crystals to melt of which the water formed trickles down into the air spaces where it freezes. This causes the snow to turn into granular mass called ***neve or firn.*** Over time the air spaces disappear and the neve is converted into a compact mass of ice known as **glacier ice.**
- When a continuous mass of ice covers a large land surface it is called an **ice sheet.** There are ice sheets in Greenland and Antarctica where some of these ice sheets reach to the coast into the sea. Large masses break off from the ice sheet and forms **icebergs**.
- When a mass of ice occupies a valley it is called a **glacier.** The largest glaciers today are in high mountain ranges such as the Himalayas, Andes, Rockies and Alps and other mountainous highlands areas in Africa.
- **A glacier** is a thick ice mass that forms over hundreds or thousands of years. It originates on land from the accumulation, compaction and re-crystallization of snow

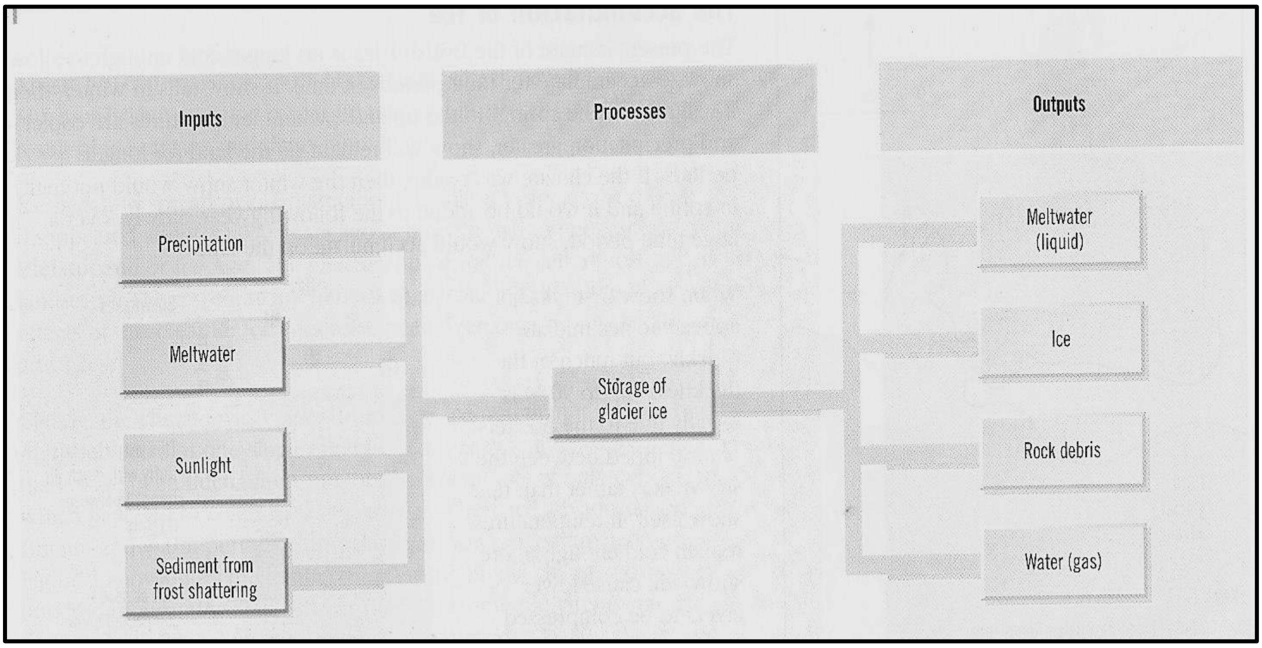


Figure 2.32: The glacier as a system

Glacial systems

A Glacial behaves as a system with inputs, stores, transfers and outputs. Inputs are derived from snow falling directly onto the glacier or from avalanches along valley sides. The glacier itself is water in storage. Outputs from the glacier system include evaporation, **calving** (the formation of the icebergs) and melt water streams which flow either on top of or under the ice during the summer months.

Glacier Forms

There are four main forms of glacier:

- **Valley or Alpine Glaciers**
  These are larger masses of ice which move down from either an icefield or a cirque basin source. They usually follow former river courses and are bounded by steep sides. This is confined to a valley.

- **Cirque or Corrie**
  Cirques or corrie are small masses of ice occupying armchair-shaped hollows in mountains. They often overspill from their hollows to feed valley glacier.

- **Continental or Ice Sheets and Icecaps** are huge areas of ice which spread outwards from central domes. Apart from exposed summits of high mountains called **nunataks**, the whole landscape is buried. Ice sheets are now confined to Antarctica (86% of present day world ice and Greenland which is 11%).

- **Piedmont Glaciers** are formed when valley glaciers extend onto lowland areas, spread out and merge. This is a very extensive mass of ice which accumulates in mountainous regions burying most of the relief features. It spreads out on to the surrounding lowlands where it often forms valley glaciers.

How Glaciers Move
The movement of glacial ice is generally referred to as flow.

Processes of Glacial Erosion
Processes associated with glacial erosion are;

1. Frost shattering
2. Abrasion
3. Plucking
4. Rotational movement
5. Extending and compressing flow

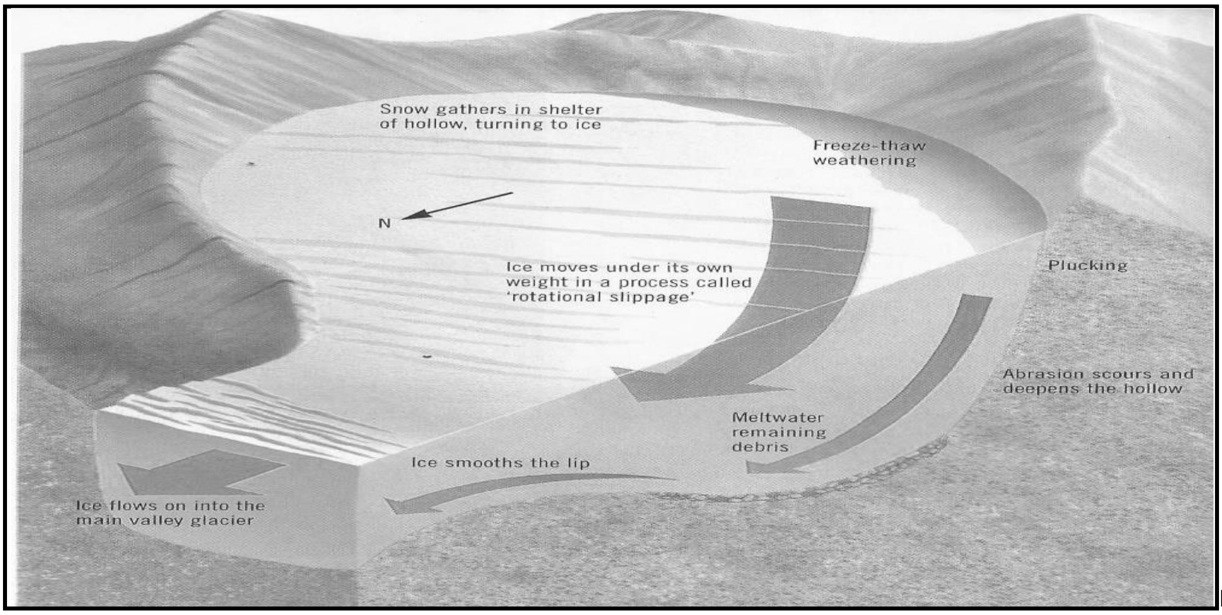


Figure 2.33 Section through a corrie

a) Frost shattering

This process produces much loose material which may fall from the valley sides on to the edges of the glacier to form lateral moraine, be covered later snowfall or plunge down crevasses to be transported as **englacial debris**.

b) Abrasion: The wearing away of rocks beneath a glacier by the scouring action of the rocks embedded in the glacier. This is the sandpapering effect of angular material embedded in the glacier as it rubs against the valley sides and floor. It usually produces smoothened, gently sloping landforms.

c) Plucking: The tearing away of blocks of rocks which have become frozen into the sides or bottom of a glacier. As the slowly moving ice scrapes against bedrock, friction between the rock and the ice causes the lowermost ice to melt.

d) Rotational movement

Rotational Movement is the downhill movement of the ice which like a landslide pivots about a point. The increase in pressure is responsible for the over deepening of a cirque floor.

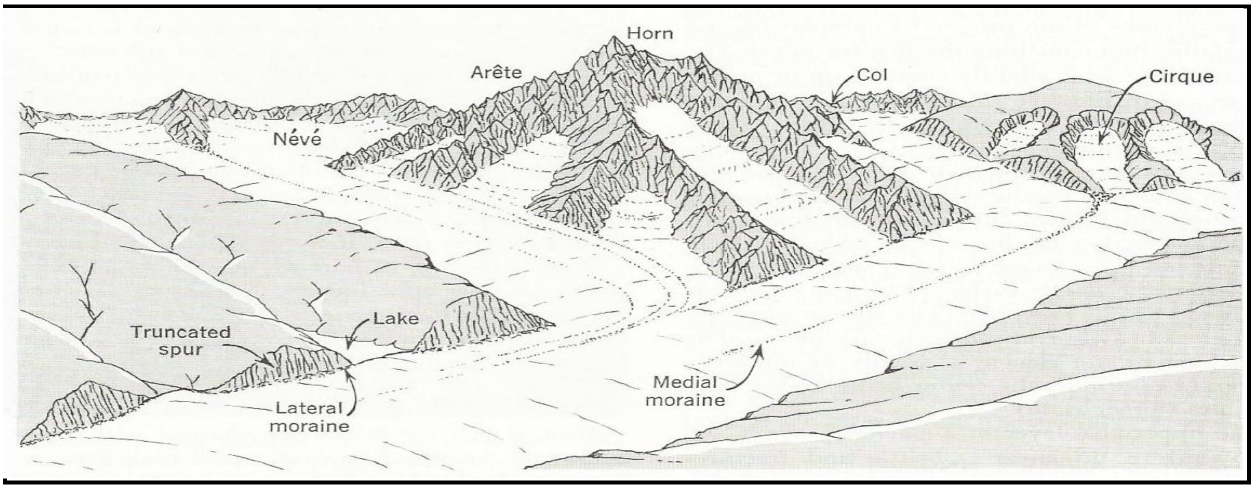


Figure 2.34: Landforms produced by alpine glaciers

Landform Produced By Glacial Erosion

The erosional features are chiefly produced by valley glaciers .Examples of such features are; glacial troughs, truncated spurs, cirques, arêtes, pyramidal peaks, hanging valleys and rock basins,

Valley Glaciers

Snow falling in mountainous regions accumulates in depressions on mountain slopes which are not facing the sun. As the snow accumulation increases a large part of it is turned to ice and snow than the depression can hold and some of it moves downslope to lower levels. The ice becomes frozen to the sides, especially to the back wall and when the ice moves forward it pulls pieces of rock out of the wall. Any material carried along by a glacier is called **moraine.**

Landforms produced by glacial erosion

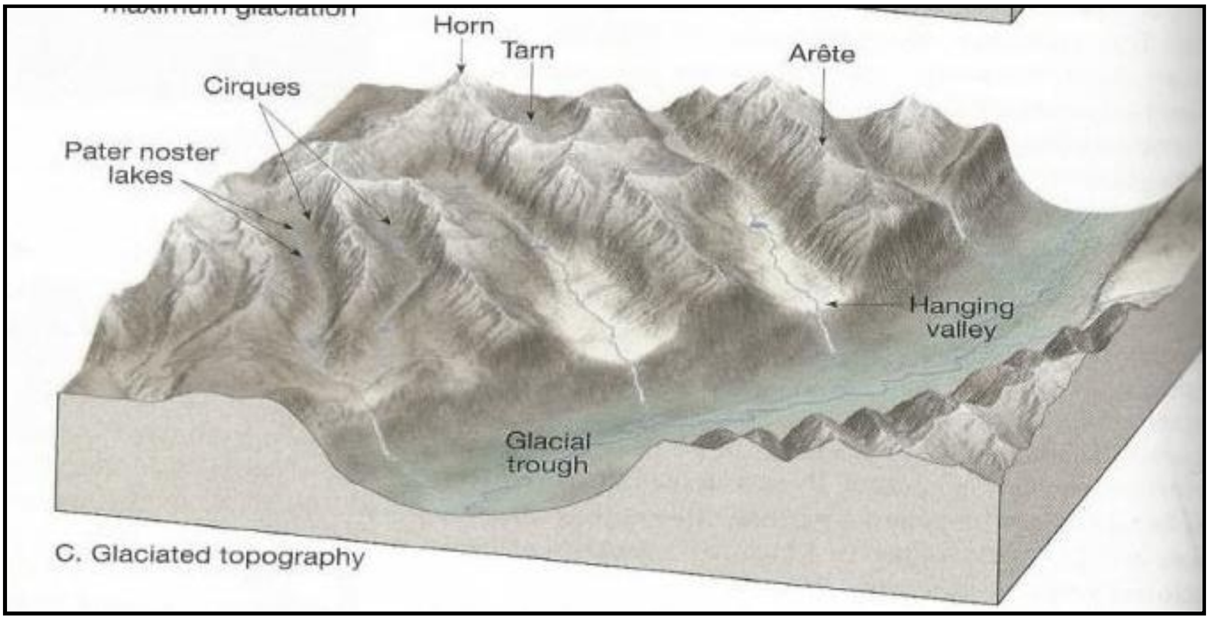


Figure 2.35: Glacial features

A. Cirques (or Corries)

- These are large bowl, shaped hollows in highland areas and generally the source of ice for valley glaciers. They are formed by the gradual accumulation of ice in hollows in high land. Erosion takes place by freeze and thaw around a patch of ice.
- They are rounded rock basins that contain the heads of alpine glaciers. They form high on glaciated peaks. Snow collects at the upper end
- They are like armchair shaped hollow on a hillside which has been cut by ice and freeze and thaw activity. If the hollow is deep enough, a lake will form in it when all the ice has melted. The sides and back wall of a cirque are steep and may be several hundred metres in height. Cirques occur in most mountainous regions.

B. Arete

- These are steep sided, knife-edged ridges separating two corries. Arêtes are formed when the backs of the back walls of corries are cut. When two adjacent cirques erode backwards or sideways towards each other, the previously rounded landscape is transformed into a rocky, steep-sided ridge called an arête. If three or more cirques develop on sides of the mountain, a **pyramidal peak** or **horn** may be formed. This feature has steep sides and several arêtes radiating from the central peak.
- Is a sharp narrow steep sided mountain ridge, especially one formed when two cirques have been developed back to back, or a narrow knife edge ridge which separates two corries or a corrie and a U shaped valley formed by glacial erosion and freeze and thaw activity.

Figure 2.36: Pyramidal peak in Switzerland

C. Pyramidal Peak or Horn

- Created by three or four corries cutting back on each other to form a horn or pyramidal peak at the centre.

Transportation by Ice

Glaciers are capable of moving large quantities of debris. This rock debris may be transported in one of the three ways:

1. **Supraglacial debris**: is **carried on the surface of the glacier** as lateral and medial moraine. In summer, the relatively small load carried by surface melt water streams often disappears down crevasses.
2. **Englacial debris** is material **carried within the body of glacier**. It may once have been on the surface, only to be buried by later snowfalls.
3. **Subglacial debris** is **moved along the floor of the valley** either by the ice or by melt water streams formed by pressure melting.

Glacial Deposition

Glacigenetic sediment or(glacial sediment) has replaced drift which was used historically when referring collectively to all glacial deposits which include boulders, gravels, sand and clays may be subdivided into till which includes all material deposited directly by the ice, and glacifluvial material which is the debris deposited by melt water streams.

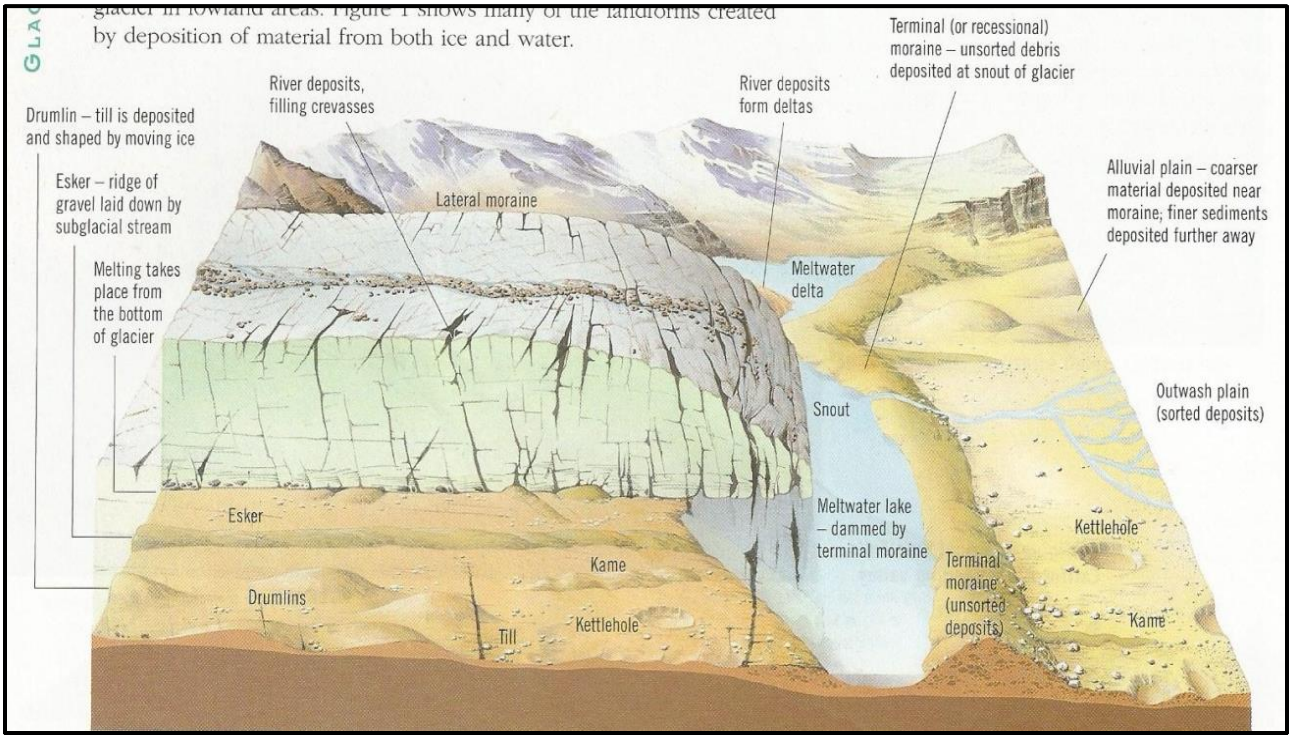


Figure 2.37: Glacial deposition and its resulting landforms

What the Ice Leaves Behind

The rocks and soil picked up by a glacier form its load or **moraine**. Material that drops onto the glacier from the valley sides is called **lateral moraine**, while the material deposited at the end or snout of the glacier is called **end moraine**, also known as terminal moraine.

Landform Characteristics of Glacial Deposition

Glacial deposits (glacigenetics sediments) collectively refers to deposits which include boulders, gravels, sand and clays may be subdivided in to **till**, which includes all material deposited directly by the ice and glacifluvial material which is the debris deposited by melt water streams. **Glacifluvial material** includes materials deposits which may have been deposited initially by the ice and which were later picked up and redeposited by melt water- either during or after the ice age.

Till consist of largely unsorted material whereas glacifluvial deposits have been sorted. Deposition occurs in upland valleys and across lowland areas.

Till Deposits: Used to mean the unsorted mixture of rocks, clays and sand. This material was largely transported as supraglacial debris and later deposited to form moraine.

A. Erratics

These are boulders picked up and carried by the ice often for many kilometers to be deposited in areas of completely different lithology (which is the study of nature and composition of rocks).

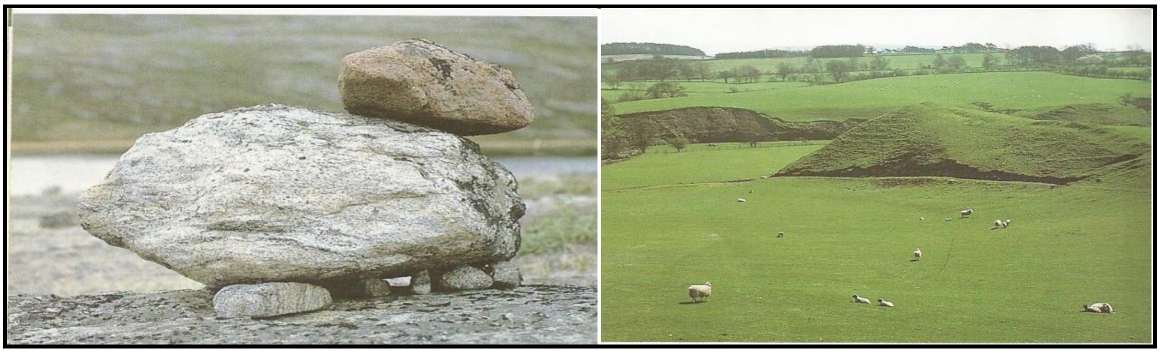


Figure 2.38: Glacial erractic in Northern Canada

B. Drumlins

Drumlins are smooth egg-shaped hills that vary in length from 100 to 800m and between 25 to 100m high. The side facing the direction from which the ice came is steeper than the downside of the glacier. These are smooth, elongated mounds of till with their long axis parallel to the direction of ice movement. Drumlins may be over 50cm in height, over 1km in length and nearly 0.5 km in width.

Drumlins rarely occur by themselves, often they will be found in swarms called drumlin fields. They are formed under the ice by ice which had molded boulder clay into their distinctive shape. The ice was still moving but was not powerful enough to erode the boulder clay.

Moraine

Moraine is the name for specific landforms produced by the deposition of glacial sediments or is **a type of landform which develops when the debris carried by a glacier is deposited**. It is not therefore the actual material that is being transported by the glacier. There are about five types of moraine.

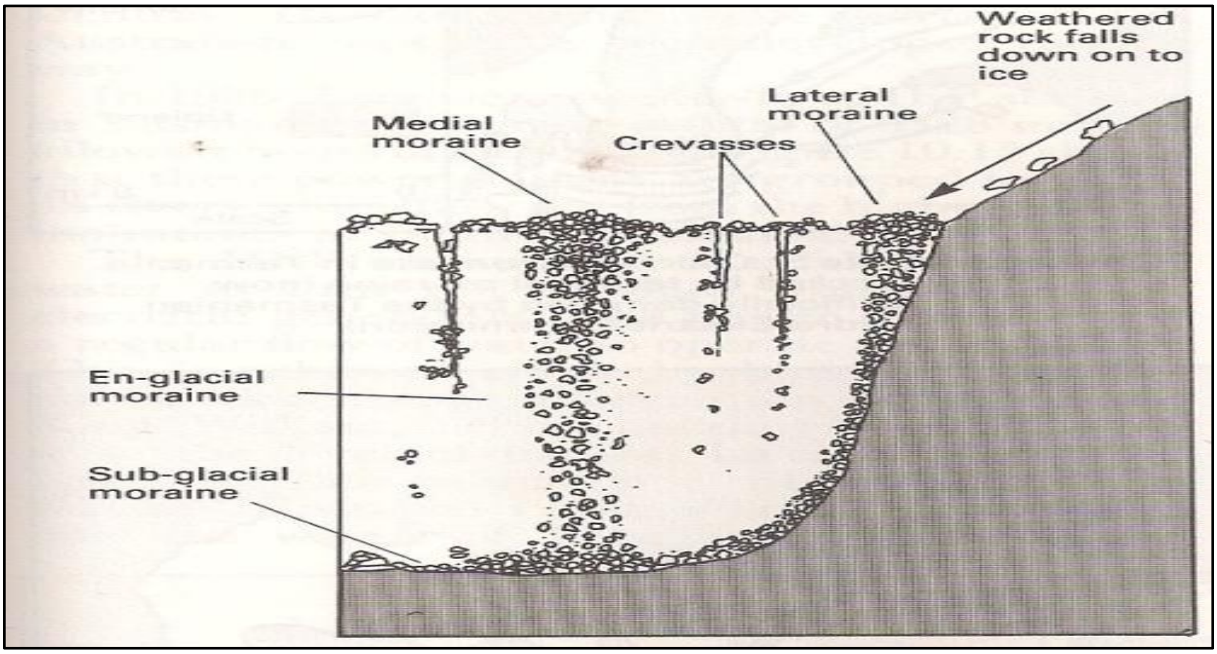


Figure 2.39: Some different types of moraines

1. **Lateral moraine**
   Lateral moraine is formed from the debris derived from frost shattering of valley sides and carried along the edges of the glacier. The lateral moraine is formed along each side of a glacier. When the glacier melts it leaves an embankment of material along the valley side. If two glaciers with lateral moraines join, a medial moraine may form.
2. **Medial moraine**
   Is found at the center of a valley and results from the merging of two lateral moraines where two glaciers joined.
3. **Terminal or end moraine**
   Is eroded debris that is dropped at the glaciers farthest extend is called terminal moraine however, there also may be end moraines formed at other points where a glacier paused after reaching a new equilibrium.
4. **Recession moraine**
   Mark interruptions in the retreat of the ice when the glacier or ice sheets remained stationary long enough for a mound of material to build up. Recessional moraines are usually parallel to the terminal moraine
5. **Push moraine**
   May develop if the climate deteriorates for the ice temporarily to advance again. Previously deposited moraine may be shunted up into a mound. It can be recognized by individual stones which have been pushed upwards from their original horizontal position

Glacifluvial Landforms

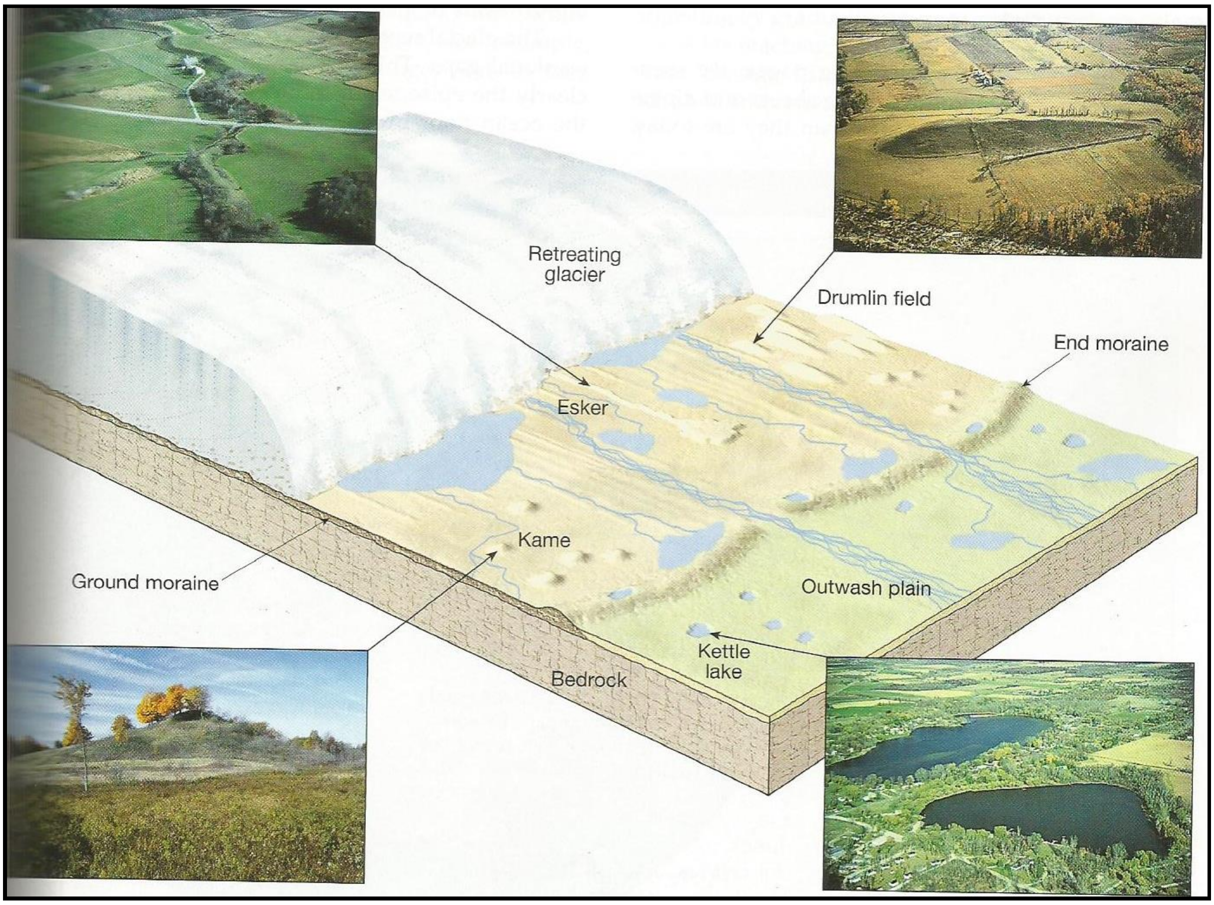


Figure 2.40: Showing melt water glacial landforms

Melt water landforms

As the ice was melting, vast quantities of water flowed over the land. It is estimated that rivers would have flowed 80 times faster during this period compared to today. Such melt waters streams created a number of distinctive features:

1. **Melt water Lakes:** Terminal moraine could often dam up a huge lake.
2. **Eskers:** are long ridges of deposited material. They usually run parallel to the direction of ice flow and are formed by deposition from melt water streams which flow under the ice. These are very long narrow ridges composed of sorted coarse sands and gravels.

Figure 2.41: Eskers

Figure 2.42: Kames

Kames: are small mounds of debris which have been washed into crevasses in the ice. This material is dropped onto the ground as the ice melts.
are mounds of gravel and sand deposited unevenly by melt water similar to a series of deltas, along the front of a stationary or slowly melting ice sheet.

3. **Kettle holes**: As the glacier retreats, it leaves behind detached blocks of ice which on melting create small kettle holes. The water remains in the hollow and will eventually be lost through evaporation or infiltration. These form from the detached blocks of ice left by the glacier as it retreats and partly buried by glacifluvial deposits left by melt water streams. When the ice block melts they leave enclosed depression which often fill with water to form the kettle hole lakes
4. **Outwash plains**: (Sandur) As melt water streams flow away from the glacier they begin to sort out material and deposit their load. The largest, heaviest particles are dropped first and so create **alluvial fans** and **outwash plains**. These are composed of gravels, sand and clay. They are deposited by melt water streams.

Now turn to the next page to do activity 4.

Student Learning Activities 4

1. Explain the process of plucking.

____

____

2. Glaciers are capable of moving large quantities of debris. One of the ways the rock debris is transported through **Supraglacial debris.** Explain this process

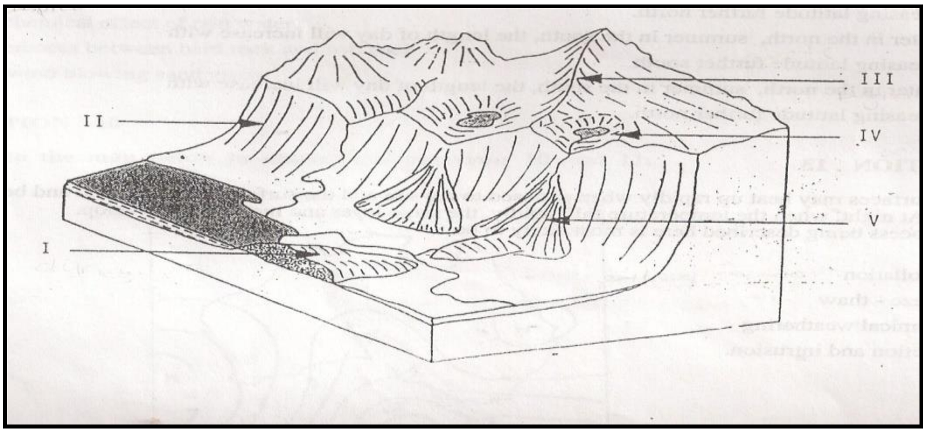
____

____

____

3. Correctly label the following features using the diagram provided below.

I: ________________ III: ________________ IV: ________________



NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.5: River Landforms

Every stream, no matter how large or small has a drainage basin. This is the land area that contributes water to the stream.

A Drainage Basin is an area of land drained by a river and its **tributaries**. A drainage basin may be described as an open system and it forms part of the hydrological cycle.

Drainage systems are networks of streams that together form distinctive patterns.

The drainage basin of one stream is separated from the drainage basin of another by an imaginary line called a *divide*.

All rivers are joined by smaller rivers which are called Tributaries, and the area drained by a river system (Main River plus all its tributaries) is known as the **river basin** or the **catchment area**.

The drainage basin provides water for the main streams and its tributaries or branches. This area is known as the **catchment area**.

If a drainage basin is viewed as a system, then its characteristics are:

- INPUTS - in the form of precipitation (snow/ rain)
- SETS OF PROCESSESS: passes through a series of transfers or flows, e.g., infiltration, percolation, through flow.
- OUTPUTS - where the river is lost from the system either by the river carrying it to the sea or through evapotranspiration. (loss of water directly from the ground, water surfaces and vegetation)

A river system develops a pattern that is related to the general structure of its basin.

Elements of the Drainage Basin System
Processes involved in the formation of the basin system

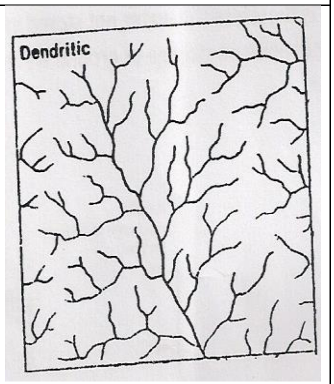
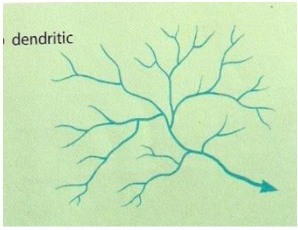
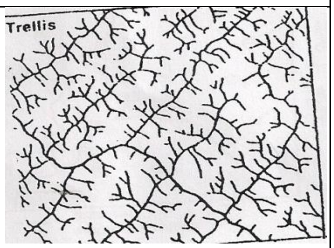
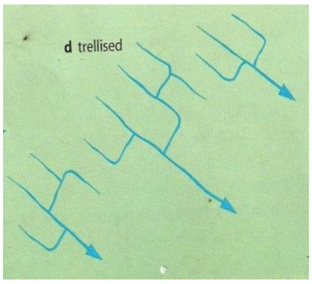
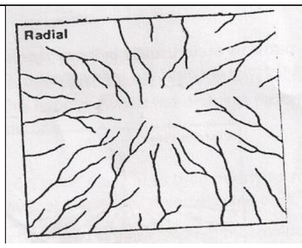
1. PRECIPITATION
   Forms the major input in the system. As a rule, the greater the intensity of a storm, the shorter its duration. Convectional thunderstorms are short, heavy and maybe confirmed to a small area.
2. RUNOFF
   a) Surface
   b) Underground

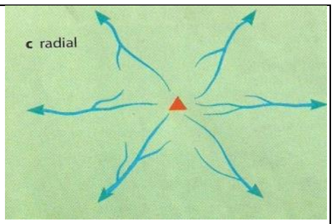
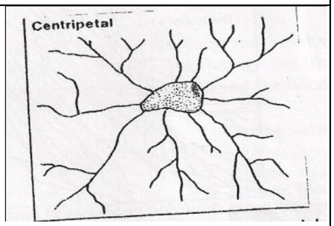
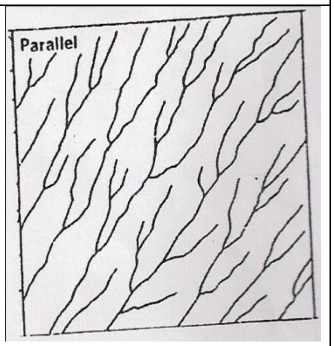
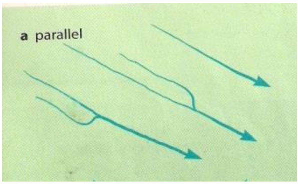
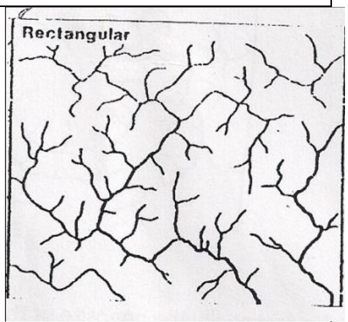
Drainage Patterns

A drainage pattern is the way in which a river and its tributaries arrange themselves within their drainage basin. Most patterns evolve over a lengthy period of time and usually become adjusted to the structure of the basin.

All rivers are joined by smaller rivers or streams called t**ributaries**.
The area drained by a river and its tributaries is called a **river basin**. And its boundary is formed by the crest line of the surrounding highlands.

Types of Drainage Patterns

TYPE OF DRAINAGE PATTERN	CHARACTERISTICS	DIAGRAM
1. DENDRITIC: (pattern independent of structure) (Dendron meaning a tree)	• The most common drainage pattern and can be found almost anywhere. • It consist of random merging of streams with tributaries joining larger streams irregularly but always at an angle smaller than 90 or acute angle. • This is a tree like a pattern in which the many tributaries (branches) converge upon the main river (trunk) or the dentritic network resembles a tree with many branches or resembles the branching pattern of a deciduous tree . Several tributaries followed towards it from many directions and meet the river. • Dentritic patterns develop in a region which is made of the same rocks types and which offer the same resistance to erosion and which has a uniform structure.	 
2. TRELLISED: (patterns dependent on structure)	• Trellis drainage patterns are rectangular patterns in which tributary streams are nearly parallel to one another and have the appearance of a garden trellis. • The trellised network occurs where the rivers flow at right angles usually guided by parallel ridges or hills. • Normally trellised drainage patterns are found where there are bands of hard and soft rocks alternatively and are often developed on eroded folded rocks • That is usually developed on alternating bands of hard and soft strata with long parallel subsequent streams linked by short right angle segments and joined by short tributaries. A system of streams in which nearly parallel tributaries occupy cut in folded	 
3 .RADIAL: (patterns dependent on structure	• When streams develop from a central like spokes from the hub of a wheel, the pattern is said to be radial. • The drainage pattern typically develops on isolated volcanic cones and domal uplifts. The rivers flow outwards forming a pattern like the spokes of a wheel • Is usually found in areas where the rocks have been lifted into a dome structure. Or where a	

	conical cone has formed. Rivers radiate outwards a central point. Drainage pattern in which consequent streams flow outward in all directions from a central dome or peak	
4. CENTRIPETAL	• A centripetal is essentially the opposite of the radial, it is usually associated with the convergence of streams i to a basin. • Occasionally, this pattern is found in limestone areas where the rivers sink as they flow towards the centre of the area guided by slope. • A basin structure in which the streams converge towards the center	
5.PARALLEL: (pattern independent of structure)	• This is the simplest pattern, occurs on newly uplifted land or the other uniformity sloping surfaces which allow rivers and tributaries to flow downhill more or less parallel with each other. • Parallel patterns in other words are formed by streams running parallel to each other. • A drainage pattern that can emerge in areas of pronounced regional slope, particularly if the gradient is gentle with long consequent streams flowing parallel to one another.	 
6.RECTANGULAR: (patterns dependent on structure)	• Rectangular arrangements of channels in which tributary streams are parallel and a very long and in which many right angle bends can be seen. • This pattern develops when the bed rock is crisscrossed by a series of joints or faults. The tributaries extend the • Patterns are a result of cross faults in rock structure and Lines of faulting provide the only lines of weakness where the streams can flow. Patterns where streams are essentially all subsequent that follow sets of faults and or joints with prominent right angled relationships.	

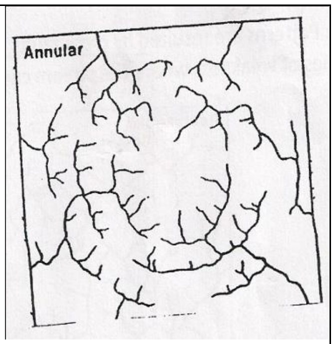
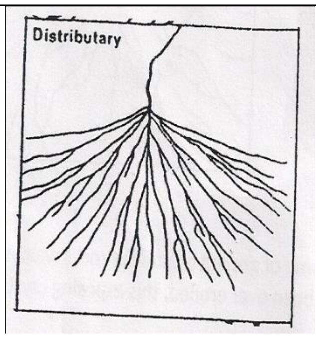
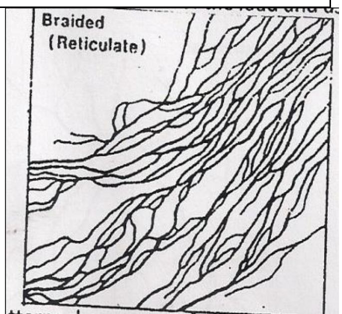
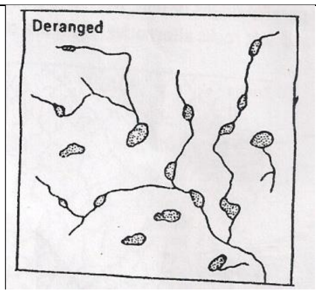
7. ANNUAL: (more complex)	• A network in which the major streams are arranged in a ring like, concentric pattern in response to a structural dome or basin • Annular pattern can develop either on a dome or in a basin` where dissection has exposed alternating bands of tilted hard and soft rock. • The principal streams follow curving courses on the softer material, occasionally breaking through the harder layers in short right angled segments. • The uplifted dome of ancient crystalline rocks are pushed up through a sedimentary layer and has been over eroded, this exposing crystallines in the higher part of the hills.	
8.DISTRIBUTARY.	• This pattern occurs usually in lower reaches of the river where there is very low gradient. One main channel divides into many stream. An example is a delta • Branching stream channels that cross a delta	
9.BRAIDED:(braided stream) patterns are formed by the deposition of the load and usually found in lowlands areas	A stream that consists of a multiplicity of interwoven and interconnected shallow channels separated by low islands of sand gravel and other loose debris	
10.DERANGED:	Deranged patterns show no geometrical pattern or constant direction. It usually includes many lakes. This pattern is found in glaciated areas	

Figure 2.43: Summary of drainage patterns

The River System

Look at any possible topographic map on which a river system is shown. If you study the system, you will see that the *small streams joins together to give larger streams* as you move from the *source* of the main stream flow to the *exit* of the river basin.

The process of the small streams joining to give larger streams and of these joining to give even larger streams produces a ***river system***. In other words, a river system has a hierarchy of *channels.* Any streams which does not have any tributaries from its source to its ending as an independent stream is called a *first order stream* (have steeper gradients) When first two order streams join up, they form second order stream and so on which then have steeper gradients than those of the third order and so on.

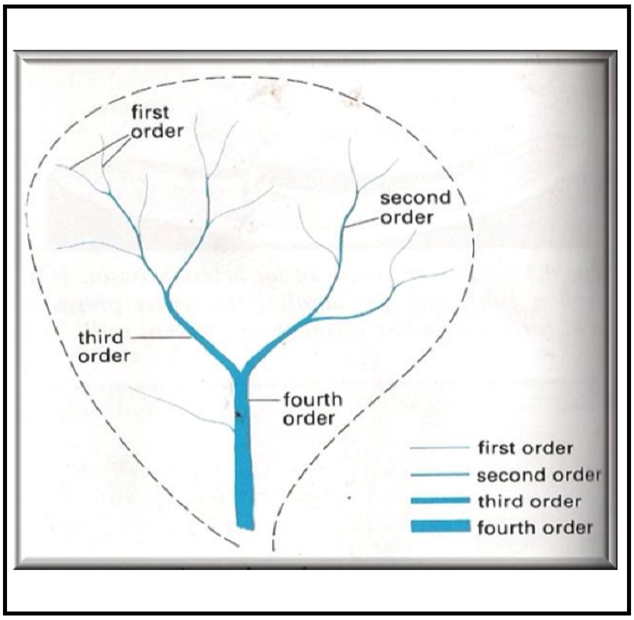


Figure 2.44: The order of Streams

The First order is the initial unbranched source tributaries. When the first two order streams join they form second order streams. It needs two streams segments of equal order to join to produce a segment of Higher Order. When a second order stream joins a third order stream, the resultant stream remains as a Third Order stream. A basin may therefore be described in terms of the highest order. E.g. third order or fourth order.

The Stream System

It is possible to recognize a number of different inputs into the stream system which interact to give the system's two main outputs, *water and load* (all material carried by flowing water)

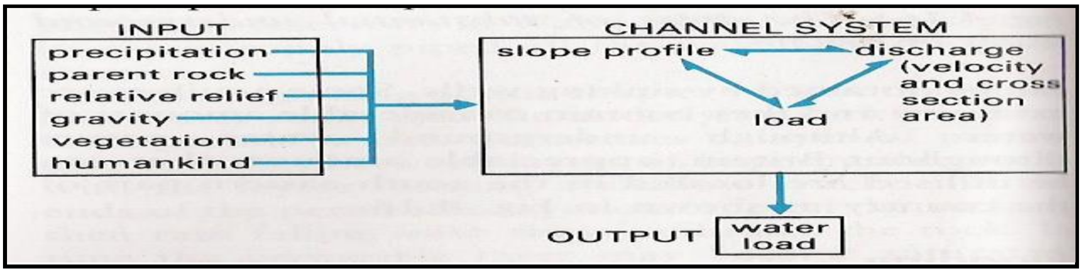


Figure 2.45: River system

River Transport
All the materials that a river transports is called its **load.**

A river transports its load in three ways:

- by traction (the dragging of large pieces of material such as pebbles along its bed)
- by suspension of light materials, such as silt and mud, in the water;
- and by solution of certain minerals which dissolve in water.

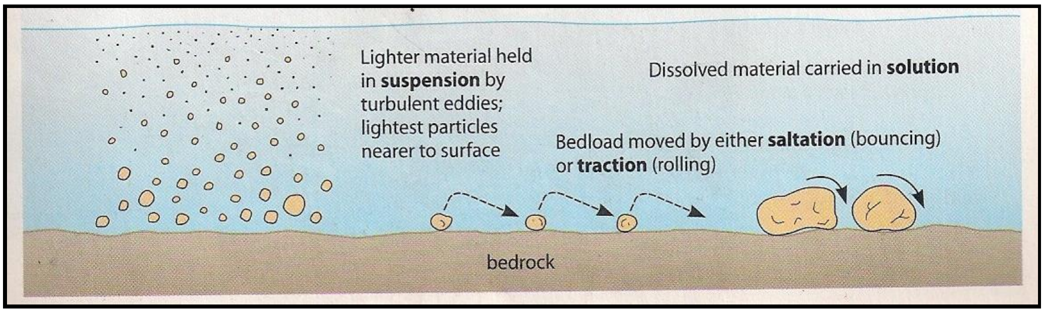


Figure 2.46 : River erosion processes

A river transports its load until it has insufficient energy to transport it any further. When this happens, the load is deposited. A river loses energy when its

- gradient decreases,
- when its channel widens,
- when it meanders and
- when it volume decreases, e.g. after a flood.

During flooding, the volume increases and the river's energy also increases. This results in increased erosion which in turn leads to an increase in the river's load. When the floods subside, the volume decreases and so does the energy. The river now has too great load, its power to erode decreases and deposition takes place.

The erosion achieved by a river depends upon its **velocity** and its **discharge.** The greater the discharge, the greater the total energy.

River Erosion

River erosion involves four processes. They are: **hydraulic action; abrasion; attrition; solution**.

1. **Hydraulic action:** This refers to the force of moving water which is able to remove loose material such as fine gravel or sand lying on the bed of the channel. It is also able to weaken solid rock by surging into cracks in the rock. But hydraulic action effects very little erosion if the river has little or no load.

   The sheer force of the water as the turbulent current hits river banks (on the outside of a meander bend) pushes water into cracks. The air in the cracks is compressed, pressure is increased and in time the bank will collapse. Thisthe slowest erosion process.

2. **Abrasion or Corrasion:** rock particles carried by a river are thrown against the sides of the channel and are dragged along the rock bed. This causes further erosion which adds to the load. The larger the particles in the load, the more rapid the erosion. Eddies in rivers flow whirl pebbles around the hollows on the bed of the channel thereby causing them to get deeper. These depressions are called pot holes.

3. **Attrition:** This is the process by which the load itself is broken down. This takes place because the rock particles which make up the load are in constant collision with each other. As the load moves downstream, its particles in general get progressively smaller. However, it is not uncommon to find angular particles of large size in the lower section of the river's course.

   As the bed rock is moved downstream, boulders collide with other material and the impact may break the rock into smaller pieces.

4. **Solution or Corrosion:** Solution is particularly well developed in limestone regions. But it should be remembered that most rocks contain minerals which are soluble in water, and solution of rocks in tropical humid regions is especially important. It is related to the chemical composition of the water.

These four processes together make up river erosion which enables a river to cut a channel into the land. River erosion operates in three ways:

1. **Head ward Erosion** by which the river increases its length. Water that flows out of the ground is called a *spring*. Sometimes a spring develops where the water table meets the surface. If the spring lies at the head of a valley, the out flowing ground water wears away material around it and this enables a river to cut back slowly into the hill slope behind the spring. This process is called **Spring Sapping.**

2. **Vertical erosion** by which a river deepens its channel.

3. **Lateral erosion** by which a river wears away the sides of its channel. This is particularly effective along the outside banks of meanders.

   River Deposition
   When the velocity of the river begins to fall, it has less energy and so no longer has the competence or capacity to carry all its load, so starting with the largest particles materials begins to be deposited.

   Deposition occurs when:
   Discharge is reduced following a period of low precipitation.

   - Velocity is lessened on entering the sea or lake (resulting in a delta)
   - The load is suddenly increased (caused by debris from a landslide)

Characteristics of a River

River Valley Characteristics- Process and Landforms

1. **The Initial Stage or Youthful Stage**

A valley in this stage usually exhibits define characteristics. The valley is narrow and deep; V shaped in transverse profile; the gradient is steep; pot holes mark the river bed; valley sides are developed into interlocking spurs; waterfalls and rapids together with plunge pools are common. Most of these features can be regarded as irregularities in the long profile.

The Characteristics Features of a Youthful Valley

- Deep narrow valley (V shaped)
- Valley has a steep gradient (river is fast flowing)
- Pot holes
- Interlocking spurs
- Waterfall and rapids

During the youthful stage of development, streams become established and a drainage pattern begins to take shape. These streams which incise deep narrow, steep sided, V- shaped valley flow rapidly and have irregular gradients marked by waterfalls and rapids. During this stage, most of the initial surfaces are broad flattish interfluves, largely unaffected by stream erosion.

Waterfalls and rapids: When a layer of resistant rock (rock resistant to erosion) lies across a rivers course , the less resistant rocks on the downstream side are more quickly eroded than the resistant rock. The river bed is therefore steepened where the two rocks meet and a waterfall or a rapid develops.

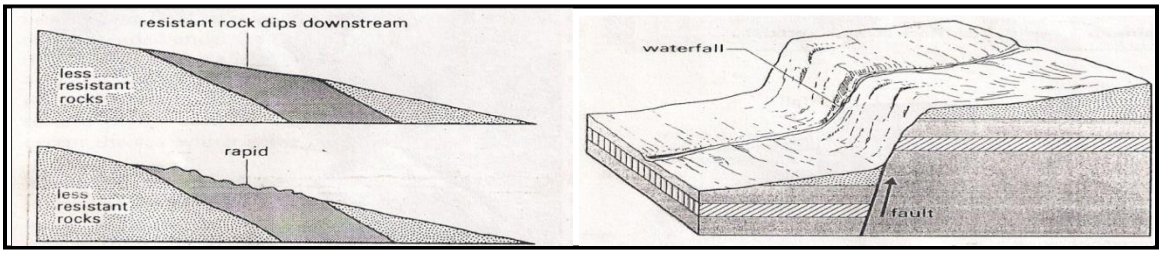


Figure 2.47 Formation of a rapid and waterfall

Vertical erosion is dominant in the initial stage and the river valley is narrow, deep and V-shaped. Weathering and mass wastage of the valley sides are limited in terms of erosion, relative to the vertical erosion effected by the river.

Gorges: Waterfalls and Rapids are often associated with gorges. In time all waterfalls migrate upstream, gradually turning into rapids. When a waterfall that has formed on a resistant rock layer that is horizontal or is gently dipping upstream, retreats, it produces a gorge. A gorge can occur in almost any part of a river's course provided the conditions are suitable.

Interlocking spurs: A river always tries to take the shortest path down a slope and also the easiest path, it tends to go round rocks that are resistant. This often results in a river developing in winding course. As this proceeds, the bends in the river become more pronounced because the water on the outside of the bend flows more quickly and it therefore erodes more strongly on this side. Eventually, projections of high land, called spurs, interlock develop.

2. **The Intermediate Stage or Matured Stage**

As the volume of the river increases, its energy, its power to erode, transport and deposit also increases. The gradient is less steep than it was in the initial stage. Lateral erosion is dominant over vertical erosion and this causes the valley to open out. Interlocking spurs are cut back to give bluffs, and this leads to a straightening of the valley.

Deposition begins to take place mainly along the inside of river bends, *called meanders*, and the deposition gradually extends across the valley as the meanders move downstream.

Towards the end of this stage, the valley floor is covered with alluvium forming a plain which slopes gently downstream. *This is called a* ***flood plain***. The meanders move progressively downstream and as they do they cut into the flood plain leaving stretches which lie above the river. This are called *terraces*. Meanders get cut through and ox-bow lakes form.

Characteristic Features of a Matured Valley

- The valley has the shape of an open V in cross -section.
- The gradient is gentler than in a young valley.
- River bends are pronounced. The concave banks stand up as river cliffs; the convex banks slope gently as slip- off slopes (smooth ends of spurs)
- Spurs are removed by lateral erosion. Their remains form a line of bluffs on each side of the valley floor.
- The valley floor is wide and by the time the valley enters the stage of old age and it is covered with a layer of sediments.

Meanders: We saw that the river begins to meander in its initial stage when outcrops of resistant rock lie in its path, but there are no such outcrops in flood plains where meanders are developed to their maximum extent. Riffles and pools may form the clue to understanding the cause of these meanders.

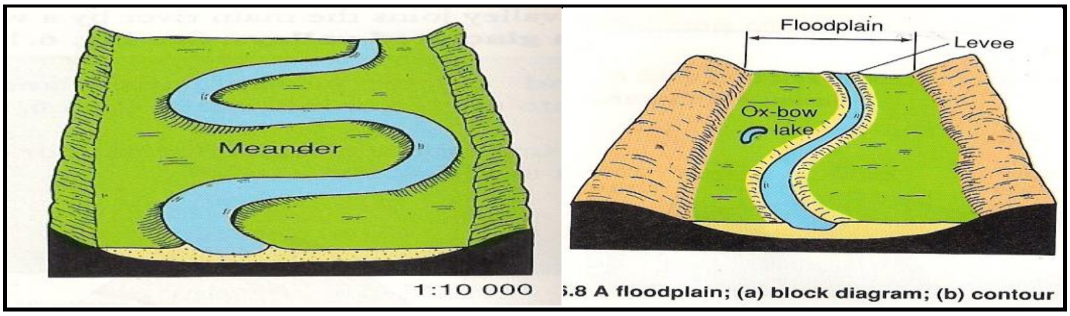


Figure 2.48: Profile of a meandering river floodplain and an oxbow lake

A riffle is an area of shallower, faster-flowing water perhaps caused by bars of sediment on the river bed. A pool is an area of deeper, slower-flowing water. Energy is used up to erode the bed of the river in the areas of riffles, but energy builds up in the areas of pools because there is little if any erosion. This stored energy is used up in the next riffle. The riffles induce the flow of water to swing towards the area of deepest water and maximum velocity on one side of the channel. It is on this side that the river's channel banks are eroded.

Flood plain: A flood plain often has areas of marsh and numerous lakes, usually crescent-shaped and called ox-bow lakes. These are the remnants of meanders that have been cut off when the river is in flood. This happens when the flooded river spills over its channel and often covers the whole of the flood plain on which it deposits sediment.

Characteristics features of a flood plain

- The river carries a heavy load, some of which is deposited on its bed. This may produce mounds which divide the river into several channels. When this happens, the river is to be braided.
- Meanders are pronounced and cut-offs develop and produce ox-bow lakes.
- The river build up its bed and banks with alluvium (the banks are called levees). The river thus flows between pronounced banks and above the level of the flood plain.
- The river mouth sometimes becomes blocked with sediments and a delta forms.

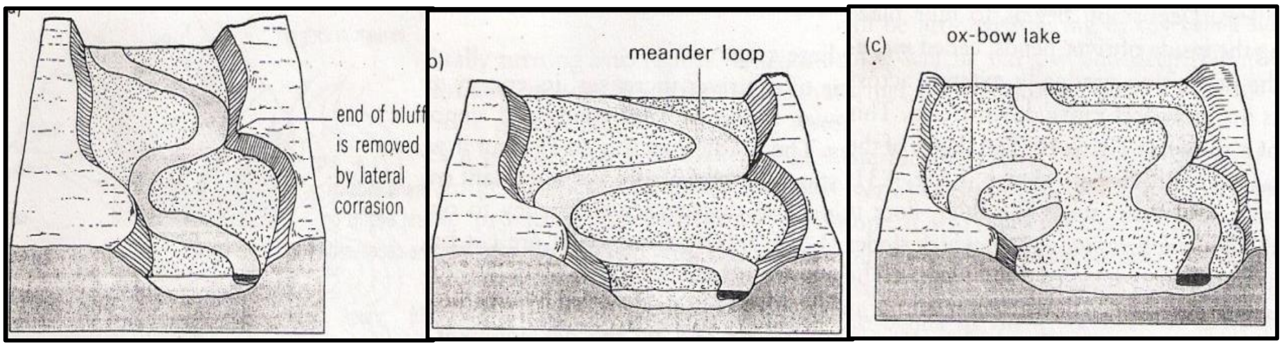


Figure 2.49: Features of a flood plain

Ox-bow Lake

The flow of water through a meander has a corkscrew characteristic. This results in active lateral erosion along the concave bank of the meander. The neck of land separating the two ends of a meander is at last cut through, usually when the river is in flood. Deposition on the convex bends of the meander gradually seals the ends of the meander, turning it into an **ox-bow lake.** Prior to this forming, the cut-off meander forms a cut-off.

The Final Stage

By the time this stage is reached the valley has become **very wide and open**. The gradient of the river is low and this tends to reduce its flow.

Volume is at its greatest because of the many large tributaries that join it. Vertical erosion is almost at an end but lateral erosion continues to wear back the divides between the river's tributaries. Deposition is still active causing the river to split into many channels which join up again farther downstream. When this happens it is called a **braided river.**

Braided river: A river with a heavy load becomes overloaded if its discharge decreases. When the discharge falls deposition takes place in the form of sandbanks and islands of alluvium that cause the channel to braid. The braided channel can be both wide and shallow.

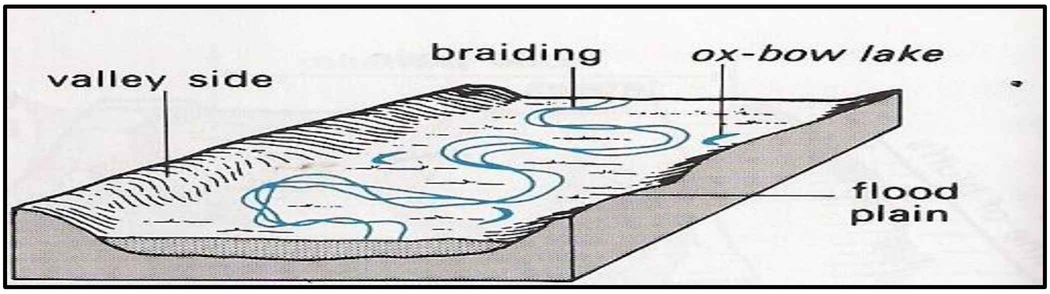


Figure 2.50: A Braided river

Deltas

Most of the load carried by the river is ultimately dumped into the sea or lake into which it flows. The deposited load sometimes collects in the river mouth where it builds up into a low- lying swampy plain called a *Delta* .As deposition goes on in the river mouth, the river is forced to divide into several *channels* each of which repeatedly divides. All these channels are called **distributaries. Spits and bars develop along the front of the delta.**

The 3 Types of Deltas

1. **Arcuate**

This is a very common type. Composed of coarse sediments such as gravel and sand and is triangular in shape. It has a great number of distributaries. Examples of rivers having this type of Deltas are: Nile, Ganges, Indus, Mekong, Niger

2. **Bird's Foot or Digitate**

This type is composed of very fine sediments called **silts**. The river channel divides into only a few distributaries. This type occurs in seas which have few currents and tides to disturb the sediments. An **Estuarine delta** develops in the mouth of submerged water. It takes the shape of the estuary.

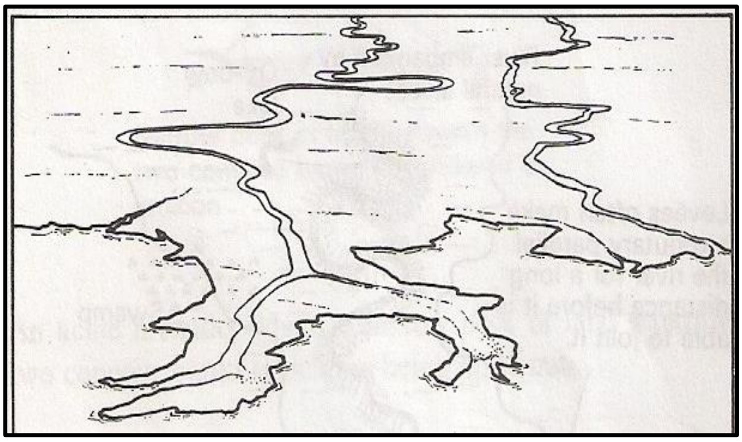


Figure 2.51: The Vardar delta

Underground Water and the Features It Produces

When rain falls, some it runs off the surface forming streams and rivers, some of it evaporates directly, or indirectly via plants; some soaks into the surface rocks.

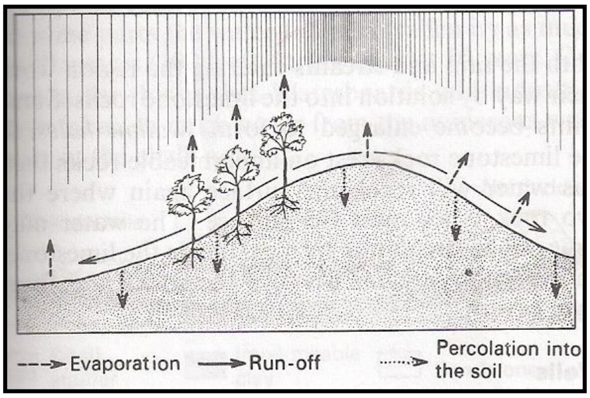


Figure 2.52: Evaporation. Run off and Percolation of water

The amount of run-off, evaporation and percolation depends upon the nature of the rocks, the slope of the land and the climate. Run-off on steep slopes is greater than on the gentle slopes; evaporation in dry climates is greater than in humid climates and water percolates into sand more easily than into granites.

How Water Enters the Rocks

Water will enter rocks which are porous (**Porous rocks:** rocks having small air spaces of rocks which have tiny spaces between their mineral grains which allow water to seep in). The most porous rock type sandstone) or rocks which are **pervious** (i.e. rocks having joints or cracks e.g. granites). Rocks which allow water to pass through them are said to be **permeable**. **Permeable rocks** have a series of gaps and fractures within them, which act as a natural 'plumbing system ' for water to pass through .For example, water can often seep along the junctions between beds of sedimentary rock (**bedding planes**), or move along **joints** (almost vertical cracks caused by earth forces. Some of the most permeable rocks are **limestone and Sandstone**.

Rocks which do not allow water to pass through them are said to be **impermeable**. Clay is an impermeable rock. Note: Clay is porous (water enters it), but it is impermeable (water will not pass through it)

The Water Table or the Level of Saturation

The water table is the level below which the ground is saturated. Any hole in the ground will fill with water, when the water table has been reached. This level often fluctuates with rainfall. Water entering the surface rocks moves downwards until it comes to a layer of impermeable rock, when further downward movements ceases. There are three water zones below the surface.

(i) The Zone Of Permanent Saturation: The pores of the rocks of this zone are always filled with water.
(ii) The Zone of Intermittent Saturation: The pores of rocks in this zone contain water only after the heavy rain.
(iii)The Zone of Non-Saturation: This lies immediately below the surface. Water passes through but never remains in the pores of the rocks of this zone.

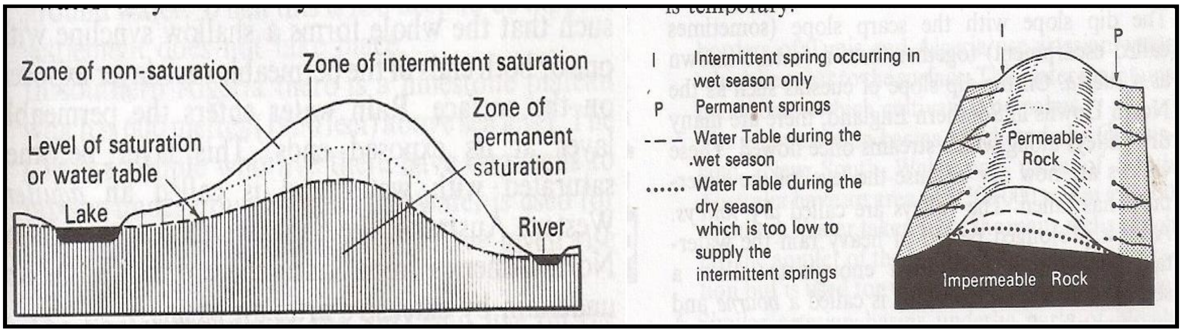


Figure 2.53: Formation of water table

Springs
When water flows naturally out of the ground, it is called a spring. There are many types of springs and here are some of the more common ones.

1. A permeable rock lying on top of an impermeable rock on a hill.
2. Well jointed rocks forming hilly country produce springs. Water enters the rocks via the joints. Springs frequently occur where the **water table** meets the surface.

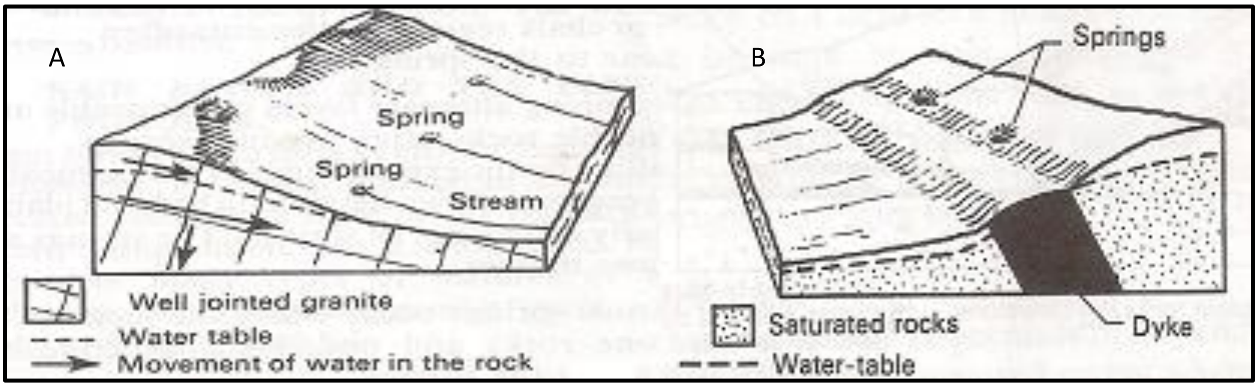


Figure 2.54: A. Formation of a spring from water table B. Formation of a spring from a dyke

3. The impounding of water by a dyke can give rise to springs. If a dyke cuts across a layer of permeable rocks, then the water on the up slope is impounded. The water table here rises and it gives rise to the springs where it meets the surface.

4. Chalk or Limestone escarpments which overlie impermeable rocks give rise to springs.

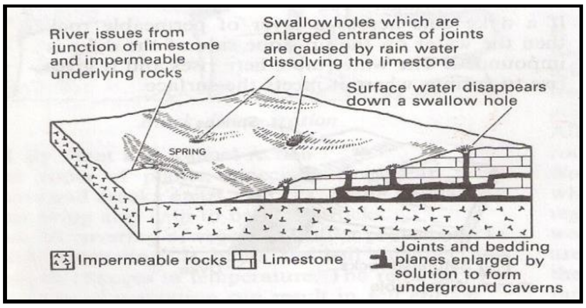


Figure 2.55: Formation of a spring from junction of limestone and impermeable underlying rocks

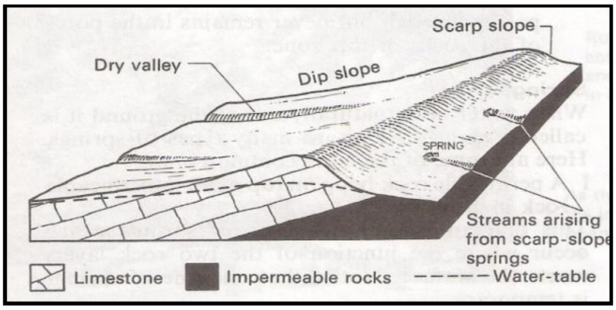


Figure 2.56: Formation of a spring from scarp slope

Wells

A well is a hole sunk in the ground to below the water table. Water then seeps out of the rocks into the well. Wells which are sunk far below the water table always contain water.

Refer to the diagram on the right. They are labeled A, B and C on the diagram.

Wells sunk only just below the water table often go dry in periods of drought when water –table fall (D). If a well does not reach the water table it will be dry.

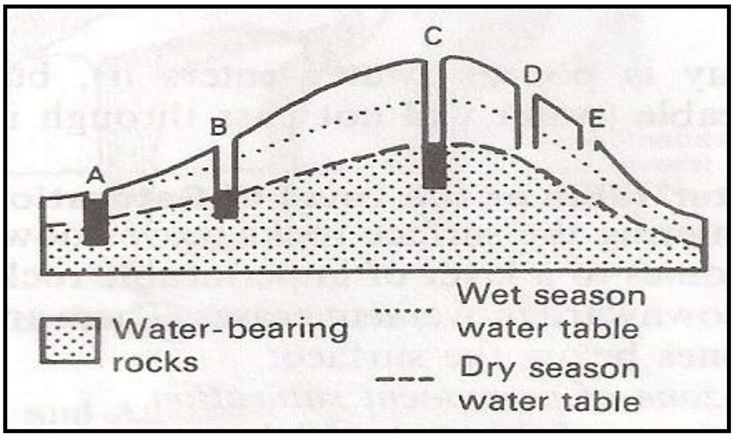


Figure 2.57: A cross section showing water table during wet and dry season

Artesian Basins and Artesian Wells

Artesian Basins

An artesian basin consists of a layer of permeable rock lying between two layers of impermeable rock such that the whole forms a shallow syncline with one or both ends of the permeable rock layer exposed on the surface. Rain water enters the permeable rock layer at its exposed end. This layer becomes saturated with water and it is called an **Aquifer**. Western Australia, the Sahara Desert and parts of North America are underlain by extensive artesian basins.

The diagram on the next page shows parts of the artesian basin of the Sahara Desert. In places where the aquifer bends up towards the surface, wind erosion sometimes exposes it. When this happens, pools of water occur and these are called **oases** (singular**, oasis**). If the Aquifer is close to the surface, wells can be dug. Also notice that the exposed part of the aquifer which receives the rain is called the **catchment area**.

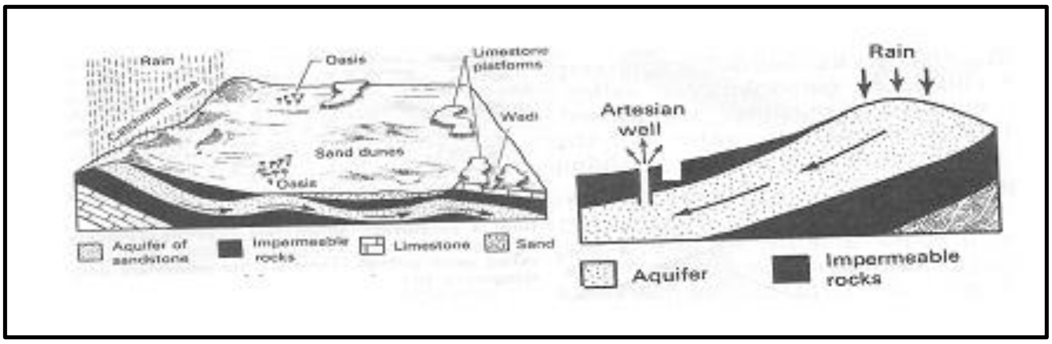


Figure 2.59: Section across the Sahara Desert showing the oases

Artesian Well

If a well is sunk in the aquifer of an artesian basin and the pressure of water is sufficient to cause the water to flow out of it, then the well is called an artesian well.

Some **groundwater** (water in the rock below the surface) finds its way naturally back to the surface at a **spring .**In other cases it provides an underground ‘reservoir’ to be drawn up from wells.

Groundwater presents problems in some mines and require special drainage tunnels and/or powerful pumps to remove it .Many old mines are now in a very dangerous flooded state .You should never enter such places without an expert guide.

Beds of rocks which provide a supply of underground water are called aquifers. Such rocks must be porous or permeable.

In general sandstones make the best aquifers, especially if they are poorly cemented and or/contain only a small amount of clay matrix. Wells have been drilled into a variety of sandstones of different ages.

Water in the aquifer fills it to a level called the water table. Water table varies according to the amount of rainfall. They can also be affected by the rate of pumping from wells. Some aquifers hold water under pressure so it rises from wells without the aid of pumps, the artesian basin

Ground water has a longer time of residence compared to surface waters such as rivers and therefore important in areas of wet and dry climates.

Turn to the next page to do activity 5.

Student Learning Activity 5

1. List the input, output and processes of the drainage system.

   Input:______________________________

   Output:____________________________

   Processes: i) _________________________ ii) ____________________________

2. What are the 3 river transportation processes?

   i) ____________________________ iii) ___________________________

   ii) ____________________________

3. When the river erodes, it grows. What are the three main ways by which a river grows?

   i) ____________________________ iii) ___________________________

   ii) ____________________________

4 What type of rocks are aquifers and what is their importance to man?

____

____

5. What is the difference between porous, pervious and impermeable? Explain

   i) Porous rock

   ____

   ____

   ii) Pervious rocks

   ____

   ____

   iii) Permeable rocks

   ____

   ____

6. Describe water table.

____

____

____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.6 : Mass Movement

Mass Movement and Resultant Landforms

The term mass wasting or movement describes all downhill movement of weathered material (regolith) including soil, loose stones and rocks in response to gravity. However it excludes movements where the material is carried by ice, water and wind. Although mass movement by definition refers to the downhill movement of material under the force of gravity, in reality water is usually present and assists the process. Mass wasting is more active than weathering.
There are three types of mass movement. They are:

- **A. Slow Movement**
- **B. Flow Movement**
- **C. Rapid Movement**

A. Slow Movement

There are two types of slow movement.

1. **Soil Creep**
2. **Solifluction**

1. Soil Creep

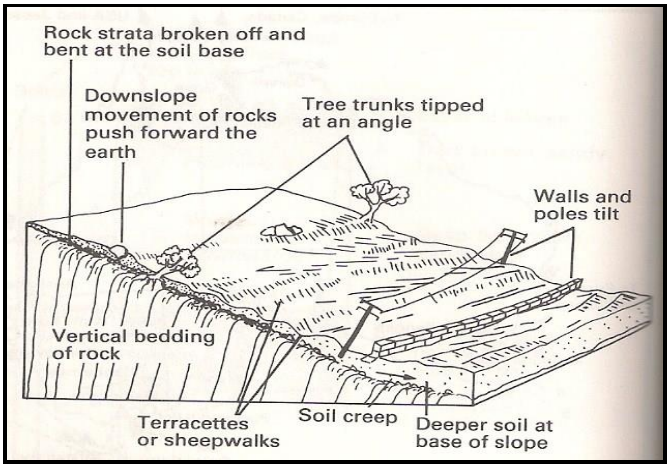


Figure 2.60: Soil creep and its effect

This is the slowest of downhill movements and is difficult to measure as it takes at a rate of less than 1 cm per year. However, unlike faster movements, it is almost a continuous movement. Soil creep occurs mainly in humid climates where there is vegetation cover and the entire slope is involved.

The changing water level in the soil and rocks causes repeated expansion and contraction which then result in soil creep. This is done in two ways.

i. Wet and Dry Periods

During times of heavy rain fall, moisture increases the volume and weight of the soil, causing expansion and allowing the regolith to move downhill under gravity. In a subsequent dry period, the soil will dry out and then contract, especially if it is clay.

ii. Freeze-Thaw

When the regolith freezes, the presence of ice crystals increases the volume by 9% per cent. As the soil expands, particles are lifted at right angles to the slope in a process called **heaving.** When the ground later thaws and the regolith contracts, these particles fall back vertically under the influence of gravity and so move downhill.

Soil Creep usually occurs in slopes of about 5^0 and produces terracettes – this is a step like features which develop as the vegetation is stretched and torn.

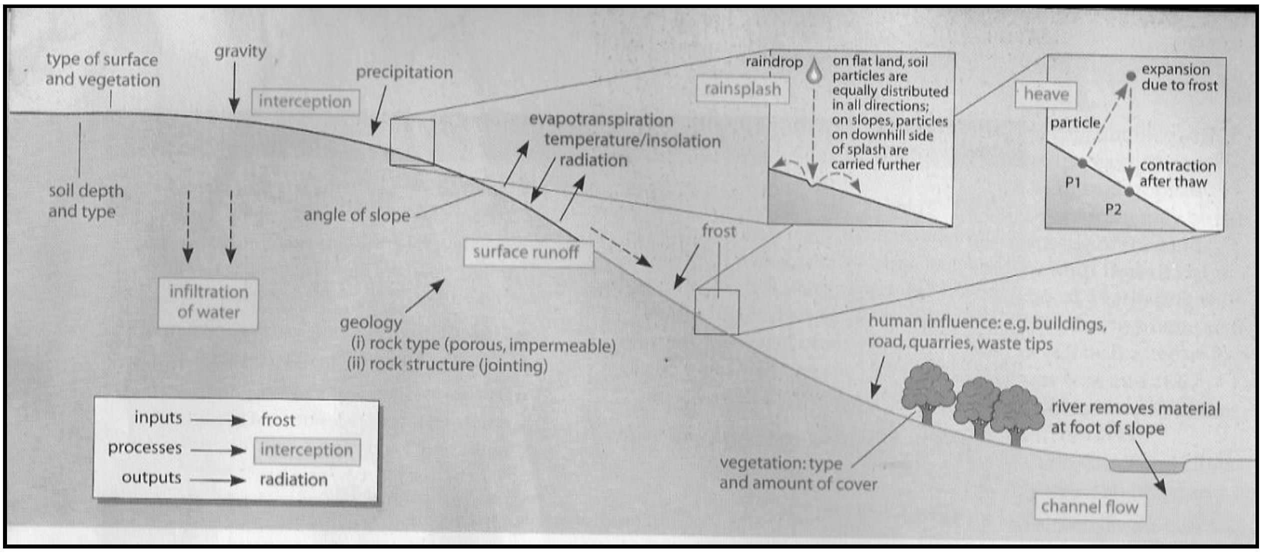


Figure 2.61 Process of heaving and solifluction

2. Solifluction

Solifluction is a special form of creep that produces a distinctive surface appearance. A process largely restricted to Tundra landscape beyond the tree line.

This process meaning “**soil flow**” is a slightly faster movement usually averaging between 5 cm and 1 m per year. Takes place under periglacial conditions where vegetation cover is limited. Periglacial refers to Tundra landscape beyond the tree line.

- During the winter season, both bedrock and regolith are frozen.
- During summer, the near surface portion of the ground (called the active layer) thaws, but the underlying layer remains frozen and acts like impermeable rock. but the melt water cannot percolate deeper because of the permafrost below. When the top layer melts and begins moving over the solid permafrost below, then there is **solifluction**. (Because surface melt water cannot infiltrate downwards, any topsoil will soon become saturated and will flow as an active layer over the frozen subsoil and bedrock. This process produces **solifluction sheet or lobes**.

B. Flow Movements

There are two types of flow movements.

1. **Earthflows** – This happens when the regolith on slopes become saturated with water and begins to flow downhill (at a rate varying between 1 and 15 km per year).
    - Occurs normally during or right after a heavy rain.

- The movement of material may produce short flow tracks yet may not be fast enough to break vegetation.
- Most common type of Flow movement.

2. **Mudflow** - A mudflow originates in drainage basins in arid and semiarid country when a heavy rain following a long dry spell produces a cascading runoff too voluminous to be absorbed into the soil. These are more rapid movements, occurring on steeper slopes and exceeding 1 km per hour. Mudflows are likely to occur following periods of intensive rainfall.
    - Occurs on slopes in arid or semi-arid country.
    - Sometimes called debris flow

C Rapid Movements

There are three types of rapid movements.

1. **Slides** - In mountainous terrain, landslides carry large masses of rock and soil down slope abruptly.
    - A landslide is an instantaneous collapse of a slope and does not necessarily involve the lubricating effect of water or clay.
    - Landslide action is both abrupt and rapid.

2. **Slump**: Slumping involves slope collapse, in which the regolith moves downward and at the same time rotates outwards.

3. **Rock Falls**

   Rock rockslide is the most catastrophic type of landslide. It involves a sudden rapid slide of bedrock along planes of weakness.

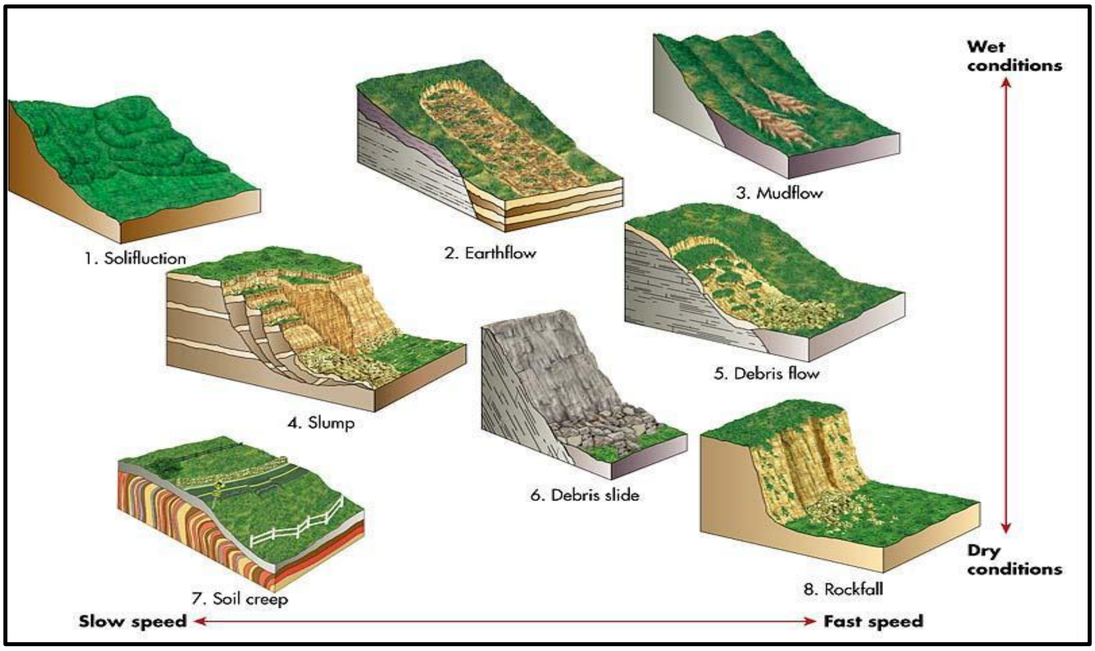


Figure 2.62: Different types of mass movement

Student Learning Activity 6

1. Denudation is accomplished by the interaction of which three types of activities?

   i) ___________________________________ iii) _____________________________

   ii) ___________________________________

2. Identify 2 examples of flow movements.

   i) ___________________________________ ii) ____________________________

3. Which type of movement involves slope collapse? ______________________________

4. Explain solifluction.

   ____

   ____

   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.2.7 : Types of Weathering

Weathering is the breaking down of the earth's rocks through direct contact with planet's atmosphere, or is the breaking down or disintegration of rocks in blocks or in grains near or at the earth's surface.

Weathering (breaking down or disintegration) occurs in **situ** or no movement and should not be confused with **erosion-** which involves the movements of rocks and minerals by agents such as water, ice, wind and gravity.

There are three types of weathering.

1. **Physical/ Mechanical weathering**
2. **Chemical weathering**
3. **Biotic/Biological weathering**

The activities of both Physical and Chemical weathering creates cracks in rocks that act as channels for air and water to get deeper into rocks interior.

1. **Physical Weathering**

Mechanical or Physical weathering involves the breaking down of rocks and soils through the direct contact with atmospheric conditions such as heat, water, ice and pressure. It is the process that causes the disintegration of the rock. The primary process in physical weathering is abrasion (process by which particles are reduced in size).

The Types of Physical Weathering

A. Thermal Expansion

- Occurs in areas like deserts where there is a; large diurnal temperature range. As the rock heats up and expands during the day and cools and contracts during the night, stress is often exerted on the outer layers.
- The stress causes the peeling off of the outer layers of rocks in thin sheets.
- Mainly caused by temperature changes but enhanced by the presence of moisture.

B. Frost Shattering

- This type of weathering is common on mountain tops or mountainous areas where the temperatures fluctuate below and above the freezing point of water.
- When water enters the joints/cracks and it freezes, the ice formed, strains the wall of the joints and causes the joints to deepen and widen.
- When the ice thaws (melts), water can flow further into the rock. Repeated freeze thaw cycle's overtime weakens the rock which over time breaks up along the joints into angular pieces.

The angular pieces/ fragments gather at the foot of the slope to form a talus or a scree slope.

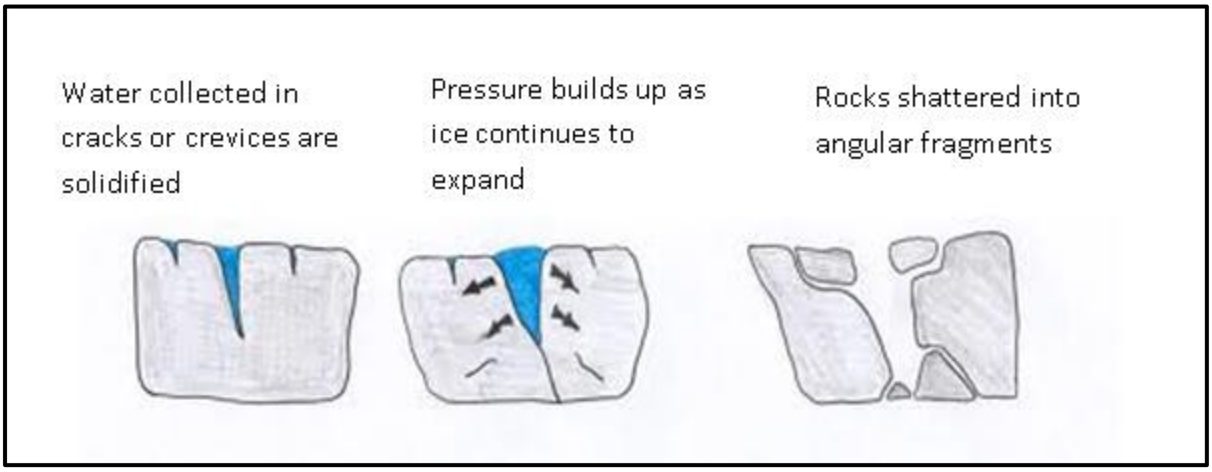


Figure 2.63: Frost shattering

Scree

Scree also called Talus is a term given to an accumulation of broken rock fragments at the base of mountain cliffs. Landforms associated with these materials are sometimes called scree slopes or talus piles.

Scree commonly refers to smaller material like mixed gravel and loose dirt (anything smaller than the human fist).While Talus refers to rocks larger than scree.

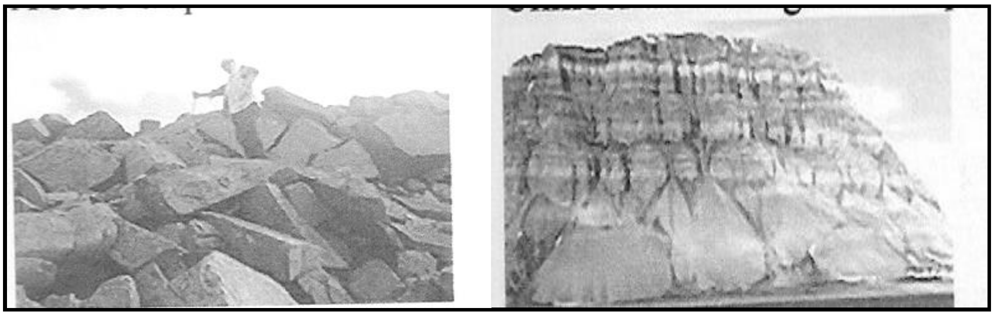


Figure2: Talus cones

Formation of scree or talus deposits results from physical and chemical weathering.

C. Pressure Release or Unloading or Sheeting

- overlying materials (not necessarily rocks) when removed causes the underlying rocks to expand and fracture.
- Often the overlying material is heavy and the underlying rocks experience high pressure under them.
- Intrusive igneous rocks (granite) are formed deep beneath the earth's surface. They are under extreme pressure because of the overlying material. When erosion removes the overlying material, these intrusive rocks are exposed and the pressure on them is released.
- The outer parts of the rocks then tend to expand.

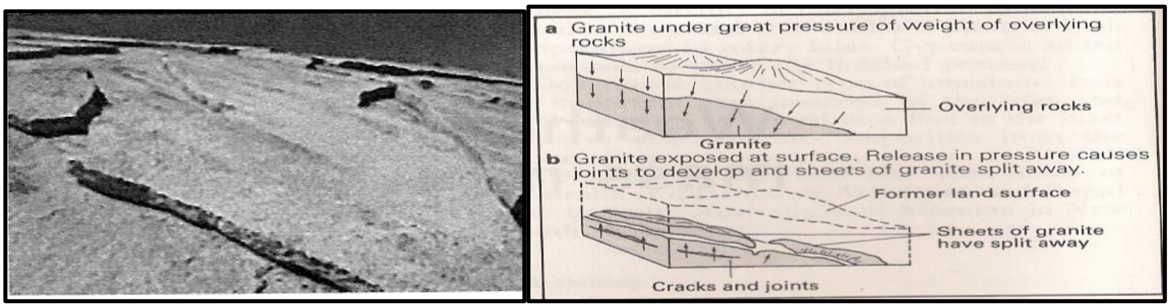


Figure 2.64: Pressure release

D. Salt Crystalisation

- Also known as haloclasty,
- Causes disintegration of rocks when saline solutions seep into cracks and joints in the rocks and evaporate, leaving salt crystals behind.
- These salt crystals expand as they are heated up, exerting pressure on the confining rock.
- Relatively important in hot deserts where there is some regular moisture. And also effective in the coastal areas where high salinity and atmospheric humidity are combined.

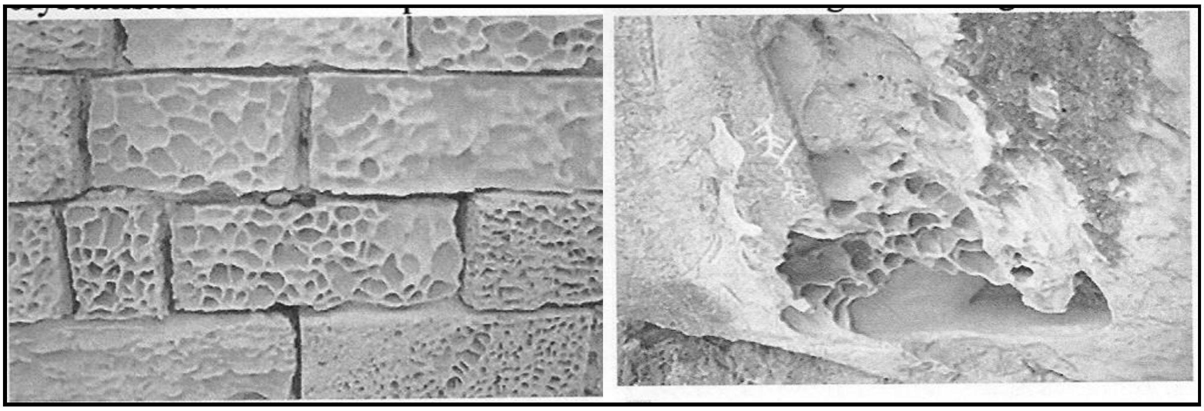


Figure 2.65: Salt weathering on the building stone

2. **Chemical Weathering**

Chemical weathering involves the direct effect of the atmospheric chemicals or biological produced materials in the breakdown of rocks, soils and minerals.This is mainly caused by the chemical actions of water and substances dissolved in it. Some rock forming minerals react with plain water (feldspars, mica). These are easily transported away to be eventually deposited as mud or clay sediment. The reaction produces tiny mica like particles known as clay minerals. The reactions that form clay minerals also release elements such as sodium, calcium, potassium, magnesium and silicon which dissolve in water and are carried away.
Rain water often contains dissolved impurities which increase chemical decomposition of rock. Chemical weathering tends to alter the colour and appearance of rocks.

Chemical weathering tends to:

- Selectively attack certain minerals
- Occur in zones of alternate wetting and drying.

- Occurs mostly at the base of the slopes where it is likely to be wetter and warmer.

Chemical weathering involves changes in the chemical character of rocks minerals. It takes places because minerals which were stable in their original environment become unstable when they come within range of the atmosphere and particularly when come into contact with water. Water which has penetrated near surface layers is the most important chemical agent affecting rocks. This type of weathering is most active in humid or wet climatic regions. The following are the main chemical weathering processes.

A. Solution

- Solution is the most initial phase of many important types of chemical weathering.
- It is the process whereby a substance in the rock is dissolved, either by rainwater, or by other substances, such as acids in the water.
- All minerals are soluble to some extent. Some, like rock salts, readily dissolve in water. Even quartz is slowly dissolved, particularly in slightly alkaline waters at high temperatures.
- Limestone is insoluble in water, but reacts with carbonated waters to form the bicarbonate which is soluble.

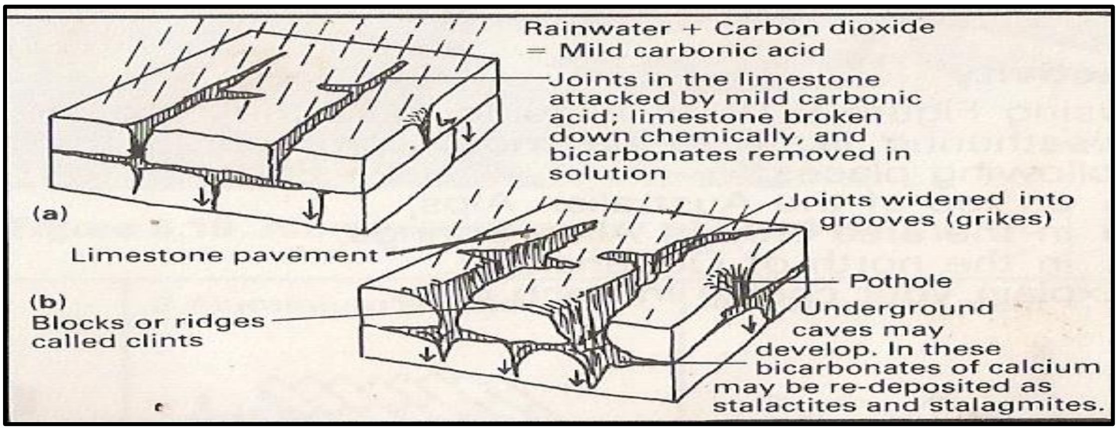


Figure 2.66: Limestone weathering

Solution is a highly significant weathering process, because of its direct effects on the rocks and also because of the reactions it initiates.

B. Hydration

- Certain rocks are capable of absorbing water into their structure, causing them to swell and to become vulnerable to future breakdown.
- This process appears to be most active following successive periods of wet and dry weather and is important in forming clay particles.

C. Oxidation

- This is the combination of minerals such as iron compounds with oxygen, whereby reaction takes place easily in the presence of water and heat.
- The process is similar to rusting of metal objects.

When oxygen dissolves in water and comes into contact with certain rock minerals, the minerals undergo oxidation in which the oxygen atoms combine with atoms of various metallic elements making up the minerals in the rock and form new products. The new substance is more voluminous softer and easily eroded than the original compounds**.**

D. Carbonation

- This is the reaction of certain minerals such as calcium, magnesium and sodium with carbon dioxide.
- Water and carbon dioxide combine to form carbonic acid, which attacks many rock mineral.
- Feldspar, the world's most abundant mineral combines with carbon dioxide to form soft clay.

Carbonation involves the reaction between the carbon dioxide in water and carbonate rocks to produce a very soluble product (calcium bicarbonate) that can readily be removed by runoff or percolation and can also be deposited in crystalline form if the water is evaporated.

E. Hydrolysis

- This is the most significant chemical process in the decomposition of rocks and formation of clays.
- Hydrogen in water reacts with minerals in the rocks. (water combines with the mineral rather than dissolving it.)

Is the chemical union of water with another substance to produce a new compound that is softer and weaker than the original. Hydrolysis increases the volume of the mineral and this expansion contributes to mechanical disintegration. In tropical areas where water frequently percolates to considerable depth, hydrolysis often occurs far below the surface.

F. Chelation

- Humic (organic) acid is derived from the decomposition of vegetation (humus) and contains important elements such as calcium, magnesium and iron.
- These are released by the process called chelation.
- The presence of organic life (plants, animals, bacteria) increases the concentration of carbon dioxide in soil and thus the level of carbonation.

3. Biological Weathering

Vegetation may cause chemical and mechanical weathering. The decay of the plants leaves may make rainwater more acid and speed up chemical weathering in the soil and at the rock surface. The presence of lichens and mosses on rocks surfaces concentrates moisture and increases the amount of chemical weathering that occurs.

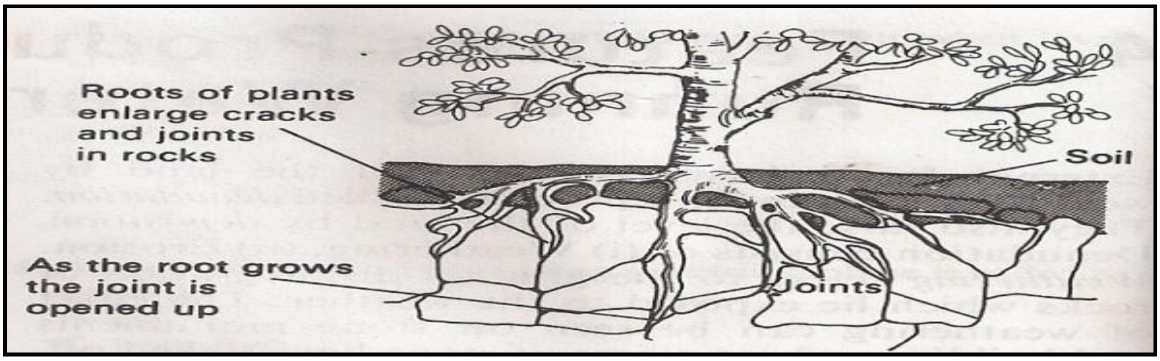


Figure 2.67 : Biotic weathering, tree roots growing into rocks cracking it apart

Tree roots as they grow prise apart rocks. This is a powerful type of mechanical rock disintegration. Organisms such as earthworms break down the fragments in the soil in their digestive systems.

Figure 2.68: Tree roots cracks open a rock

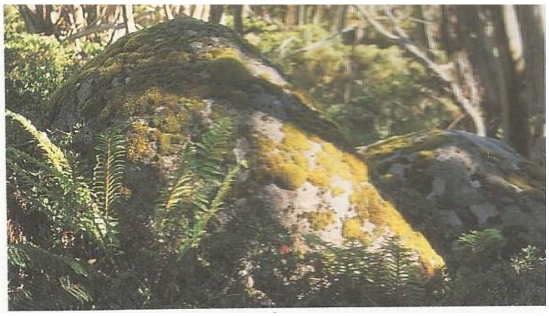


Figure 2.69: A moss covered rock

Tree roots may grow or extend into joints, widening them until blocks of rocks become detached**.**

The Effect of Weathering

The main significance of weathering is that it prepares rock for erosion and transportation. Without preliminary weathering agents of erosion such as running water, ice and wind, it would be much less significant.

Factors Affecting the Type and Rate of Weathering

Observation show that the type of weathering varies from place to place. The climate, type of rock, and the slope appear to be the most important factors.

a) Climate

Chemical weathering is most important in the humid tropics where temperatures are consistently high, and there is ample moisture and abundant vegetation. Solution and Hydrolysis are significant. Chemical weathering may be three to four times as rapid here as in temperate regions.

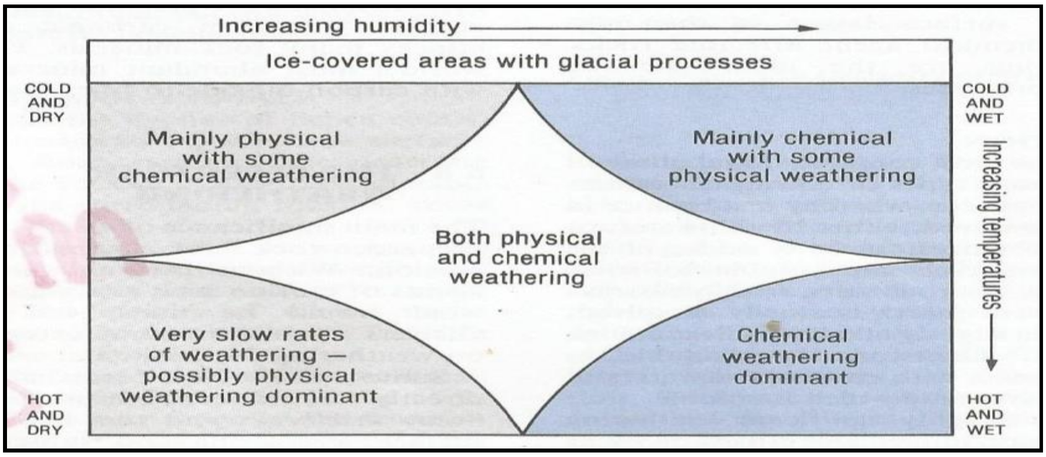


Figure 2.70 Influence of climate on weathering

Climatic Controls on Weathering

The diagram below illustrates how climate influences weathering.

This increases as temperatures and rainfall total increases. It has been claimed that the rate of chemical weathering doubles with every 10 ^{0}C temperature increase.

Chemical weathering will be rapid at **S** (figure 2.9b) due to humic acid from the vegetation. It will be limited at **P,** because temperatures are low, and at **R**, where there is insufficient moisture for the chemical decomposition of rocks.

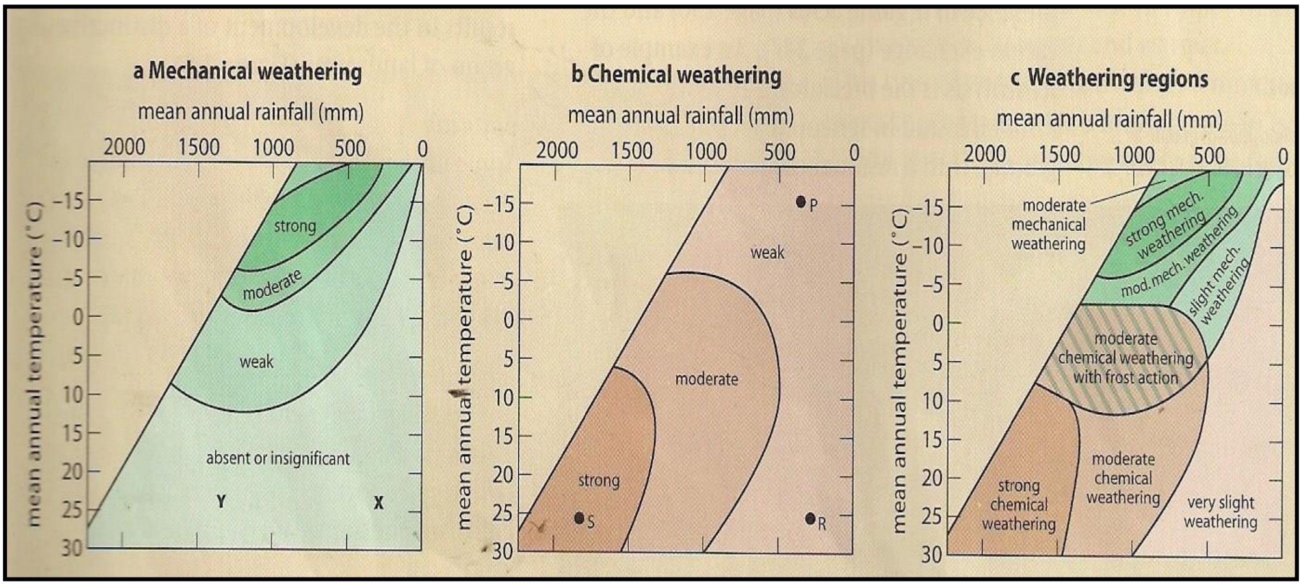


Figure 2.70: Effects of climate on weathering

- Frost shattering is important is temperature fluctuates around 0^{0} C, but will not operate if the climate is too cold (permanently frozen) too warm (no freezing), too dry (no moisture to freeze), or too wet (covered by vegetation).

- Mechanical weathering will not take place at X (on figure 2.9a) where it is too warm and there is insufficient moisture, while at **Y,** the high temperature and heavy rainfall will give a thick protective vegetation cover against insolation.

b) Rock Type

The rock type is important in determining the rate and the type of weathering. A rock as such as shale is far more susceptible to chemical weathering than quartz or sandstone and weathers more rapidly. Basalt also is subject to rapid chemical weathering, particularly where ample moisture is available.

c.) Slope

The slope influences the movement of water and thus, the rate of chemical weathering. There is less water available for weathering on a steep slope than on a flat lope in the same climatic zone.

Now do the activity on the next page.

Student Learning Activity 7

1. What is weathering?

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2. What are the main weathering processes?

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3. List the main types of Physical weathering processes

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4. What is the main difference between scree and talus?

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NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3 : INTERNAL FORCES AND PLATE MOVEMENTS

In the last topic you looked at the external forces or the geomorphic processes that work on the surface of the earth that build and shape land. In this topic you will look at the internal forces and the plate tectonics. These are processes that work within the earth's crust and are also responsible for building and shaping the earth's surface.

Objectives or aims

On successful completion of this module, you will be able to:

- discuss the theory of plate tectonics, continental drift and isostacy.
- identify the types of plate movements and their resultant landform features and
- define earthquakes, volcanism and elaborate on their associated hazards.

Time Frame

This unit should be completed within 3 weeks.

11.1.3.1 : Plate Tectonics Theory

The theory of plate tectonics

The lithosphere (the earth's crust and the rigid upper part of the mantle) is divided into seven large and several smaller **plates.** The plates, which are rigid, float like rafts on the underlying semi-molten mantle (the **asthenosphere**) and are moved by **convection currents**.

Plate tectonics is the study of the movement of these plates and their resultant landforms.

There are two types of plates or crust: **continental** and **oceanic**. However, these terms do not refer to actual continents and oceans, but to different types of crust or rock.
Continental crust, or **sial**, is composed of older, lighter rock of granitic type. It is dominated by minerals rich in silica (Si) and aluminium (Al), from which the term **sial** is derived.

Oceanic crust, or **sima**, consists of much younger and denser rock of basaltic composition. Its dominant minerals are silica (Si) and magnesium (Ma) which forms the deep ocean basin floors. The symbols of silica and magnesium forms the word sima.

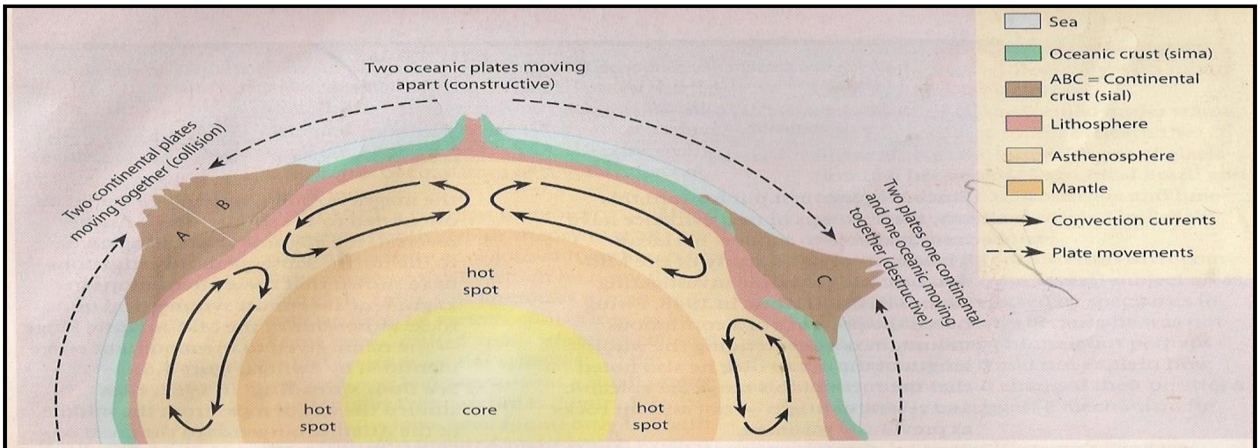

Figure 1.6
How plates move

Figure 1.7
Differences between continental and oceanic crust

	Continental crust (sial)	Oceanic crust (sima)
Thickness	35-40 km on average, reaching 60-70 km under mountain chains	6-10 km on average
Age of rocks	very old, mainly over 1500 million years	very young, mainly under 200 million years
Weight of rocks	lighter, with an average density of 2.6	heavier, with an average density of 3.0
Nature of rocks	light in colour; many contain silica and aluminium numerous types, granite is the most common	dark in colour; many contain silica and magnesium few types, mainly basalt

Figure 3.1 Plate movements and differences between continental and oceanic crust

Plate movement and Differences between Continental and Oceanic Crust
As a result of convection currents generated by heat from the centre of the earth, plates may move towards, away from or sideways along adjacent plates. It is at plate boundaries that most of the world's major landforms occur, and where earthquake, volcanic and mountain-building zones are located.

Important Notes to take note of:

1. The continental plate is thick and less dense while the oceanic plate is thin and dense. This results in the oceanic plate or crust being formed and destroyed continuously.
2. Continental plates, such as the Eurasian plate, may consist of both continental and oceanic crust.
3. Continental crust may extend far beyond the margin of the landmass.
4. Plates cannot overlap. This means that either they must be pushed upwards on impact to form mountain or one plate must be forced down –wards into the mantle and destroyed.
5. No 'gaps 'may occur on the earth's surface so, if two plates are moving apart, new oceanic crust originating from the mantle is being formed.
6. The earth is neither expanding nor shrinking in size. Thus, when new oceanic crust is being formed in one place, older oceanic crust is being destroyed in another.
7. Plate movement is slow (though not in geological terms) and is usually continuous.

There are three types of plate boundaries:

1. Convergent **2. Divergent** **3. Passive boundary**

Plate Boundaries

1. Destructive Margins or Convergent Boundaries

At spreading centers, new oceanic lithosphere is continually being generated. However, because the total surface area of the earth remains constant, lithosphere must also be consumed. Zones of plates' convergence are the sites where Oceanic lithosphere is subducted and absorbed into the mantle.

When two plates converge, the leading edge of one is bent downward, allowing it to descend beneath the other. The region where the oceanic plate descends into the asthenosphere is called a **Subduction Zone**. As the oceanic plate slides beneath the overriding plate, the oceanic plate bends, hereby producing a Deep Ocean Trench (Peru-Chile trench).

There are three types of plate movements at Destructive Margins or Convergent Boundaries.

i) Oceanic-Continental Convergence

When the continental crust converges with an oceanic plate, the denser oceanic plate sinks into the asthenosphere. When a descending plate reaches the depth of about 100 to 150 kilometers, the increase in pressure can trigger off major earthquakes while the heat produced by friction helps to convert the disappearing crust back into magma. The newly formed silica rich magma being less dense than the rocks in the mantle may migrate to the surface, which can give rise to volcanoes and volcanic eruptions. These volcanoes are likely to form either a long chain of fold mountains, (e.g. Andes) or if the eruption takes place offshore, (e.g. Japan, West Indies)
Mountains such as the Andes, which are produced in part by volcanic activity associated with the subduction of oceanic lithosphere are called **continental volcanic arc.**

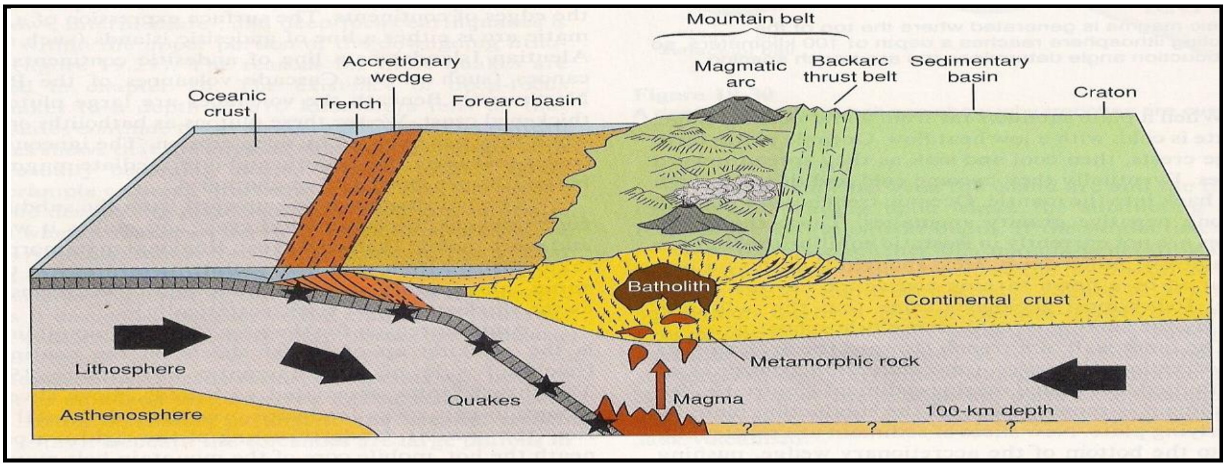

Figure 3.2: Collision Zones

ii) Oceanic-Oceanic Convergence

When two oceanic plates converge, one descends beneath the other, initiating volcanic activity in a manner similar to that which occurs at the continental –oceanic convergence boundary.

In this case however, the volcanoes form on the ocean floor rather than on the continent. These activities sometimes built volcanic structures that emerge as islands.

Example: The Tonga, Marianas Aleutian islands are examples of volcanic arc. Located adjacent to this island arc are the Aleutian, the Tonga and the Marianas Trench.

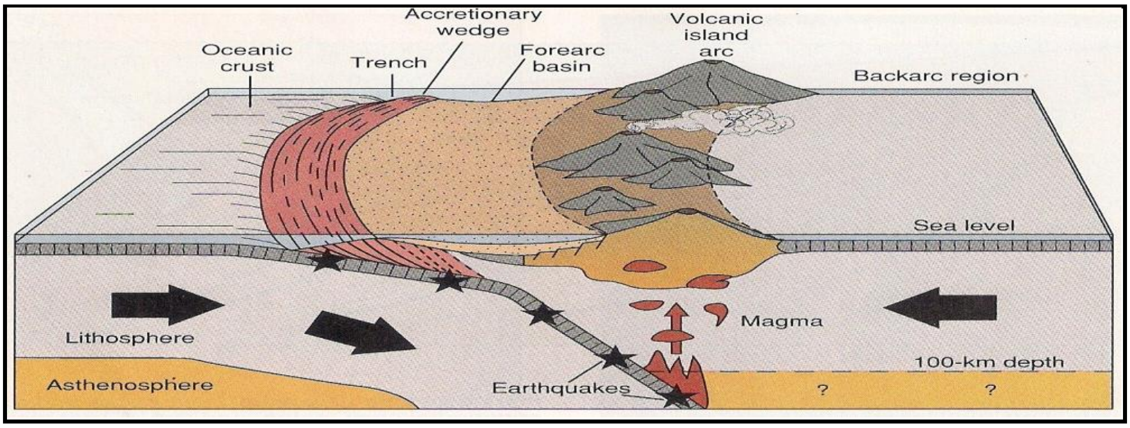

Figure 3.3: Destructive zone

iii) Continental-Continental Convergence

When two plates carrying continental crust converge, neither plate will subduct beneath the other because of the low density. The result is a collision between the two continental blocks. It is where this continental collision occurs, that fold mountains form and the earth's crust is at its thickness. Collision zone refers to where two continental collisions occur. Example: Himalayas, Alps, Urals and Appalachians.

iv) Constructive Plate Margin or Divergent Boundaries

Constructive margins occur where two plates **diverge** or move away from each other and new crust is created at the boundary. Most divergent boundaries, where **plate spreading** occurs are situated along the crest of **oceanic ridge***s*. Sea Floor Spreading occurs in the mid-Atlantic where the North America and the South American plates are being pulled apart by convection currents form the Eurasia and African plates, initially this may cause huge **rift valleys** to form on the sea floor.

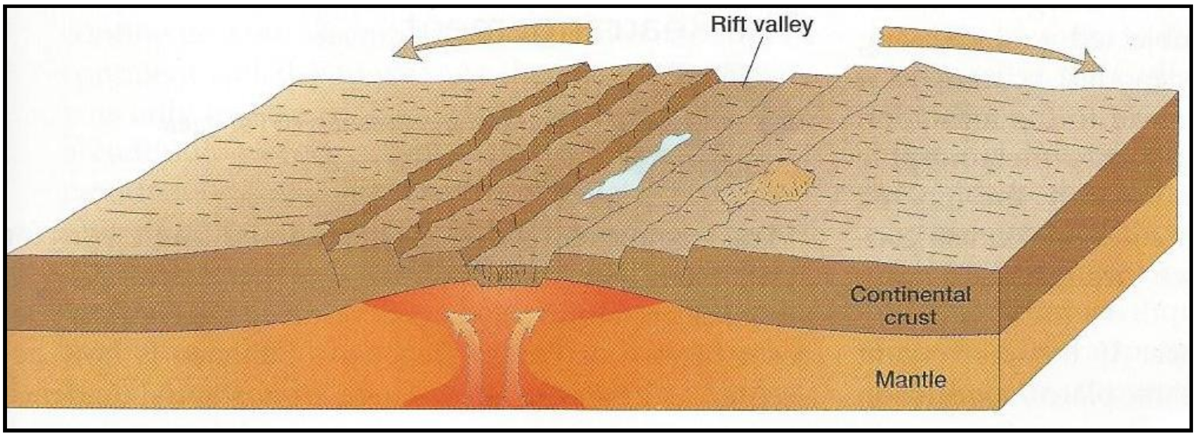

Figure 3.4: Divergence boundary

However, molten rock or magma from the hot asthenosphere (mantle) rises to fill any possible gap between the two plates. This mechanism is called **sea floor spreading**. This magma produces **submarine volcanoes** which in time may grow above sea level. Examples: Mid Atlantic ridge, Easter Island, surtsey.

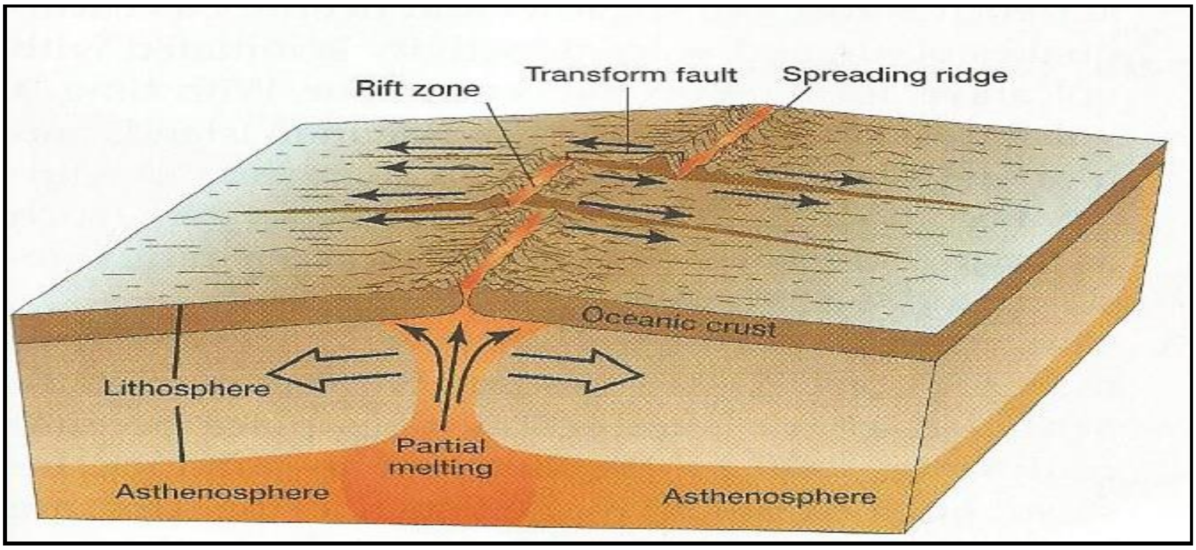

Figure 3.5: Mid ocean ridge spreading centre

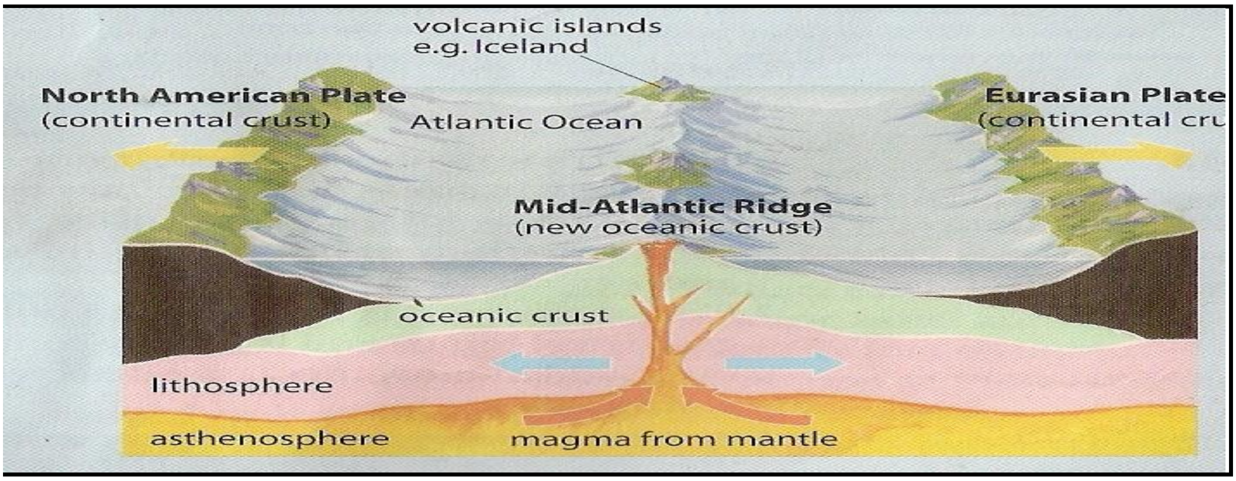

Figure 3.6: Cross section of the Mid-Atlantic Ridge

4. Conservative Plate Margins or Passive Transform Fault Boundaries

At transform fault boundaries, plates grind past one another or where two plates move parallel to one another without the producing or destroying the lithosphere. Although frequent small earth tremors and occasional severe earthquakes may occur as a consequence of the plates trying to slide past each other, the margins between the plates is said to be conservative because crustal rocks are neither being created nor destroyed. The boundary between the two plates is characterized by pronounced **transform faults**. For Example; San Andreas Fault in California, USA.

Type of plate boundary	Description of changes	Examples
A Constructive margins (spreading or divergent plates)	two plates move away from each other; new oceanic crust appears forming mid-ocean ridges with volcanoes	Mid-Atlantic Ridge (Americas moving away from Eurasian and African Plates) East Pacific Rise (Nazca and Pacific Plates moving apart)
B Destructive margins (subduction zones)	oceanic crust moves towards continental crust but, being heavier, sinks and is destroyed forming deep sea trenches and island arcs with volcanoes	Nazca sinks under South American Plate (Andes) Juan de Fuca sinks under North American Plate (Rockies) Island arcs of the West Indies and Aleutians
Collision zones	two continental crusts collide and, as neither can sink, are forced up into fold mountains	Indian Plate collided with Eurasian Plate, forming Himalayas African Plate collided with Eurasian, forming Alps
C Conservative or passive margins (transform faults)	two plates move sideways past each other – land is neither formed nor destroyed	San Andreas fault in California
Note: centres of plates are rigid...	rigid plate centres form a shields lands (cratons) of ancient worn-down rocks b depressions on edges of the shield which develop into large river basins	 Canadian (Laurentian) Shield, Brazilian Shield Mississippi-Missouri, Amazon
...with one main exception	(Africa dividing to form a rift valley and possibly a new sea)	(African Rift Valley and the Red Sea)

Figure 3.7: The major landforms from plate movement

Student Learning Activity 1

1. What type of plate movements occurs under the Destructive margin?

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2. When Indian plate collides with the Eurasian plate , what is the resultant landform feature that forms from that collision?

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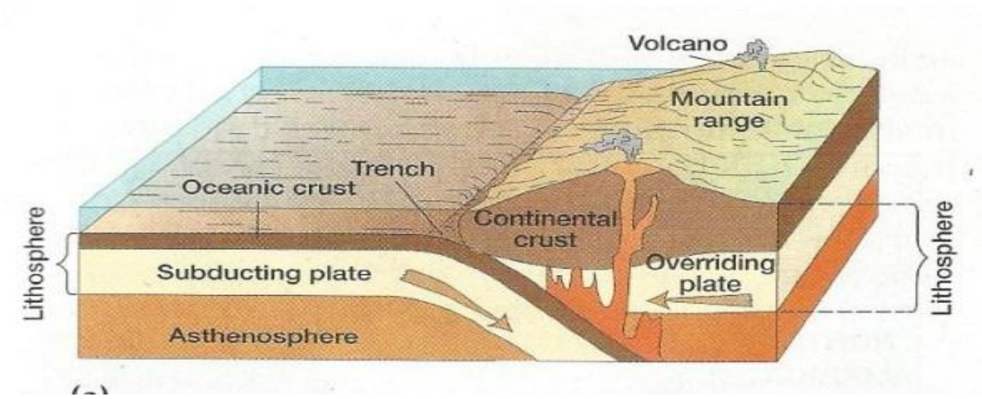
3. Explain the type of plate movement as illustrated by the diagram below.



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NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.2 : Continental Drift Theory

As early as 1620, Francis Bacon noted the jigsaw - like fit between the east coast of South America and the west coast of Africa. In 1912, a German meteorologist, Alfred Wegener, published his theory that all continents were once joined together in one large supercontinent which he named Pangaea. The word Pangaea means all Lands. Later, this landmass somehow split up in to various continents, as we know them today. This was the result of the one world continent drifting apart. Wegener collected evidence from several sciences.

- **Biology**:
  1. Fossils of Mesosaurus, a small aquatic reptile found only in Africa and South America (Brazil)
  2. A coal plant usually forms in hot swampy conditions found only in India and Antarctica.
- **Geology**: Rocks of similar type, age, formation and structure occur in South East Brazil and South America.
- **Climatology**: Coal formed under warm, wet conditions is found beneath the Antarctic ice cap and evidence of glaciation has been noted in Tropical Brazil and central India.

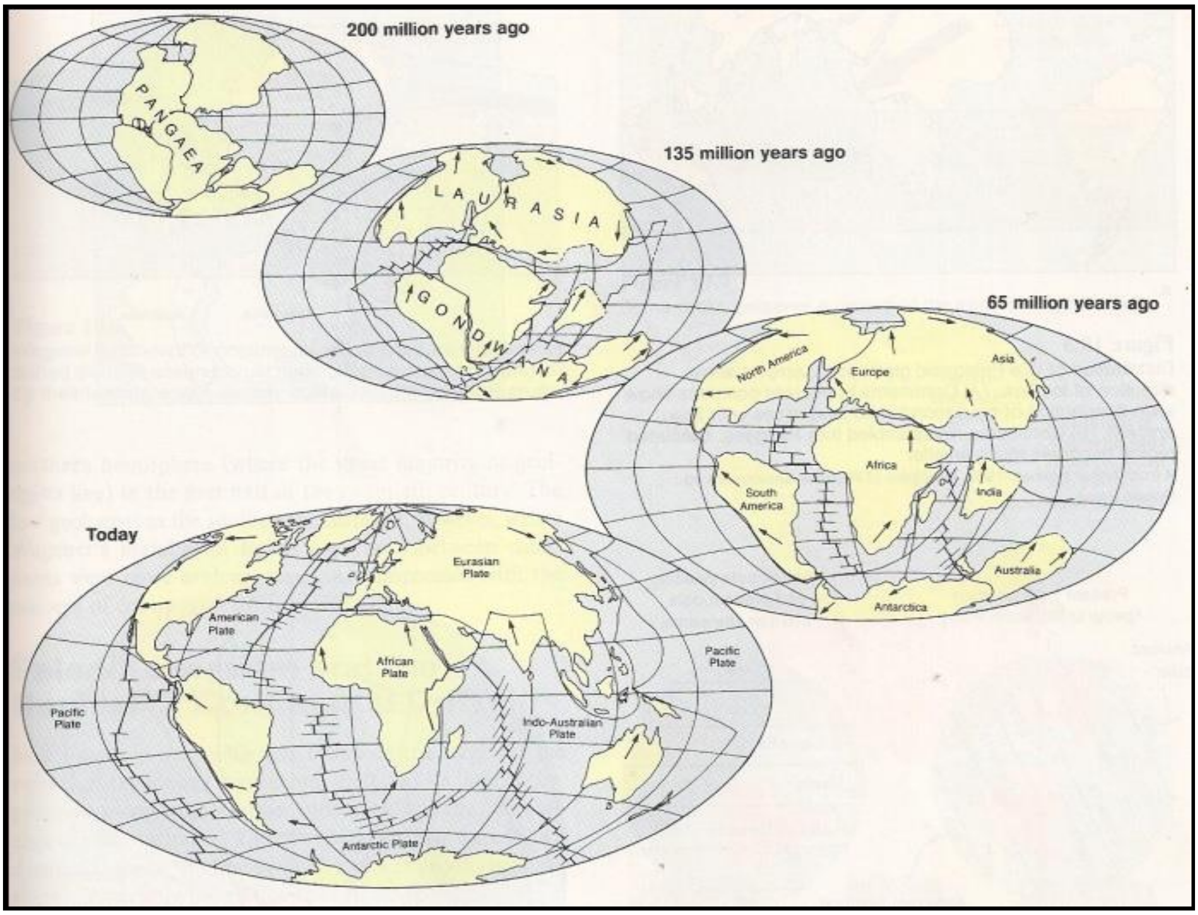

Figure 3.8: Continental drift from Pangaea

Wegener's theory of continental drift combined information from several subject areas but his ideas were rejected by specialists in those disciplines partly because he was not regarded as an expert himself but perhaps because he could not explain how solid continents had changed their position. He was unable to explain a mechanism for a drift.

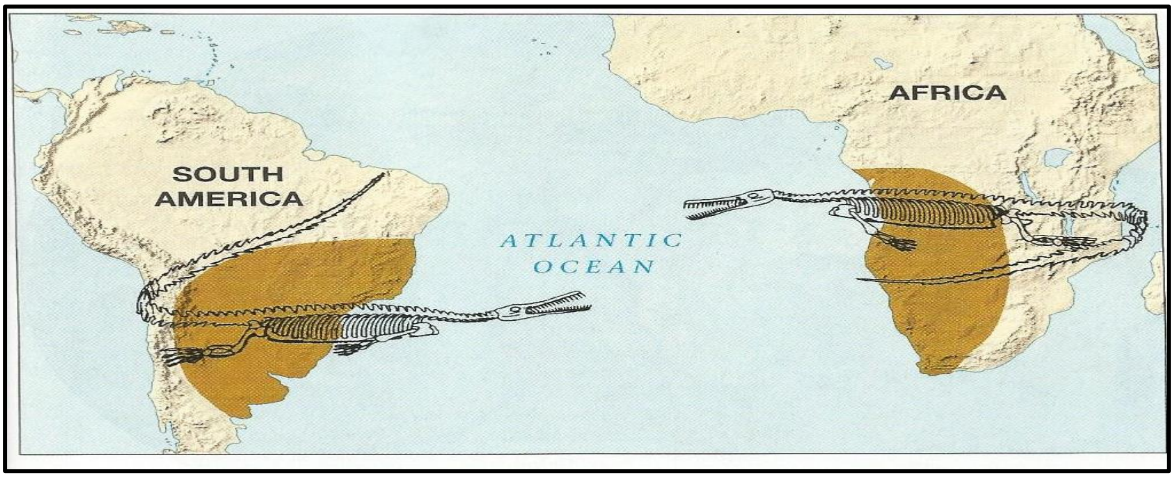

Figure 3.9: Matching of the Mesosaurus fossils in South America and Africa

Pangaea was divided in two large continents which he named **Laurasia** and **Gondwanaland**. He also suggested how the world may look in the future if the continents continue to drift.
The Northern half of Pangaea is called Laurasia which is a name derived from Laurentia (an old name for the core of Canada and from Eurasia a combined term for Asia and Europe.)

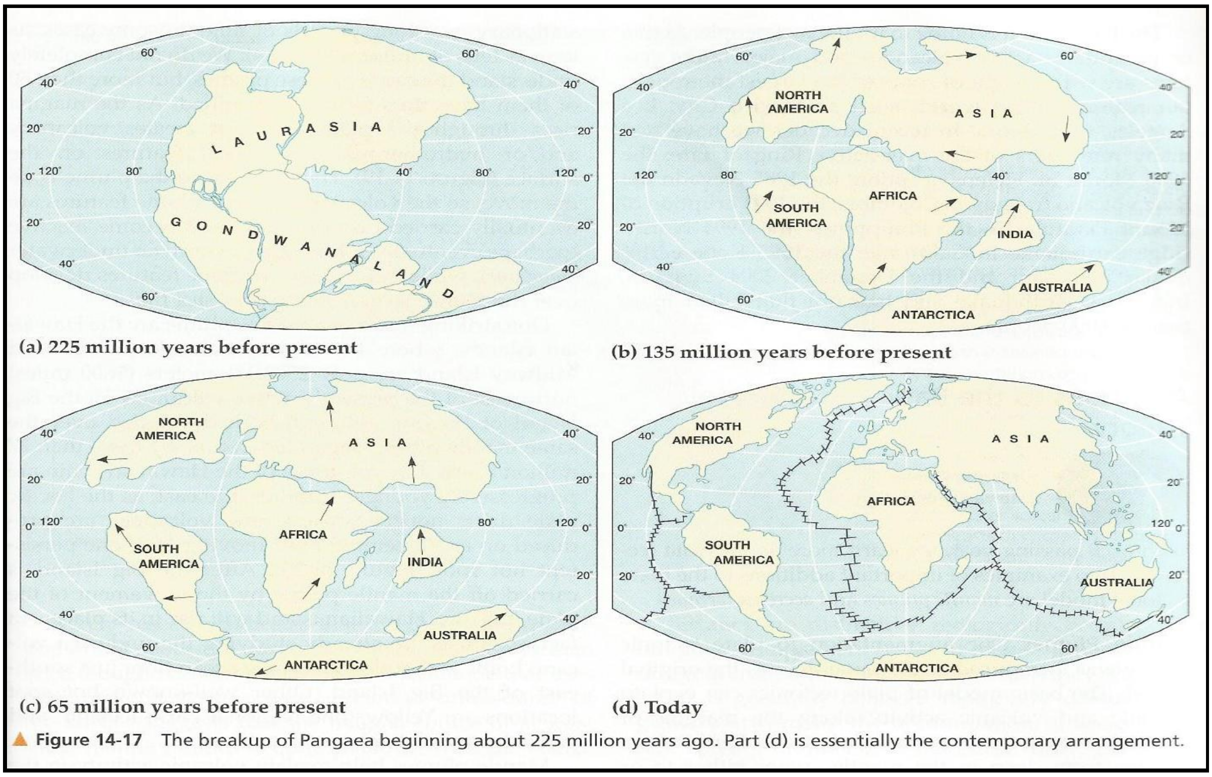

Figure 3.10: Breakup of Pangaea

The southern half, called Gondwanaland which is a name derived from a distinctive group of rocks found in central India. Similar rocks are found in Africa, Antarctica, Australia and South America.

Now do the activity below.

Student Learning Activity 2

1. Alfred Wegner used evidences from which science fields to explain his theory.

   i) ____

   ii) ____

   iii) ____

2. What is the main idea behind the continental drift theory?

   ____

   ____

   ____

   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.3 : Theory of Isostasy

We know that the force of gravity must play an important role in determining the elevation of the land. In particular, the dense crust is believed to float on top of the denser and more easily deformed rocks of the mantle. This concept of a floating crust in gravitational balance is called **isostasy.**

The theory of isostasy has been accepted for a long time to explain why vertically and horizontally or the earth's crust moves upwards or downwards at times. This theory compares the continental blocks with corks floating on liquid. The theory states that the light **sial** rocks of the continents are floating on the denser **sima** rocks of the ocean.

Isostasy is a balance between adjacent blocks or brittle crust floating on the plastic upper mantle called the **aesthenosphere**. Since crustal rocks weigh less than mantle rocks, the crust can be thought of as floating on denser mantle similar to a wood floating on water.

The process of keeping a state of balance in the crust is called isostasy. Isostatic balance is changed; when erosion takes on the continental crust deposition taking place in the adjacent oceanic crust .To achieve isostatic balance the crust will do one of these two things:

1. Volcanism (volcanic eruption)
2. diastrophism a) folding (horizontal movement)
   b) faulting(vertical movement)

Isostatic imbalance is shown by eartquakes.

Now do the activity on the next page.

Student Learning Activity 3

1. What is the theory of isostacy?

____

____

2. What is the main idea behind this theory?

____

____

____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.4: The Process of Folding In Land Formation

Tectonic action is responsible for the formation of;

- Folds
- Faults

Folding are bends in the layered bed rock. A bend rock layer or series of layers that was originally horizontally and subsequently deformed.

When crustal rocks are subjected to certain forces, particularly lateral compression, they are often deformed by being bent in a process called folding. The notion of folding is sometimes difficult to conceptualize. Our common experience is that, rocks are hard and brittle. If subjected to stresses, they might be expected to break. Bending is harder to visualize.

Rocks become folded when they are affected by forces of compression (pushing together or squeezing). Fold structures are most obviously seen in sedimentary rocks. Beds which have been folded will no longer be lying in their original horizontal position- the forces of compression will have buckled them so that they DIP (tilt) at an angle.

Although a range of fold structures can occur, they are really variations of two main types,

1. the upward fold (an anticline) and
2. the downward fold (a syncline).

Types of Folds

The two most common types of folds are anticlines or synclines. Anticlines or Synclines vary in symmetry. They may be symmetrical or asymmetrical or if one limb is tilted beyond the overturned.

An anticline is most commonly formed by upfolding or arching of rock layers. Anticlines are sometimes spectacularly displayed where highways have been cut through deformed strata. Often found in association with anticlines are downfolds, or troughs called syncline

Anticlines and synclines vary in symmetry. They may be symmetrical, asymmetrical or if one limb has been tilted beyond the vertical, overturned.

Sometimes folding is never intense and this simple folding gives rise to mountains and valleys as in the Jura of France. Anticlines become the mountains and the synclines the valleys. Simple folds are rare.

Folds do not continue on forever rather their ends die out much like wrinkles in cloths. These folds are said to be plunging as the axis of the fold plunges to the ground.

The diagrams on the next page show the progression of fold from a simple or symmetrical fold to an asymmetrical fold, then to overfold and recumbent fold and finally to an overthrust or nappe.

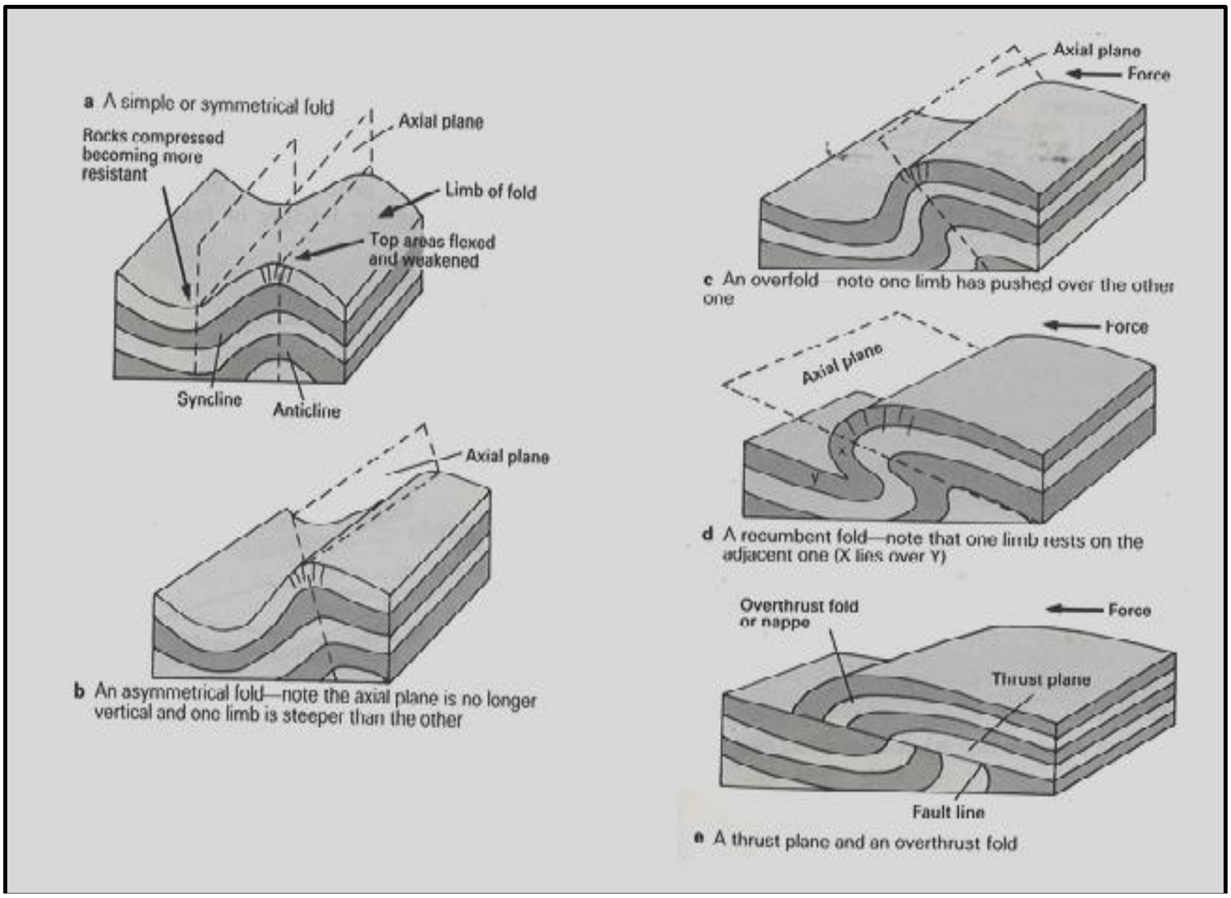

Figure 3.11: Types of Fold

Fold mountains consist of great masses of folded sedimentary rocks.

Now do the activity on the next page.

Student Learning Activity 4

1. Identify two main types of folds?

   i) ___________________________ ii)________________________________

2. What is the main difference between fold and fault? Explain

   ____

   ____

   ____

   ____

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   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.5 : The Processes of Faulting In Land Formation

Faults are fractures in the crust along which or a break in a rock mass along which movement has occurred.

Another prominent result of crustal stresses is the breaking apart of rock material. When rock is broken with accompanying displacement (i.e., actual movement of the crust on one or both sides of the break), the action is called **faulting**. The movement can be vertical or horizontal or a combination of both. Faulting usually takes place along zones of weakness in the crust, such an area is referred to as a **fault zone**, and the intersection of that zone with earth's surface is called a **fault line**.

Movement of the crust along a fault zone is sometimes very slow, but it may also occur as a sudden slippage. A single slippage may result in a displacement of only a few centimeters or so. Major faults penetrate many kilometers into the earth's crust. The deeper fault zones apparently serve as conduits to allow both water and heat from inside earth to approach the surface. Frequently springs are found along fault lines, sometimes with hot water gushing forth. Volcanic activity is also associated with some fault zones as magma forces its way upward in the zone of weakness.

There are four (4) types of faults:

1. **Normal fault**: A normal fault develops from tensional stress- a stress that results when a landscape is rifting or pulling apart. Movement along the normal fault line is predominately vertical, although the orientation of the fault plane may not be perpendicular to the surface.

   As the landscape is extended, notice that one side of the fault plane drops relative to the other. The fault scarp formed along the uplifted mountain front eventually erodes away, leaving little surface evidence of the fault. Many landforms can develop from normal faulting, including tilted fault block mountains, down dropped basins known as grabens and uplifted mountains blocks called horst.

2. **Reverse fault** develops from compressional stress. Movement along a reverse fault is also [predominantly vertical- although in a type of reverse fault known as the overthrust fault, the upthrown block overrides the down thrown block at a very low angle. Conversely, reverse faults occur when the hanging wall moves upward relative to the footwall. In mountainous regions such as the Alps and the Appalachians, reverse faults with dips less than 45^0, are called **thrust fault.** Landslides normally accompany reverse faulting.

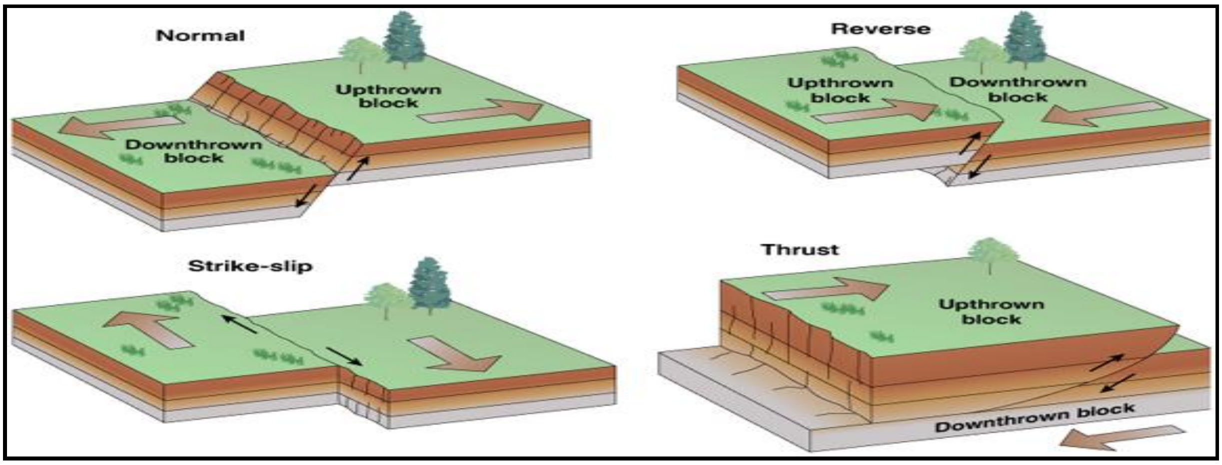

Figure 3.11

3. **Strike-strip faults**. The movement is entirely horizontal with the adjacent blocks being displaced laterally relative to each other. **Strike-strip faults** are faults in which the dominant displacement is along the strike, or trend. Many large strike –strip faults are associated with plate boundaries and are called transform faults.
4. **Thrust Faults:** More complicated in structure and more impressive in their dynamics are the **thrust or overthrust faults** in which their compression forces the upthrown block to override the downthrown block at a relative low angle.

Horst: Another frequent occurrence in nature is the uplift of a block of land between two parallel faults, an action that produces a structure called a horst. The same result can be achieved if the land on both sides has been downthrown. In either cases, the horst is a block elevated above the surrounding land. It may take the form of a plateau or mountain mass with two steep, straight sides.

Graben: At the other extreme is a graben, which is a block of land bounded by parallel faults in which the block has been downthrown, producing a distinctive structural valley with a straight, steep-sided fault scarp on either side.

Grabens and Horst often occur side by side.

Now do the activity on the next page.

Student Learning Activity 5

1. What is a fault?

   ____

   ____

2. What is the main difference between normal and reverse fault? Explain

   ____

   ____

   ____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.6: Earthquakes

An Earthquake is the vibration of Earth produced by the rapid release of energy caused by the sudden slippage along a fault in the earth's crust between two plates and includes the ground shaking and radiating seismic activities that is caused by the slip.

An earthquake is essentially a vibration in the earth produced by shockwaves, resulting from a sudden displacement along a fault (earthquakes may also develop from the movement of magma or sudden ground subsidence). The fault movement allows an abrupt release of energy, usually after a long, slow accumulation of strain. While a fault rupture can take place at the surface. The deepest earthquakes take place at plate boundaries, where the earth's plate is subducted into the mantle.

Earthquakes Waves and Focus and Epicenter

The energy release in an Earthquake moves through the earth in several different kinds of seismic waves that originate at the center of the fault motion, called the **focus** of these waves travel outwards in widening circles, like the ripples produced when a rock is thrown into a pond, gradually losing momentum with increasing distance from the focus, at the location known as the **epicentre** of the earthquake. In reality, because most earthquakes are caused by movements on a fault, the *focus* is not a point but rather a region that may extend for several kilometres. An earth quake *focus* lies at some depth below the earth's surface.

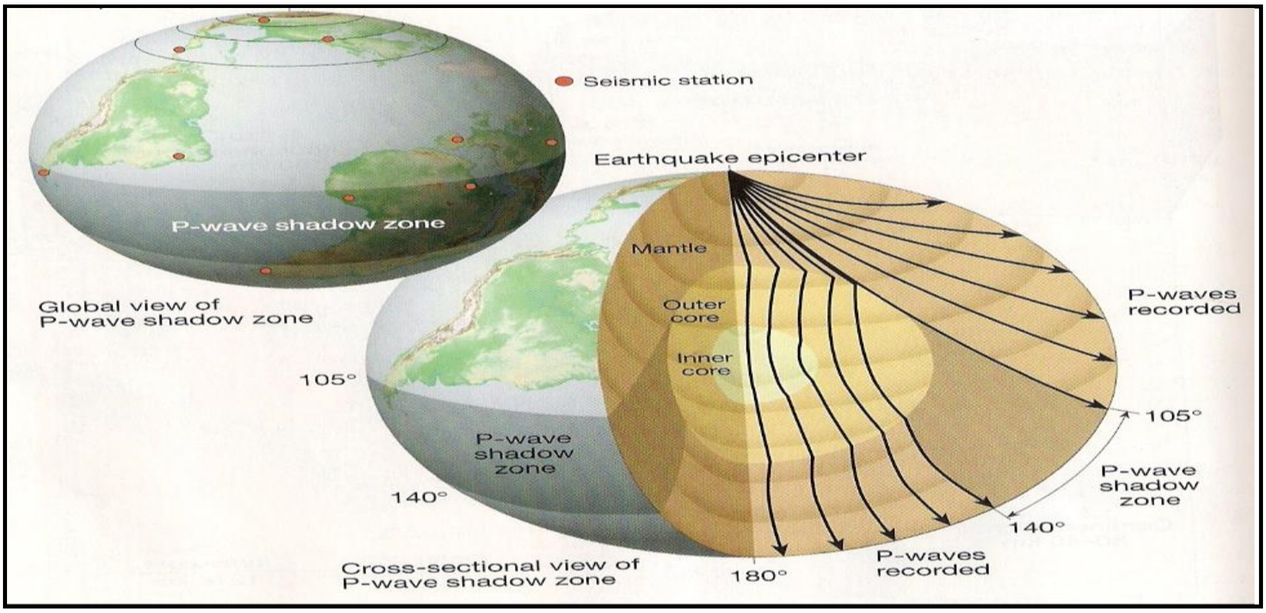

Figure 3.12: Diagram showing seismic activities

It is more convenient to identify the site of the earthquake from the **epicentre** which is the point on the earth's surface that lies vertically above the focus of an earthquake.

The strongest shocks and greatest crustal vibrations are often felt on the ground directly above the focus called the Epicenter of the earthquake.

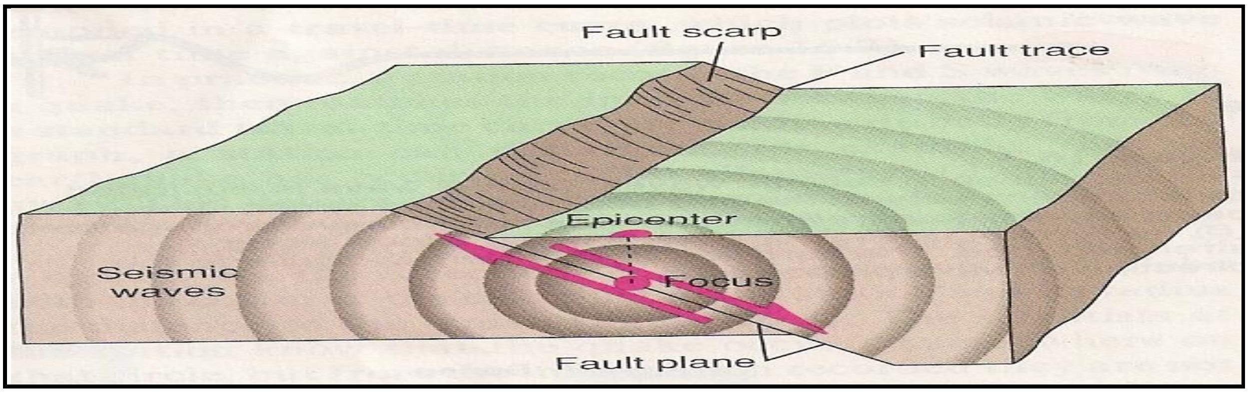

Figure 3.13: Epicenter of earthquakes

Terminology

- **The focus of an earthquake is the point where rocks first break along a fault: seismic waves radiate from the focus.**
- **The epicentre is the point on the earth's surface directly above a focus**
- **Seismograph is an instrument that records detects and measures earthquakes.**
- **Richter scale is an instrument that measures the strength of an earthquake**
- **Seismologists are scientist who study earthquakes**
- **Seismology is the study of earthquakes**

Seismic Waves

There are two types of Earthquake (seismic) waves. The Two types of seismic waves that radiate outwards from the earthquake focus are:

1. **Body waves** are the seismic waves that travel through the earth's interior spreading outward from the focus in all directions, like sound waves moving through air. They travel inside the earth and transmit foreshocks that have little destructive power. They are divided into P and S waves.

2. **Surface waves** are seismic waves that travel on the earth's surface away from the epicentre, like water waves spreading out from a pebble thrown into a pond. These waves typically arrive immediately after the S waves

They appear on the surface after the P and S waves reach the epicentre. Having low frequency, surface waves have a greater effect on solids which makes them more destructive. They travel along the earth's surface, but because of the tremors they produce in all directions, they cause the most destruction.

- Surface waves are the slowest waves set off by quakes.
- They travel along the outer layer of the earth
- In general surface waves cause more property damage than body waves because the waves produce more ground movement and travel more slowly so they take longer to pass.

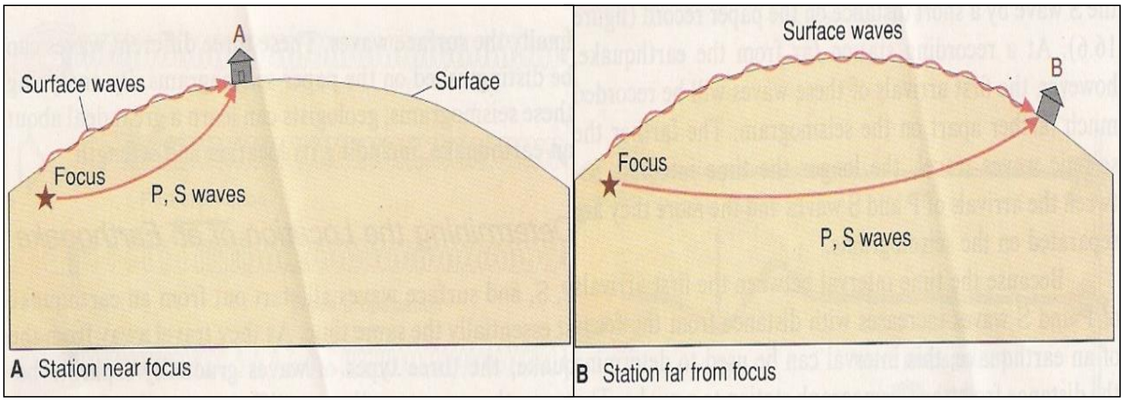

Figure 3.14: Surface waves

Intervals between P and S waves and surface waves increase with distance from the focus.

Types of Body Waves
There are two main types of Body waves.

1. The fastest moving earthquake waves and the first to be felt during an earthquake are known as P or Primary waves. P waves move through the earth in the same fashion as the soundwaves. **P Wave** is a wave which push (compress) and pull (expand) rocks in the direction the wave is travelling. They are very fast or high speed waves that travel in straight lines, compressing and stretching solids and liquids they pass through. It is the First or Primary wave to arrive at the recording station following an earthquake. They travel 3.7 miles per second (6km/s) in the crust. P waves travel through all types of materials (gas, solid, liquids)

2. **The S** or secondary wave shakes the particles in the rock at right angles to their direction of travel or they are waves that shake the rock up and down and side to side as they move. Secondary wave is a slower wave that travels at 2 to 5 km per second. (2.2 miles p/s) 3.6 km/s. They travel only through solids and cause the splitting motions that do not have an effect. An S wave is propagated by a shearing motion much like that in a stretched rope, shaken rope.

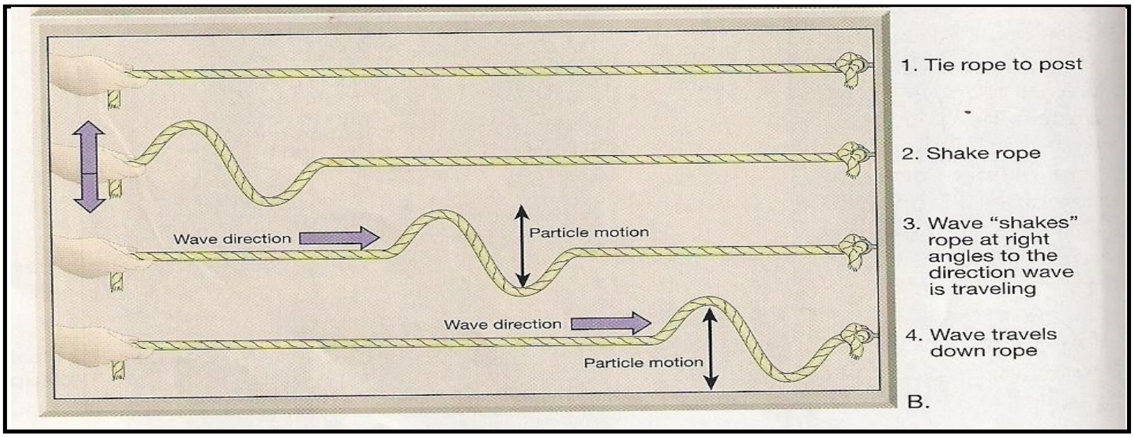

Figure 3.15: Movement of the S waves

P S and Surface waves all start out from an earthquake at the same time. As they travel away from the earthquake, the three waves separate because they are travelling at different speeds and will be recorded at different times.

- Both P and S waves pass easily through solid rock.
- A **P** wave can also pass through a fluid (gas or liquid) but
- an S wave cannot pass through fluid..

Earthquake Magnitude

Magnitude describes the relative amount of energy released during an earthquake. Magnitudes are calculated on a logarithmic scale, with an energy increase from one magnitude to the next of about 32 times. The difference in size between small earthquakes (magnitudes less than 3) and large earthquakes (magnitude 7 and higher) is enormous. The most commonly quoted magnitude is the Richter scale devised in 1935 by Charles Richter at the California Institute of Technology in Pasedena.

Tsunamis

The sudden movement of the sea floor upward or downward during a submarine earthquake can generate very large sea waves, called tidal waves (Tsunamis). Tsunamis are also called seismic waves-as they are caused by great earthquakes (magnitude of 8+) that disturb the sea floor.

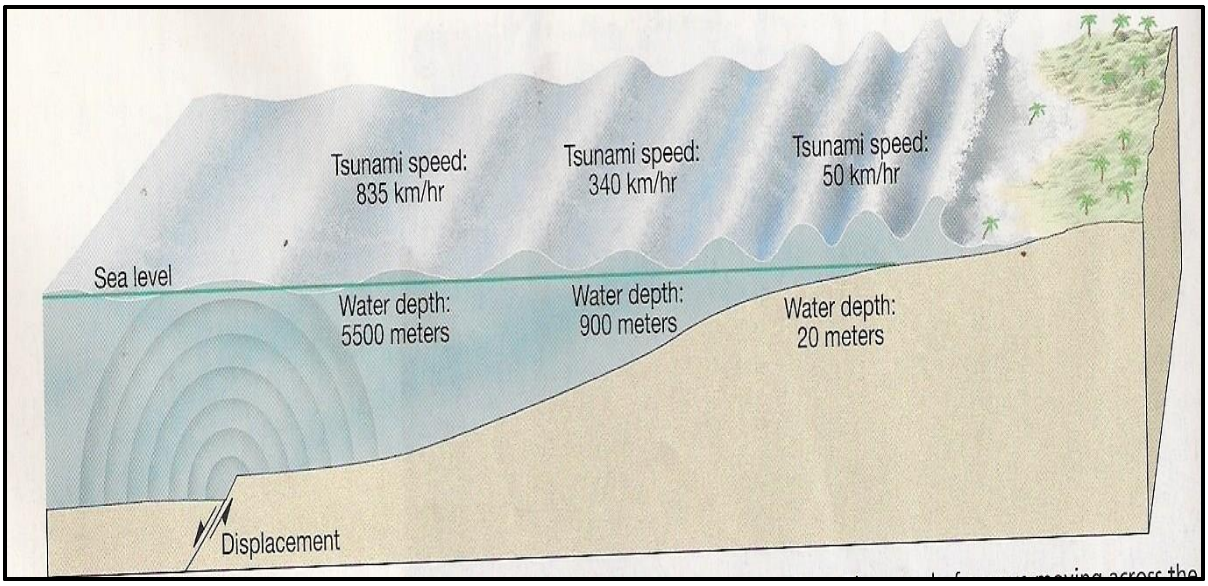

Figure 3.16: A Tsunami generated by displacement of the ocean floor

Now do the activity on the next page.

Student Learning Activity 6

1. What type of energy wave reaches the recording station first?

____

2. What are the two types of seimic waves?

i) _________________________________ ii) ______________________________

3. Which area is more convenient to identify the site of the earthquake from?

____

4. Explain the difference between the body waves and the surface waves.

____

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NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1.3.7 : Volcanism and Associated Hazards

A **volcano** is an opening, in a planet's crust, which allows hot magma, ash and gases to escape from below the surface. The word *volcano* is derived from the name of an island off Sicily called vulcano. It was named after Vulcan, the Roman god of fire.

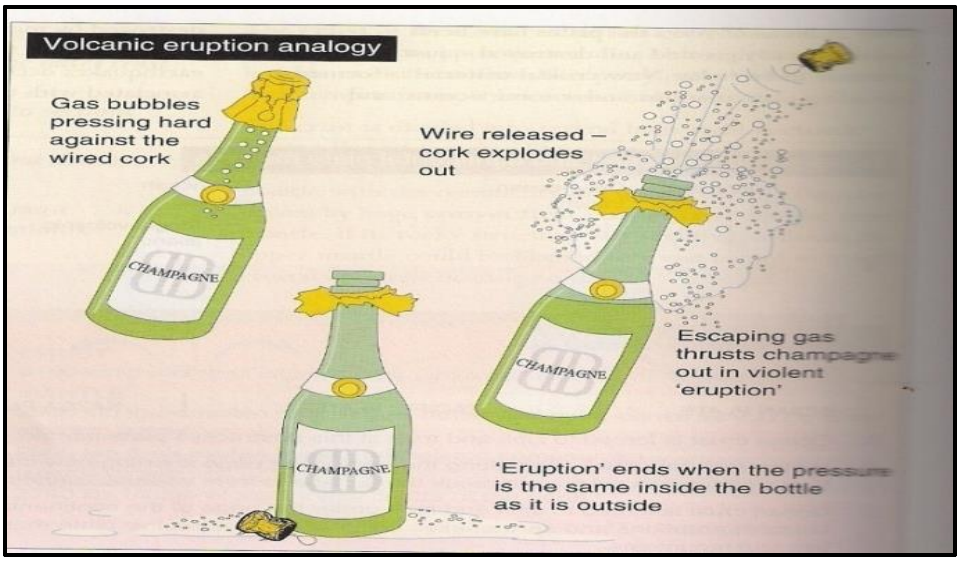


Figure 3.17: Volcanic eruption analogy

A typical volcano is a cone shape mountain .It is produced by molten rock called **magma** reaching the surface. The mountain is formed out of layers of material that has been forced out of a vent (crack) in an eruption. The molten rock is called **magma** when it is below the surface and **Lava** when *on* the surface. When lava and other materials reach the surface, they are called **extrusive**. The resulting landforms vary in size from tiny cones to widespread lava flows. Rocks below the crust have a very high temperature but the great pressure upon these keeps them in a semi-solid state. If the pressure weakens, then some of the rocks become liquid. This liquid is called MAGMA.

Molten rock (magma) at very high temperature, rises under enormous pressure from the upper mantle. The magma exploits weaknesses in the crust in order to force its way to the surface. When Magma forces its way into the cracks of the crust and may either reach the surface where it forms Volcanoes or Lava Flows, or it may collect in the crust where it forms BATHOLITHS, SILLS and DYKES**.** This is common along tectonic plate margins but can also occur where the crust is very thin such as Hawaii. Materials injected into the crust are referred to as **intrusive.** These may later be exposed at the surface by erosion of the overlying rocks. Both extrusive and intrusive materials cooled from magma are known as **igneous rocks.**

Volcanology: The term Volcanology includes all the processes by which solid, liquid or gaseous materials are forced into the earth's crust or are ejected onto the surface. Although, material in the mantle has high temperature, it is kept in a *semi- solid* state because of the great pressure exerted upon it.

Volcanism: Volcanic activity is important to Geology for several reasons. Landforms are created and portions of the earth's surface are built up. Less commonly landforms are destroyed by violent eruptions.

Volcanoes are important to the science of geology because they provide clues about the nature of the earth's inaccessible interior and help us understand how the earth's internal processes work.

Ash
Ash is made up of fine powered rock and lava droplets. It is formed in violet explosion within the volcano. Gases trapped by the rock above them, expand rapidly in an explosion eruption.

Bombs
Sometimes a volcano will throw out large bombs of melt lava called bombs lapilli. Lava bombs are ejected with such force that they may travel several kilometers from the vent As they pass through the air, the outer skin cools, then they land. They may break apart to reveal a soft molten center.

Volcanic Landforms

Volcanic **landforms** are divided into **extrusive** and **intrusive landforms** based on weather magma cools within the crust or above the crust. Rocks formed by cooling of magma within the crust are called **'Plutonic rocks'**. Rocks formed by cooling of lava above the surface are called **'Igneous rocks'**.

Extrusive Landforms

Volcanoes are part of what is called **extrusive igneous activity**. This means that magma is poured out onto the earth's surface, then cools and solidifies. **Extrusive igneous rocks** are formed by solidification of lava. The amount of silica in lava strongly determines the viscosity of lava, violence of eruption and which particular rock is formed.

Intrusive Landforms

Igneous intrusions are any igneous rock which hardens underground. There are 6 types of igneous intrusions.

1. Batholiths
By far the largest and most amorphous igneous intrusions are the **batholiths**, which is a subterranean igneous body of indefinite depth and enormous size or a huge dome shaped mass of granite. Batholiths often form the core of major mountain ranges, their intrusive uplift being a fundamental part of the mountain building process.

2. Sills
A sill is a long, thin intrusive body, but its orientation is determined by the structure of pre-existing rocks. It is formed when magma is forced between strata that are already in place. The result is often a horizontal igneous sheet between horizontal sedimentary layers.

3. Dike
A dike is an igneous intrusion that cuts across rock layers.

4. Laccolith
A laccolith is a mushroom-shaped igneous intrusion.

5. Stock
A stock is a small batholith less than 100 square kilometers.

6. Volcanic Neck
A volcanic neck is the remnants of the hardened lava in the throat of a volcano after erosion.

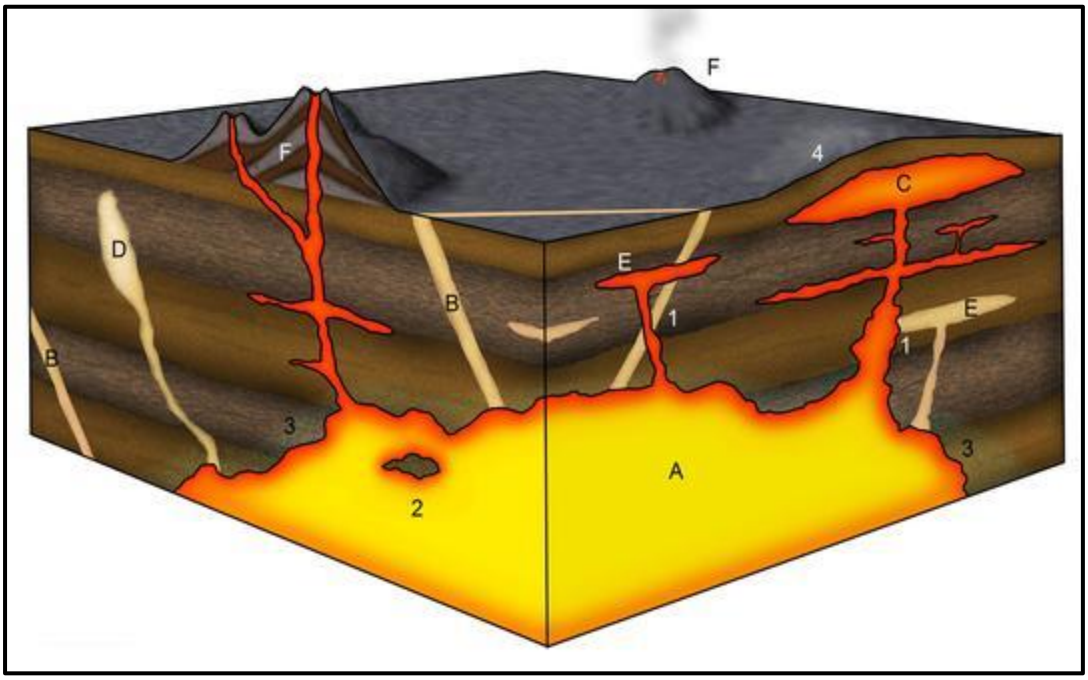


Figure3.18: Model showing intrusive landforms

In the picture above, there are examples of the six igneous intrusions.

A. Batholith
B. Dike
C. Laccolith
D. Pegmatite, an intrusion not mentioned above.
E. Sill
F. Volcano

1. Newer intrusion cutting through the older one
2. Roof Pendant
3. Contact Metamorphism
4. Uplift due to laccolith emplacement

When plates push together, one plate slides beneath the other. This is a **subduction zone**. When the plunging plate gets deep enough inside the **mantle**, some of the rock on the overlying plate melts and forms magma that can move upward and erupt at the Earth's surface. It is apparent that the most notable area of volcanism is around the margin of the Pacific Ocean, often referred to as the Pacific Ring of Fire.

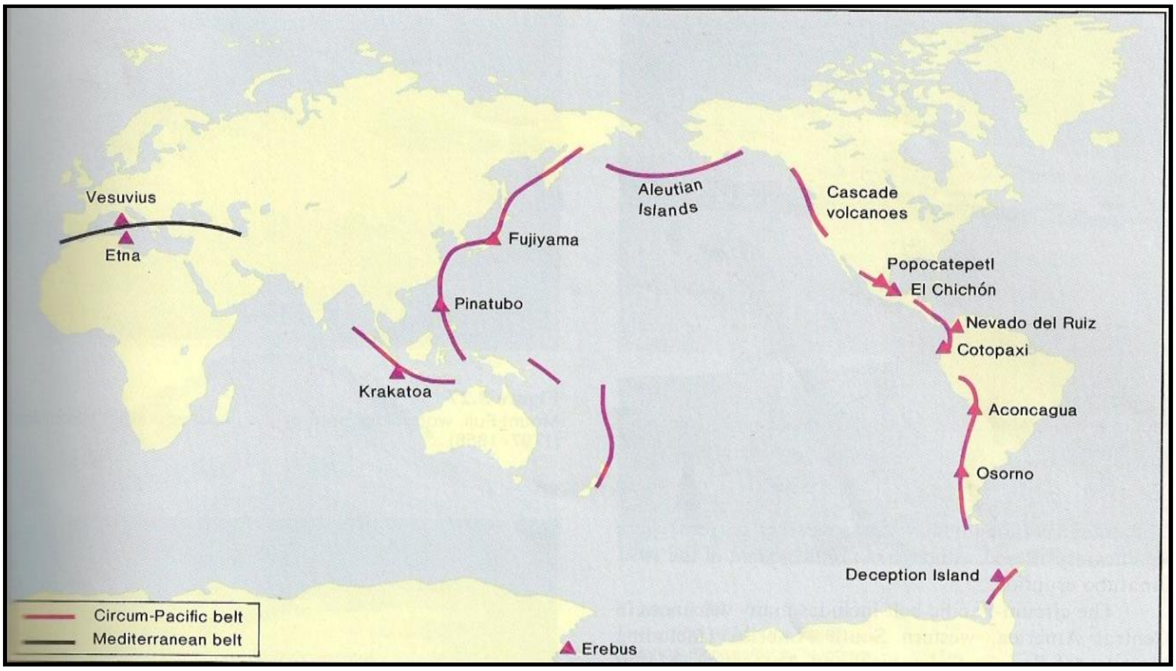


Figure 3.19: Pacific ring of fire

What Causes Volcanoes?

The simplest answer to this question is to say that they are caused by rising magma, but how does magma form in the first place? In fact magma exist in isolated pockets. These pockets are especially common at ocean ridges, where there is tension .Rising convection currents in the magma ensures that the rocks are hot rough to melt. Where there is release of pressure along the tensional faults, the magma can get to surface.

Why Do Volcanoes Erupt?

Deep within the Earth it is so hot that some rocks slowly melt and become a thick flowing substance called **magma**. Because it is lighter than the solid rock around it, magma rises and collects in magma chambers. Eventually some of the magmas push through **vents** and **fissures** in the Earth's surface. A volcanic eruption occurs! Magma that has erupted is called **lava**.

Why Do Volcanoes Erupt Violently?

Most magma contains gases which are under great pressure. In some instances there is a sudden decrease in pressure in the rising magma which causes the gases in it to expand very rapidly. This sudden expansion can cause violent explosion. When eruption is violent, the lava explodes into small pieces which are blown to great heights. These are called **volcanic bombs**.

How Can Volcanoes Be Classified?

Because of the large number of volcanoes and a wide variety of eruptions, it is convenient to group together those with similar characteristics. One of the two most quoted groupings is according to the shape of the volcano and it’s vent which, because it describes landforms, which is of value to the geographer. The other is the nature of the eruption, a method valued by volcanologist.

Active: A popular way of classifying magmatic volcanoes is by their frequency of eruption, with those that erupt regularly called active, those that have erupted in historical times but are now quiet are called dormant, and those that have not erupted in historical times are called extinct.

Extinct volcanoes: are those that scientists consider unlikely to erupt again, because the volcano no longer has a lava supply. Examples of extinct volcanoes are many volcanoes on the Hawaiian Islands in the U.S

Volcanic Features Formed On the Surface

Sometimes Magma reaches the surface through a VENT (Hole) or a FISSURE (Crack) in the surface. When magma emerges on the surface it is called lava. If lava emerges via a vent, it builds up a volcano and if it emerges via a fissure, it builds up a lava platform or lava flow.

The Shape of The Volcano and It's Vent

1. Fissure Eruption

When two plates move apart, lava may be ejected through fissures rather than via a central vent. Fissures are lines of weakness that lava forces its way out through, or long narrow openings found mainly in the mid-ocean ridges and sides of composite cones or near shield volcanoes.

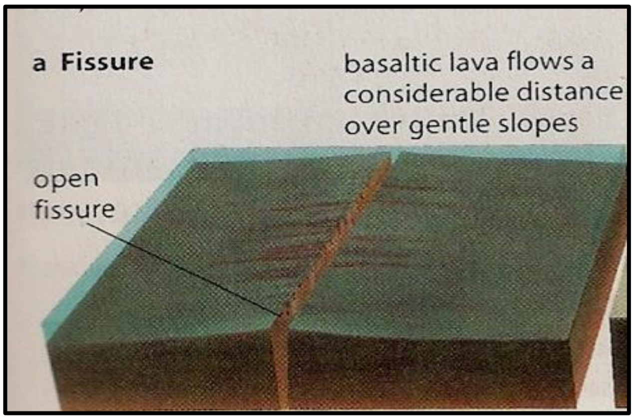


Figure 3.20: Fissure volcano

2. Shield Volcano

Shield volcanoes are named for their broad,gently sloping cones constructed of solidified lava flows.(wide or flat volcano) shield-like profiles, are formed by the eruption of low-viscosity lava that can flow a great distance from a vent, Shield volcanoes are more common in oceanic than continental settings.

Shield volcanoes are the largest volcanoes on the planet and the eruption produces Icelandic shield. The diameter of a shield volcano is much greater than their height and they are formed by their accumulation of highly fluid lava flows- with gently sloping sides and nearly flat sides.

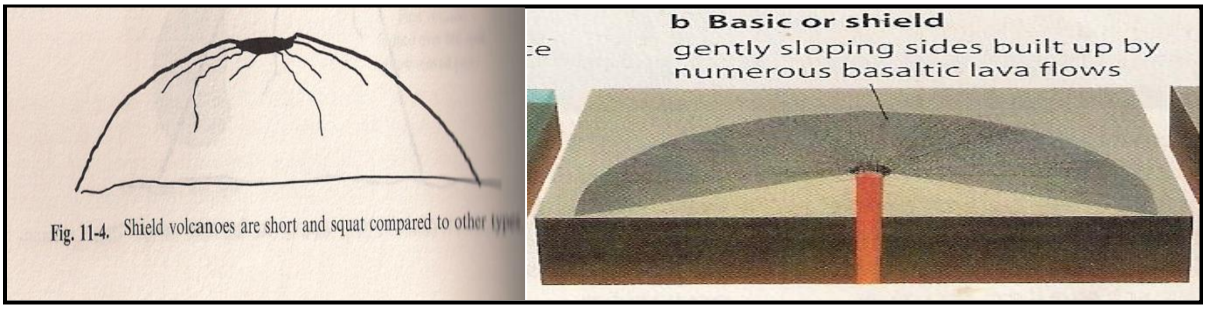


Figure 3.21: Basic volcano

3. Acid Lava Dome / Spine Volcanoes

Volcanic domes are steep-sided or spine –shaped masses of volcanic rock formed from viscous lava that solidifies in or immediately above a volcanic vent. Acid lava quickly solidifies on exposure to the air. This produces a steep- sided convex cone as in most cases the lava solidifies near to the crater. It erupts thick treacle like lava that cools and hardens rapidly.

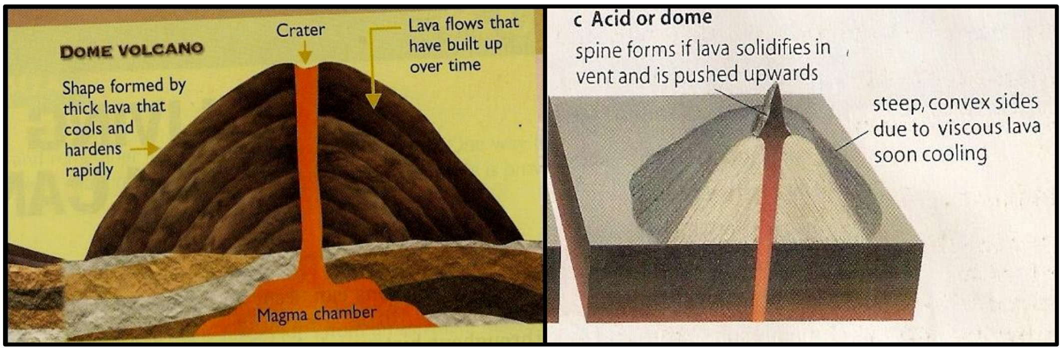


Figure 3.22: Dome volcano

Acid lava is viscous and does not flow easily soon solidifies, building up steep cones near the vent. Sometimes, the lava is so viscous that it forms a spine sticking up from the vent rather than flowing away down the sides of the volcano. The sides are formed by the accumulation of hard lava made viscous by its high silicon content. Instead of flowing, it quickly hardens in place. Example: Mt Pele'e

4. Ash and Cinder Cones

The cinder cone volcanoes are the most common type of volcano and also the smallest type of volcano. The Layers of ash and cinders, varying in size built up a symmetrical cone with a large crater. These volcanoes generally have a strombolian type of eruption. They are formed when falling debris or ash accumulates near the crater and the cones have gently sloping sides. Example: Mt Paricutin. (Mexico)

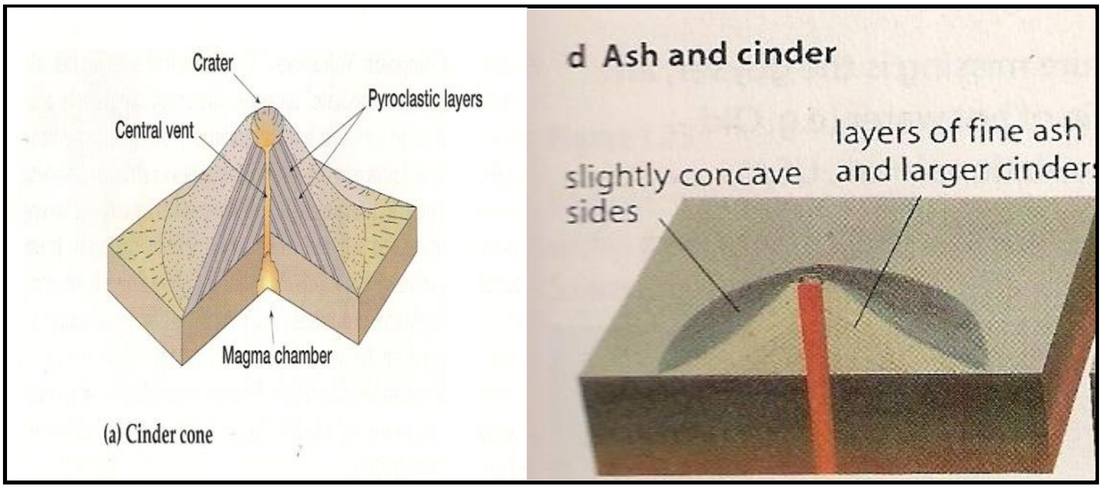


Figure 3.23: Ash and Cinder volcano

Volcanic cones or **cinder cones** are the result from eruptions that erupt mostly small pieces of scoria and pyroclastics (both resemble cinders) that build up around the vent. These can be relatively short-lived eruptions that produce a cone-shaped hill. Most cinder cones erupt only once.

- Relatively small less than 300 or 1000 ft high.
- Relatively steep slopes- 30 to 40 degrees.
- Made of pyroclastic material.
- Erupt only once

5. Composite Cones

This type of cone is formed of alternate layers of lava and ash. The volcano begins each eruption with great violence forming a layer of ash as the eruption proceeds. The violence ceases and lava pours out forming a layer on top of the ash.

A composite cone sometimes has its top blow off by violent explosions and the top disintegrates into mass of rocks and ash leaving a crater greatly enlarged. The huge crater-like depression is now called a Caldera.

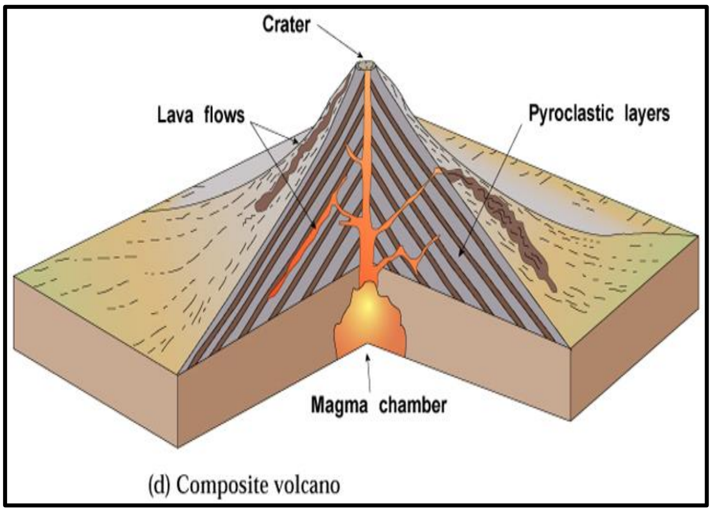


Figure 3.24: composite volcano

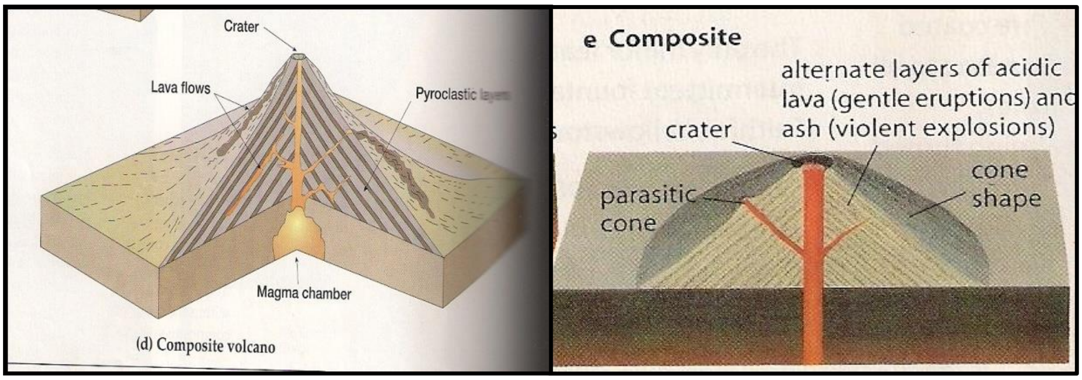


Figure 3.25: Composite volcano

6. Calderas

When the building of gases become extreme, huge explosions may clear the magma chamber beneath the volcano and remove the summit of the cone. This causes the sides of the crater to subside, thus widening the opening to several kilometers in diameter. Example: Crater Lake-Oregon

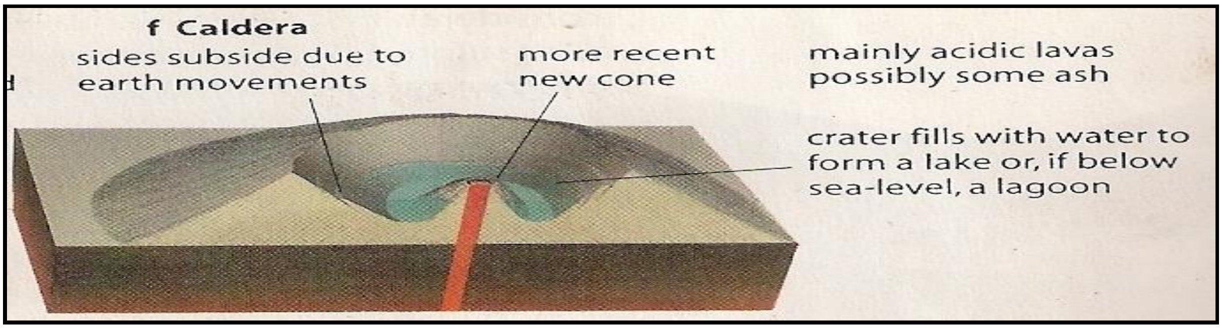


Figure 3.26: Caldera

Types of Eruption

Several **types of volcanic eruptions** have been distinguished by volcanologists. These are often named after famous volcanoes where that type of behaviour has been observed. Some volcanoes may exhibit only one characteristic type of eruption during a period of activity, while others may display an entire sequence of types. During a volcanic eruption, lava, tephra (ash, lapilli, solid chunks of rock), and various gases, are expelled from a volcanic vent or fissure

The Nature of Eruption

This classification of volcanoes is based on the degree of violence of the explosion which is a consequence of the pressure and the amount of gas in the magma. Its categories may be summarized as follows;

1. **Icelandic**, where lava flows gently from a fissure
2. **Hawaiian**, where lava is emitted gently but from a vent

A Hawaiian eruption is a type of volcanic eruption where Lava flows from the vent in a relative gentle low level eruption, so called because it is a characteristic of Hawaiian volcanoes. Typically they are effusive eruptions with Basaltic Magmas of Low viscosity, low content of gases and high temperature at the vent. Very little amount of volcanic gas is produced.

Hawaiian eruption: 1: Ash plume, 2: Lava fountain, 3: Crater, 4: Lava lake, 5: Fumaroles, 6 Lava flow, 7 Layers of lava and ash, 8: Stratum, 9: Sill, 10: Magma conduit, 11: Magma chamber, 12: Dike

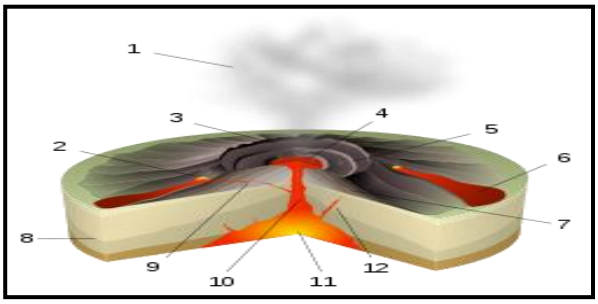


Figure 3.27: Hawaiian eruption

3. Strombolian eruptions are relatively low-level volcanic eruptions, named after the Italian volcano Stromboli, where such eruptions consist of ejection of lapilli. They are defined as "...Mildly explosive at discrete but fairly regular intervals of seconds to minutes.

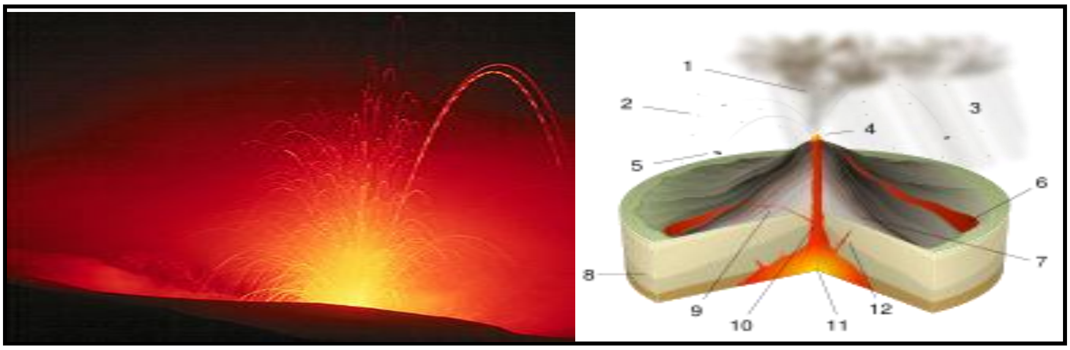


Figure 3.28: A Strombolian eruption

4. Vesubian, which has a violent explosion after a long period of inactivity.

5. Krakatoan, which has an exceptionally violent explosion that move much of the original cone.

6. Pelean, where a violent eruption is accompanied by pyroclastic flows that may include a nuee ardent (glowing cloud).

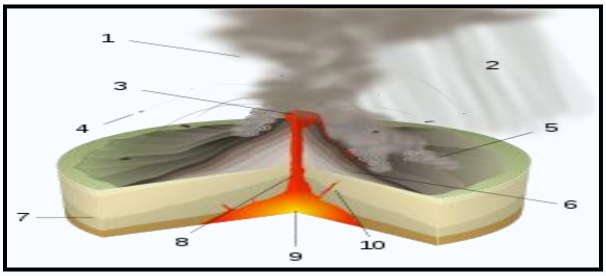


Figure 3.29: Pelean eruption

Pelean Eruption: 1 Ash Plume 2.Volcanic ash rain 3. Lava Dome 4. Volcanic Bomb 5. Pyroclastic Flow 6. Layers of ash and lava 7. Strata 8. Magma conduit 9. Magma chamber 10. Dyke.

They can occur when viscous magma is involved. (Rhyolitic or Andesitic) and they share some similarities with the Vulcanian eruptions. The most important characteristics of a Pelean eruption are the presence of a glowing avalanche of hot lava.

7. Plinian, where large amount of lava and pyroclastic material are ejected.

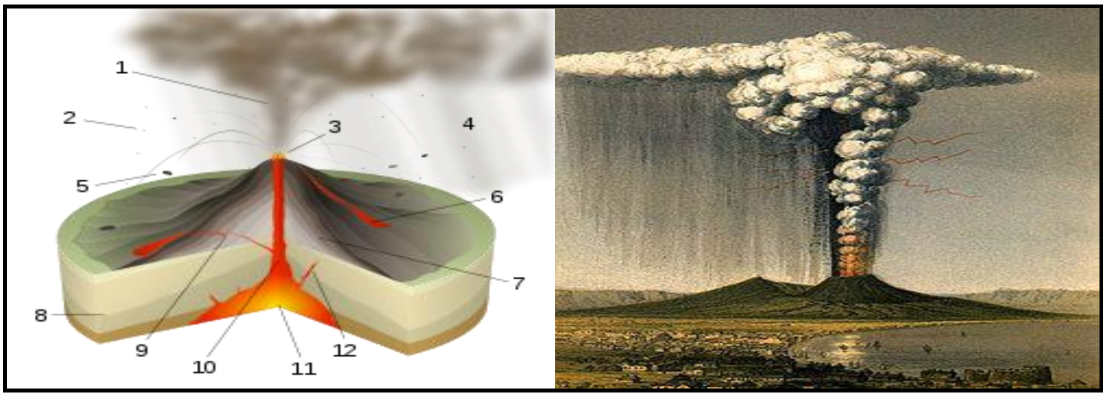


Figure 3.30: Plinian eruption

Volcanic eruption: 1 Ash plume, 2 Lapilli, 3 Lava fountain, 4 Volcanic ash rain, 5 Volcanic bomb, 6 Lava flow, 7 Layers of lava and ash, 8 Stratum, 9 Sill, 10 Magma conduit, 11 Magma chamber, 12 Dike

Plinian Eruptions are marked by columns of gas and Volcanic ash extending high into the stratosphere, a high layer of the atmosphere. The key characteristics are ejection of large amount of Pumice and a very powerful continuous gas blast eruption. Shorter eruptions can end in less than a day but longer events can take several days to months.

Vulcanian eruptions are a type of volcanic eruption characterised by a dense cloud of ash-laden gas exploding from the crater and rising high above the peak. This is usually followed by the explosive clearing of the vent.

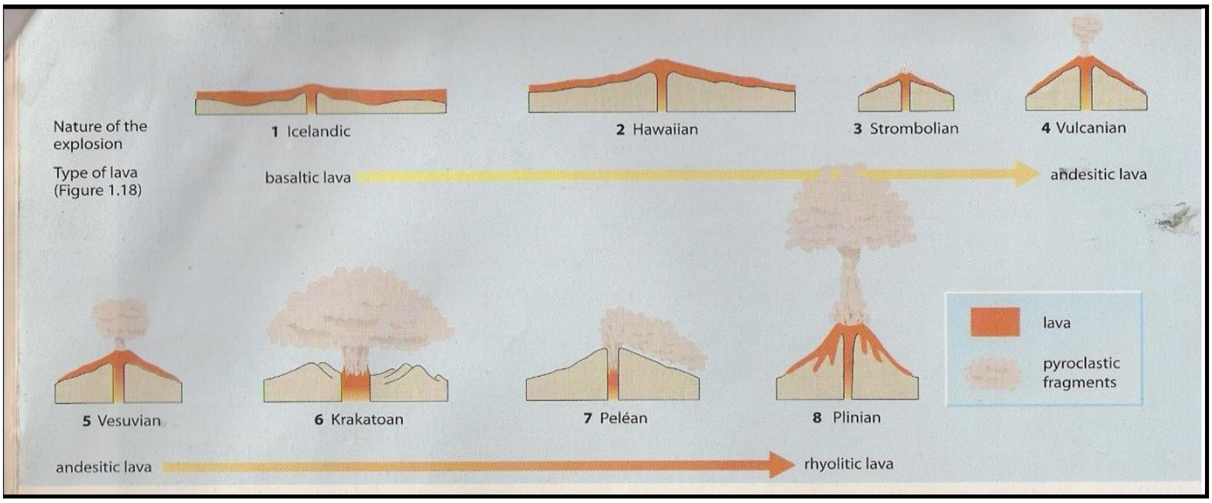


Figure 3.31: Different types of volcanic eruptions

Student Learning Activity 7

1. What are the different ways volcanoes are classified?

   i) ______________________ ii)_______________________

2 Explain what is meant by intrusive volcanism and extrusive volcanism?

____

____

____

3 What is the main difference between Volcanology and volcanism? Explain

____

____

____

____

NOW CHECK YOUR ANSWERS AT THE END OF THE UNIT SUMMARY

11.1 UNIT SUMMARY

11.1.1 COMPOSITION OF THE EARTH

- The Earth's spheres relates to the division of the Earth into broadly four interacting spheres sometimes referred to as the Biophysical environment.
- The Earth's atmosphere consists of a mixture of gases surrounding the earth. This mixture of gases is held to the earth by gravitational attraction.
- The atmosphere is divided into layers according to the mixing of gases and their chemical properties as well as temperature .The atmosphere of the earth exist as four distinct layers, beginning with the closest layers to the ground of which are: Troposphere, Stratosphere,. Mesosphere, Thermosphere.
- Hydrosphere includes all the earth's waters.
- The lithosphere consist of 6 large plates and many smaller ones that slide slowly over the asthenosphere at rates up to 12 cm/yr.
- Plates of the lithosphere have three kinds of margins, divergence, convergent and transform fault.
- The rock cycle arises from the interactions of the Earth's internal and external processes.
- The rock cycle in the oceanic crust interacts with thart in the continental crust through the agency of plate tectonics.
- Igneous rock is eroded, creating sediment, which is deposited in layers that become sedimentary rock. Burial may lead to changes in temperature and pressure forming metamorphic rock. Eventually temperature and pressure may become so high that rock melts and forms new magma. The magma rises, forms new igneous rock and the cycle is repeated.
- Igneous rock forms from magma that cools and solidifies in a process called crystallization. Sedimentary rocks forms from lithification of sediments . Metamorphic rocks forms from the rock that has been subjected to great pressure and heat in a process called metamorphism.
- Igneous rock are classified by their texture and mineral composition.
- Lithification refers to the processes by which sediments are transformed into solid sedimentary rocks.
- Soils are made from rocks and sediments by two two stage sequence development. Weathering produces the parent material, which is then acted upon to produce the soil profile. The particular profile formed at any point on the earth depend upon the prevailing climate, vegetation, rock type and topography, together with the length of time of soil formation.

- The soil profile is the vertical section from the soil surface down to underlying rock. The profile is formed by vertical movements of water and materials both downwards and upwards.
- The soil layer is a complex mixture of solid liquid and gaseous components. It is derived from parent material or regolith that is produced from rock by weathering.The main factors influencing the soil and soil development are parent material, climate, vegetation and time.
- Soil texture refers to the proportion of sand, silt and clay that are present.
- Loams have the right soil texture and are suitable for growing most crops.
- Soil structure refers to the way in which soil grains are grouped together into larger masses called peds.
- Besides providing nutrients for plant growth, the soil layer serves as a reservoir for the moisture that plants require.
- Soil organism includes bacteria, fungi and earthworms.
- Nutrient is the term given to chemical elements found in the soil which is essential for plant growth and maintenance of the fertility of the soil.
- Leaching is the removal of soluble material in solution.
- Podsolisation is more common in cool climates where precipitation is greatly in excess of evapotranspiration and where soils are well drained or sandy.
- Gleying occurs when the output of water in the soil system is restricted giving anaerobic or waterlogged conditions.
- Salination is the process that concentrates salts in soils in climates with excessive potential evapotranspiration.

11.1.2 GEOMORPHIC PROCESSES

- Geomorphology is the science that studies landforms.
- Geomorphic processes modify the earth's crust and the shape of the land surface.
- Denudation refers to the processes that destroy or wear away the rocks and landforms of the earth's surface.
- Denudation is accomplished through weathering, mass wasting and erosion.
- Erosion is the process that wears away the land surface by natural agents such as running water, ice, wave action and wind.
- Transportation is the carrying of the material from one place to another.
- Deposition is the dropping of materials which have been picked up and transported by wind, water, or ice.
- Coastal erosion is the wearing away and breaking up of rock along the coast.

- The bigger the waves are and the more sediment they carry, the more erosion they cause.
- Constructive waves-flat waves that are thrown on the beach, travels longer distances up the beach (swash) at an oblique angle and deposits sediments it has carried.
- Destructive waves-steep or high waves are those that retreat back to the sea as the backwash. It removes sediments from the beach and carries more sediments than swash into the open waters.
- Landforms created by wave erosion include headland, caves, arches, cliffs, sea stacks, blow hole and inlets.
- Landforms produced by wave deposition include beaches, spits bar, Barrier Island and tombolo.
- Wind-erosion, transportation, and deposition is called eolian (also spelled Aeolian)
- Most of the world's deserts are located in latitudinal belts of 15° to 30° north and south of the equator. Most of the world's deserts have tropical latitude.
- In hot deserts, days are often very hot while nights are very cold due to high evaporation rate and no or minimal vegetation.
- Diurnal Range is the difference between the highest and the lowest temperature in a day**.**
- Insulation refers to the cover that acts like blanket to trap heat in the atmosphere.
- Heavy rain in deserts causes floods that may cause landforms such as wadis, mesas, butte, playas, pediments, badlands, alluvial fans and canyons.
- Wind erosion in deserts produces depressions, rock pedestals, zuegens, yandangs and inselberges.
- Wind transport causes fine particles of rock waste called desert dust to be carried great distances.
- Wind can move material by three processes; suspension, saltation and surface creep.
- Wind deposition gives rise to dunes which are made of sand and loess (German for loose) which is made of desert dust.

11.1.3 INTERNAL FORCES AND PLATE MOVEMENT

- Plate tectonics is the study of the movement of these plates and their resultant landforms.
- There are two types of plates or crust: **continental** and **oceanic**.
- **Continental crust**, or **sial**, is composed of older, lighter rock of granitic type. It is dominated by minerals rich in silica (Si) and aluminium (Al), from which the term **sial** is derived.
- **Oceanic crust**, or **sima**, consists of much younger and denser rock of basaltic composition. Its dominant minerals are silica (Si) and magnesium (Ma) which forms the deep ocean basin floors. The symbol of silica and magnesium forms the word sima.

- There are three types of plate boundaries: 1. Convergent, 2. Divergent and 3. Passive boundary
- In 1912, a German meteorologist, Alfred Wegener, published his theory that all continents were once joined together in one large supercontinent which he named Pangaea. The word Pangaea means all Lands
- Isostasy is a balance between adjacent blocks or brittle crust floating on the plastic upper mantle called the **aesthenosphere**.
- To achieve isostatic balance the crust will do one of these two things:

  3. Volcanism (volcanic eruption)
  4. diastrophism a) folding (horizontal movement)

     b) faulting(vertical movement)

- Folding are bends in the layered bed rock. A bend rock layer or series of layers that was originally horizontally and subsequently deformed.
- The two most common types of folds are anticlines or synclines. Anticlines or Synclines vary in symmetry.
- Faults are fractures in the crust along which or a break in a rock mass along which movement has occurred.
- Types of faults include normal fault, reverse fault, thrust fault and strike-strip fault.
- An Earthquake is the vibration of Earth produced by the rapid release of energy caused by the sudden slippage along a fault in the earth's crust between two plates and includes the ground shaking and radiating seismic activities that is caused by the slip.
- It is more convenient to identify the site of the earthquake from the epicentre which is the point on the earth's surface that lies vertically above the focus of an earthquake.
- The strongest shocks and greatest crustal vibrations are often felt on the ground directly above the focus called the Epicentre of the earthquake.
- Magnitude describes the relative amount of energy released during an earthquake.
- The sudden movement of the sea floor upward or downward during a submarine earthquake can generate very large sea waves, called tidal waves (Tsunamis).
- Tsunamis are also called seismic waves-as they are caused by great earthquakes (magnitude of 8+) that disturb the sea floor.
- A volcano is an opening, in a planet's crust, which allows hot magma, ash and gases to escape from below the surface.
- The term Volcanology includes all the processes by which solid, liquid or gaseous materials are forced into the earth's crust or are ejected onto the surface.
- Volcanic landforms are divided into extrusive and intrusive landforms based on weather magma cools within the crust or above the crust. Rocks formed by cooling of magma within the crust are called 'Plutonic rocks'. Rocks formed by cooling of lava above the surface are called 'Igneous rocks'.

ANSWERS TO STUDENTS ACTIVITIES

ANSWERS TO 11.1. COMPOSITION OF THE EARTH

Student Learning Activity 1

1. i) **biotic** **ii) abiotic**

2. The Biotic environment is made up of the **Living organisms**

3.

SPHERES	EXAMPLES OF THINGS FOUND IN THE SPHERES			
1.BIOSPHERE	**i) bear**	**ii) orchid**	**iii) dogs**	**iv) pear**
2.ATMOSPHERE	**i) methane**	**ii) stars**	**iii) oxygen**	**iv) troposphere**
3.LITHOSPHERE	**i) sand**	**ii) pencil**	**iii) stamp pad**	**iv)pebbles gravel**
4.HYDROSPHERE	**i) sea**	**ii) lakes**	**iii) rivers**	**iv) streams**

4. Lithosphere: 4.6 billion years ago
Atmosphere and hydrosphere: 3.6 billion years ago
Biosphere: 1 billion years ago

5. The four (4) spheres of the biophysical environment.
i) lithosphere ii) atmosphere iii) hydrosphere iv) biosphere

Student Learning Activity 2

1. i)Troposphere ii)stratosphere iii) Mesosphere iv) Thermosphere

2. Troposphere 3. Troposphere 4. Stratosphere 5. Thermosphere

Student Learning Activity 3

1. sun

2. hydrological/water cycle

3. If water is used and managed wisely, water can be replaced or renewed through the water cycle.

4. Water cycle is the transfer of water from the oceans into the atmosphere, then on to the land, and back to the ocean / the movement of water around over and through the earth.

5. Precipitation, evaporation, condensation, runoff

6. Condensation

Student Learning Activity 4

1. i) Continental crust ii) Oceanic

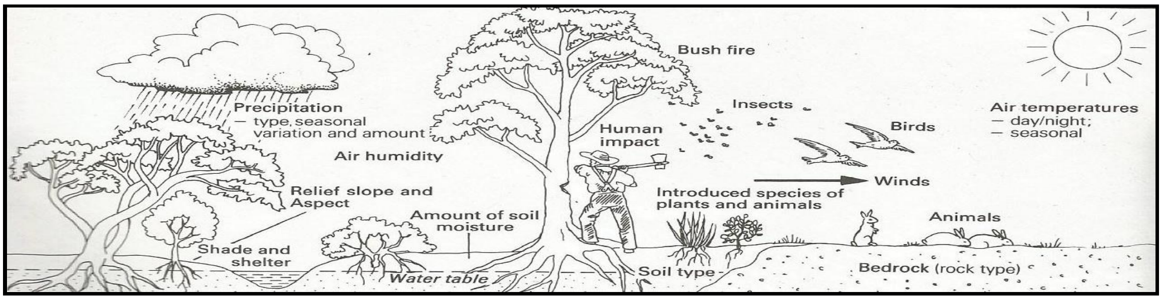
2. The oceanic lithosphere, is associated with Oceanic crust and exists in the ocean basins while the continental lithosphere, is associated with continental crust.

3. a) North American plates
   b) South American plates
   c) African plates
   d) Eurasian plates
   e) Antarctic plate
   f) Indo –Australian plate
   g) Pacific plate

Student Learning Activities 5

1. I) biosphere: The portion of the earth and its atmosphere that supports life.
   Ii) Ecosystem: refers to Living things

2.



(If you have stated factors in the diagram above, they are correct.)

Student Learning Activity 6

1. mohorovicic discontinuity

2. asthenosphere

3.

EARTH STRUCTURE	MATERIAL	THICKNESS
OCEANIC CRUST	Mainly basalt	5-6 km
CONTINENTAL CRUST	Granites and sedimentary rocks	50 km
MANTLE	Iron and manganese	2900 km
OUTER CORE	Molten iron and nickel	2000 km
INNER CORE	Solid iron	1370 km

Student Learning Activity 7

1 a) igneous b) sedimentary c) metarmorphic

2. **Intrusive rocks** are rocks that are formed through the solidification of magma masses deep within other rocks.
   Extrusive rocks are formed through the fast cooling of magma on or near the earth's surface.

3. The new metamorphic minerals are often aligned (arranged) in a parallel pattern because they have been formed under pressure.

4. i) The mineralogy is changed; although no elements are added to or taken from the original rock, its mineral will react and re-crystallize to suit the new condition.

   ii) The texture is changed; as new minerals develop, their size shape and their arrangement will depend on the conditions under which they form.

5. Denudation /transportation /deposition / Lithifaction

Student Learning Activity 8

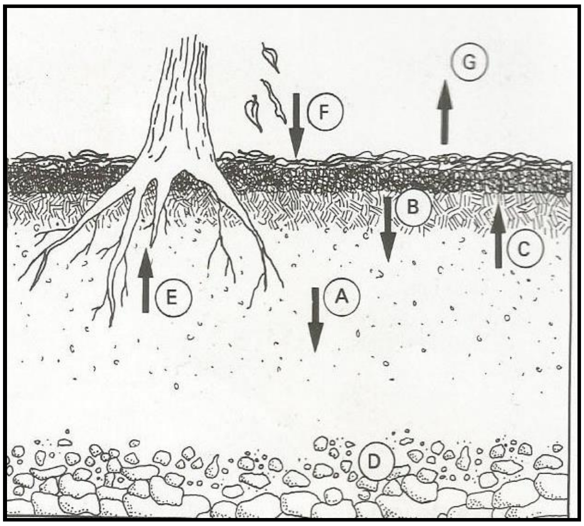
1. Soil is what plants grow on or
   Soil refers to the loose material or the upper layer of the Mantle Rock, made up of very small particles. It is penetrated by the roots of plants that derive from its nutrients and moisture

2. i) Water movement in the soil ii) laterite

3. i) climate iv) parent material
   ii) topography v) time

iii) organism

4. Study the diagram below and match the following labels with the arrows (A – G)



i) Leaves accumulate on the soil: ______F
ii) Rock weathering: _______D
iii) Soil moisture loss by evaporation: G
iv) Leaching takes clay into B horizon: _____________B
v) Soil moisture drawn upwards by capillary action: __________E
vi) Humus washed through A horizon. _______________A
vii) Roots take up water and minerals**.** _______________ C

5. Leaching is the continued removal by water solution of soluble matter from bedrock or regolith.

ANSWERS TO 11.1.2: GEOMORPHIC PROCESSES

Student Learning Activity 1

1. Weathering

2. Erosion, transportation and deposition

3. Erosion is the wearing away of materials by agents of erosion such as running water, ice, wave action and wind.

Student Learning Activity 2

1. A. headland B. bay C. arch D. stack E. wave cut platform

2. An arch (C) is formed when the roof the Arch collapses due to wave erosion which results in the formation of the stack. .

3. The waves meet the shore obliquely and materials are pushed up the beach in a zigzag manner.

Student Learning Activity 3

1. i) abrasion ii) deflation

2. i) Suspension ii) saltation iii) surface creep

3. When wind speeds moves particles by the skipping and bouncing action.

4. A: messa B: butte C: canyon D: playa

Student Learning Activity 4

1. The tearing away of blocks of rocks which have become frozen into the sides or bottom of a glacier. As the slowly moving ice scrapes against bedrock, friction between the rock and the ice causes the lowermost ice to melt.

2. Supraglacial debris is when debris is *carried on the surface of the glacier* as lateral and medial moraine. In summer, the relatively small load carried by surface melt water streams often disappears down the crevasses

3. i: playa iii: arete iv: cirque

Student Learning Activity 5

1. Input: precipitation

   Output: evapotranspiration

   Processes: i) infiltration ii) percolation

2. i) suspension ii) traction iii) solution

3. i) Headward erosion ii) lateral erosion iii) Vertical erosion

4. Aquifers are Beds of rocks which provide a supply of underground water. Such rocks must be porous or permeable. Water in the aquifer fills it to a level called the water table. Water table varies according to the amount of rainfall. They can also be affected by the rate of pumping from wells. Some aquifers hold water under pressure so it rises from wells without the aid of pumps, the artesian basin. Man has used the acquifers to source water from especially in areas where water is scarce.

5. i) Porous rock: rocks having small air spaces of rocks which have tiny spaces between their mineral grains which allow water to seep in .The most porous rock type is sandstone.

   ii) Pervious rocks: rocks having joints or cracks e.g. granites.

iii) Permeable rocks: Rocks which allow water to pass through them

6. The level below which the ground is saturated. Any hole in the ground will fill with water when the water table has been reached. This level often fluctuates with rainfall.

Student Learning Activity 6

1. i) Weathering iii) erosion iii) mass wasting
2. i) earthflow ii) mudflow
3. Rapid movement e.g.: slump
4. Is a special form of creep that produces a distinctive surface appearance. A process largerly restricted to Tundra landscape beyond the tree line

Student Learning Activity 7

1. Weathering is the breaking down of the earth's rocks through direct contact with planet's atmosphere, or is the breaking down / disintegration of rocks in blocks or in grains near or at the earth's surface.
2. When water enters the joints/cracks and it freezes, the ice formed, strains the wall of the joints and causes the joints to deepen and widen. Repeated freeze thaw cycles overtime weakens the rock which over time break up along the joints into angular pieces.
3. Thermal Expansion, Pressure Release or Unloading or Sheeting, Frost Shattering and Salt Crystalisation
4. Scree commonly refers to smaller material like mixed gravel and loose dirt (anything smaller than the human fist) while Talus refers to rocks larger than scree.

ANSWERS TO 11.1.3: INTERNAL FORCES AND PLATE MOVEMENTS

Student Learning Activity 1

1. i) Subduction zones ii) collision zones
2. Fold mountains
3. When the Continental crust converges with an oceanic plate, the plate with the less dense the denser oceanic sinks into the asthenosphere. When a descending plate reaches the depth of about 100 to 150 kilometers, the increase in pressure can trigger off major earthquakes while the heat produced by friction helps to convert the disappearing crust

back into magma. The newly formed silica rich magma being less dense than the rocks in the mantle may migrate to the surface, which can give rise to volcanoes and volcanic eruptions. These volcanoes are likely to form either a long chain of Fold mountains,(e.g. Andes) or if the eruption takes place offshore, (e.g. Japan, West Indies)

Student Learning Activity 2

1. i) Biology ii) Geology iii) Climatology

2. That all continents were once joined together in one large supercontinent which he named Pangaea. Pangaea means all Lands. Later this landmass somehow split up in to various continents, as we know them today. This was the result of the one world continent drifting apart.

Student Learning Activity 3

1. The continental crust of the earth has a visible part above the surface and a lower, invisible one. The balance between this two is isostasy.

2. The main idea behind the theory is to explain why the earth sometimes moves vertically and horizontally or moves upwards or downwards.

Student Learning Activity 4

1. i) Anticlines ii) Synclines

2. Folds are bends in the layered bed rock and Faults are fractures in the crust along which or a break in a rock mass along which movement has occurred.

Student Learning Activity 5

1. Faults are fractures in the crust along which or a break in a rock mass along which movement has occurred

2. A normal fault develops from tensional stress. That is the stress that results when a landscape is rifting or pulling apart.
   A reverse fault develops from compressional stress. Movement along a reverse fault is also predominantly vertical.

Student Learning Activity 6

1. P wave

2. i) Primary waves ii) secondary waves

3. The Epicenter

4. Body waves are the seismic waves that travel through the earth's interior spreading outward from the focus in all directions, like sound waves moving through air. They travel inside the earth and transmit foreshocks that have little destructive power. They are divided into P and S waves.
   Surface waves are seismic waves that travel on the earth's surface away from the epicentre, like water waves spreading out from a pebble thrown into a pond. These waves typically arrive immediately after the S waves.

Student Learning Activity 7

1. i) the shape of the volcano ii) the nature of eruption

2. Intrusive volcanism involves volcanic activities that occur inside a volcano resulting in intrusive landforms such as batholiths, sills, dikes and laccoliths. Extrusive involves pouring out of magma onto the earth's surface. The lava solidifies and forms rocks

3. i) It is the study of volcano. It includes all the processes by which solid, liquid or gaseous materials are forced in to the earth's crust or are ejected on to the surface.
   ii) Volcanism: refers to volcanic activity

YOU HAVE COME TO THE END OF THIS UNIT BOOK. NOW YOU MUST COMPLETE ALL THE ASSESSMENT TASKS IN ASSESSMENT BOOK 1 OF THIS UNIT. WHEN YOU FINISH, CROSS CHECK YOUR ANSWERS AND THEN SEND IT TO THE PROVINCIAL COORDINATOR FOR MARKING.

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2	KEREMA	P. O. Box 86, Kerema	6481303	72228124	The Coordinator	Senior Clerk	72229049
3	CENTRAL	C/- FODE HQ	3419228	72228110	The Coordinator	Senior Clerk	72229050
4	ALOTAU	P. O. Box 822, Alotau	6411343 / 6419195	72228130	The Coordinator	Senior Clerk	72229051
5	POPONDETTA	P. O. Box 71, Popondetta	6297160 / 6297678	72228138	The Coordinator	Senior Clerk	72229052
6	MENDI	P. O. Box 237, Mendi	5491264 / 72895095	72228142	The Coordinator	Senior Clerk	72229053
7	GOROKA	P. O. Box 990, Goroka	5322085 / 5322321	72228116	The Coordinator	Senior Clerk	72229054
8	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	The Coordinator	Senior Clerk	72229056
9	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194 / 5423332	72228148	The Coordinator	Senior Clerk	72229057
10	VANIMO	P. O. Box 38, Vanimo	4571175 / 4571438	72228140	The Coordinator	Senior Clerk	72229060
11	WEWAK	P. O. Box 583, Wewak	4562231/ 4561114	72228122	The Coordinator	Senior Clerk	72229062
12	MADANG	P. O. Box 2071, Madang	4222418	72228126	The Coordinator	Senior Clerk	72229063
13	LAE	P. O. Box 4969, Lae	4725508 / 4721162	72228132	The Coordinator	Senior Clerk	72229064
14	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	The Coordinator	Senior Clerk	72229065
15	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	The Coordinator	Senior Clerk	72229067
16	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	The Coordinator	Senior Clerk	72229069
17	BUKA	P. O. Box 154, Buka	9739838	72228108	The Coordinator	Senior Clerk	72229073
18	MANUS	P. O. Box 41, Lorengau	9709251	72228128	The Coordinator	Senior Clerk	72229080
19	NCD	C/- FODE HQ	3230299 Ext 26	72228134	The Coordinator	Senior Clerk	72229081
20	WABAG	P. O. Box 259, Wabag	5471114	72228120	The Coordinator	Senior Clerk	72229082
21	HELA	P. O. Box 63, Tari	73197115	72228141	The Coordinator	Senior Clerk	72229083
22	JIWAKA	c/- FODE Hagen		72228143	The Coordinator	Senior Clerk	72229085

SUBJECT AND GRADE TO STUDY

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English 2. Mathematics 3. Personal Development 4. Social Science 5. Science 6. Making a Living
Grades 9 and 10	1. English 2. Mathematics 3. Personal Development 4. Science 5. Social Science 6. Business Studies 7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature 2. Mathematics - Mathematics A / Mathematics B 3. Science – Biology/Chemistry/Physics 4. Social Science – History/Geography/Economics 5. Personal Development 6. Business Studies 7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) courses.
- For Grades 9 and 10, you must study English, Mathematics, Science, Personal Development, Social Science and Commerce. Design and Technology-Computing is optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) courses to be certified.

GRADES 11 & 12 COURSE PROGRAMMES

No	Science	Humanities	Business
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics A/B	Mathematics A/B	Mathematics A/B
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:
You must successfully complete 8 courses: 5 compulsory and 3 optional.