UNIT ONE

MAJOR GEOLOGICAL PROCESSES ASSOCIATED WITH PLATE TECTONICS

Introduction

- Knowledge of the earth's movement and the forces that work behind is, therefore, highly desirable so as
  - ✓ To predict the ground motion and the forces like earthquake and volcanism.
  - ✓ To minimize the damage from moderate forces, and
  - ✓ To avoid total collapse during the occurrence of these forces

1.1 THE CONTINENTAL DRIFT THEORY

- ✓ It was formulated by the German metrologies Alfred Wegener in 1912
- ✓ The Continental drift theory presupposes that the earth's continents have moved over geologic time relative to each other; thus, appearing to have "drifted" across the ocean bed.
- ✓ The continental drift theory suggests that the present continents were formed from a single continent called PANGAEA.
- ✓ During the Carboniferous period, some 350 million years ago, Pangaea was located around the South Pole.
- ✓ In the Triassic period of Mesozoic era, Pangaea started to break into several parts. The northern part of Pangaea is known as LAURASIA.
- ✓ The southern part of Pangaea is known as GONDWANALAND.
- ✓ Both continents are further subdivided into the present continents.
- ✓ Through the process of drifting, the continents reached their present location.
- ✓ This process of continental drift as a whole took place over millions of years.
- ✓ One of the basic concepts that helped Wegener's continental drift theory the idea of a large united landmass consisting of most of the Earth's continental regions.

- Wegener used the following geological evidence, among others, to support his theory:

  1. Coastline Similarity: The coastlines of Africa and South America have remarkable similarity in opposite side of the Atlantic Ocean. These coastlines fit together like pieces of a jigsaw puzzle.

  2. Rock type and structural similarities: When we fit the continents of Africa and South America "back together again", we find that: Similar rock types, age and mountain belt extend from one continent to the other

  3. Fossil Evidence: cases of several fossil organisms had been found on either side of the Atlantic Ocean, implying that the continents were once joined together. Fossils of Mesosaurus are found on both sides of the Atlantic in South America and Africa. Mesosaurus was a small reptile that lived about 250 million years ago.

  4. Paleoclimatic Evidence: similarities of climatic data reconstructed from rock structure are similar in the present continents.

❖ Why Wegener's continental drift theory was not easily accepted?

1. Wegener was not a geologist by profession,
2. Most influential geoscientists at that time were based in the Northern Hemisphere, whereas most of the conclusive data came from the Southern Hemisphere.
3. Wegener thought that Pangaea did not break up until Cenozoic era, and scientists found it hard to believe that so much continental drift could have occurred in so short a time
4. Lack of direct evidence for the movements of continents and the needed explanation for the mechanism.

- ✓ Regardless of the controversies mentioned above, perhaps Wegener's most important legacy is to have introduced the idea of lateral mobility of continents, that is, offering a paradigm change from fixism to mobilism to the scientific community and the public

1.2 PLATE TECTONICS THEORY

- ✓ According to plate tectonic theory, the layer, called the asthenosphere, allows the uppermost mantle and crust, together called the lithosphere to slide across the top of it.
- ✓ Earth's lithosphere is broken into about a dozen large pieces (plus some smaller ones), called plates
- ✓ These plates move slowly at a rate of a few centimeters per year and change size.
- ✓ Plates may be entirely made up of continental rocks, both continental and oceanic rocks, or entirely of oceanic rocks.
- ✓ Plate tectonics is a theory developed in the late 1960s by Morgan to explain how the outer layers of the earth move and deform.
- ✓ The theory states that the earth's lithosphere is divided into plates that move around on the top of the asthenosphere.
- ✓ Continental crust is embodied within the lithospheric plate. The plates move in different directions, and meet each other at plate boundaries.
- ✓ Plate tectonics has been proven to be so useful that it can predict geologic events and explain almost all aspects of what we see on the earth
- ✓ The edges of these plates do not necessarily correspond to the boundaries of continents or oceans. For example, the North American Plate includes the western half of the North Atlantic Ocean's seafloor.
- ✓ The plate tectonics theory is based on a broad synthesis of geologic and geophysical data.
- ✓ It is now universally accepted, and its adoption represents a true scientific revolution.
- ✓ Plate tectonic process influences the composition of the atmosphere and oceans, cause of long term climate change and makes a significant contribution to the chemical and physical environment in which life evolves. Today, science has shown that the surface of the Earth is in a constant state of change.
- ✓ We are able to observe and measure mountains rising and eroding, oceans expanding and shrinking, volcanoes erupting and earthquakes striking. Thus, this theory serves as the foundation upon which we understand the geologic processes that shape the Earth.

- ✓ The plate tectonics theory provides a framework for understanding many of Earth's features, such as mountains, earthquakes, and volcanoes, as well as the distribution of fossils and the ages of rocks.

1.3. PLATE MOVEMENTS AND PLATE BOUNDARIES

- ✓ The way the plates interact at their margins depends on whether the crust forming the top of the plate (at the point of contact) is oceanic or continental.
- ✓ Continental crust, made largely of granite, is less dense than oceanic crust made largely of basalt.
- ✓ As the plates move, they may:

1. Converge or come together; forming convergent (Destructive) boundary;
2. Diverge, or spread apart; forming divergent (Constructive) boundary or
3. Slide past each other along fractures called transform (Conservative) boundary.

1. Convergent plate boundaries

- ✓ These are boundaries where two plates move toward each other.
- ✓ At such boundaries, the denser plate will be forced under, or subducted beneath, the less dense one.
- ✓ The subducted crust is eventually destroyed.
- ✓ This happens when oceanic crust meets continental crust and when oceanic crust meets another oceanic crust. For example, the eastward-moving Nazca Plate, under the southeastern Pacific Ocean, is being subducted under the westward moving South American Plate. The denser oceanic crust is pushed down into the mantle, causing it to melt and produce magma (molten rock). The magma and gases rise to the surface, and are vented through the western crust of South America, forming the volcanoes of the Andes Mountains.
- ✓ If two oceanic plates converge, subduction of one under the other may produce an arc of volcanic islands. The **Mariana Islands** of the western Pacific Ocean were formed this way.
- ✓ Two blocks of continental crust may converge as well. The resulting pressure can deform the crust. If one block is denser, that block may slide under the other, mainly lifting the other plate rather than sinking too much itself. A good example of this is the convergence of the northward moving Indo-Australian Plate with the Eurasian Plate. Thus, as India met Asia, the collision produced the highest mountain range on Earth: the Himalayas.

2. Divergent plate boundary

- ✓ This occurs where plates move away from each other at oceanic ridges, such as in the middle of the Atlantic Ocean.
- ✓ There, rising magma from underlying asthenosphere intrude and erupt beneath and at oceanic ridge to create a new seafloor. This pushes the plates on either side away from each other in opposite directions.
- ✓ Undersea volcanoes and crust expanded by heating have produced a long undersea ridge, but with a rift in the middle where the plates are separating. This process is known as seafloor spreading.
- ✓ Shallow earthquakes are common at oceanic ridges.

- ✓ Divergence can also happen on continents, producing fractures called rift valleys example is the East African Rift Valley.
- ✓ Over millions of years, the continental crust may separate completely, with the area between flooding with water to become a new ocean.

3. **Transform Fault boundaries**

- ✓ In some places, plates slide past each other laterally along fractures in the crust. These places are called transform faults. The plates stick and then occasionally slip, producing earthquakes.
- ✓ Most transform faults are found on the seafloor along the undersea mountain chains called oceanic ridges, but the faults also occur on continents, such as the San Andreas Fault in California
- ✓ As plates move past each other along transform faults, crust is neither destroyed nor created.
- ✓ Plate tectonics is driven by the internal energy of the Earth.
- ✓ Most agree that motion of the plates is ultimately driven by convection currents in the mantle.
- ✓ Convection is a means of heat transfer wherein the heat moves with the material.
- ✓ It occurs when conduction is inefficient at transporting heat, particularly if the material has a low thermal conductivity, like rocks.
- ✓ The Earth's asthenosphere is ductile, and therefore is likely to flow more readily (it will bend or deform if you apply enough force to it) than the overlying lithosphere.

1.4. MAJOR GEOLOGICAL PROCESSES

- ✓ The Earth is a dynamic planet.
- ✓ The term "geological processes" describes the natural forces that shape the physical makeup of our planet earth. Plate tectonics, erosion, chemical weathering and sedimentation are all examples of forces that significantly affect the Earth's surface and account for its major features.
- ✓ The geological processes are closely studied by geologists and earth scientists to:
  - ➢ Improve the understanding of the planet's history;
  - ➢ Help to locate useful resources, such as metal ores; and
  - ➢ Aid the prediction of potentially disastrous events, such as earthquakes, tsunamis and volcanic eruptions.
- ✓ The forces that bring about changes on the earth's surface are divided into two. They are:

1. Endogenic (Internal) forces
2. Exogenic (External) forces.

1.4.1. INTERNAL (ENDOGENIC) FORCES

- ✓ Internal forces are forces that come from the inside of the earth. These forces create irregularities or unevenness on the face of the earth.
- ✓ They form ups and downs on the crust of the earth by breaking, bending, or folding the rock. Let us briefly examine some of them: folding, faulting, earthquakes and volcanic eruptions. **1. FOLDING**
- ✓ Folding occurs when rock layers are pushed by earth movements sideways.

- ✓ The movement may be only from one direction. It may also be from two directions. When rock layers are pushed from two directions, they are compressed. The rock layers are folded
- ✓ The layers of rock bend up from an up fold or anticline. Those which bend down form a downward arch or syncline.
- ✓ If compression continues then simple folds are changed into asymmetrical folds, over folds and over thrust folds.
- ✓ Symmetrical fold: angle of one limb is almost equal to another limb.
- ✓ Asymmetrical fold: one limb is steeper than the other.
- ✓ Over fold: One limb is pushed over the other limb.
- ✓ Over thrust fold: When pressure is very great, a fracture occurs in the fold and one limb is pushed forward over the other limb.
- ✓ The main landform which associated with folding is fold mountain
- ✓ Fold Mountain is formed when the earth's curst by compressional force.
- ✓ The process of fold mountain formation is known as orogenesis
- ✓ The Fold Mountains of the world are grouped into two: They are:

1. **Young fold mountains 2. Old fold mountains**

- ✓ During the last 400 million years, there have been three main mountain-building periods.
- ✓ Young fold Mountain.:the last and the recent is known as Alpine orogeny.
- ✓ Mountains belonging to this period include the Andes, Rockies, Alps, Himalayas, Atlas and Australian Alps. They are called young fold mountains.
- ✓ The old fold mountains are the oldest, dating back 250 to 300 million years, and they are characterized by lower heights are more weathered. Example Scandinavian (Calidonides) Mountains, Appalachian Mountains, and the Urals.

2. Faulting

- ✓ A fault is a crack on the earth's crust.
- ✓ It is formed by the forces of tension and compression.
- ✓ A fault may occur in the rocks along a single line. When this happens, rocks are displaced either upward or downward.
- ✓ . Where parallel faults have occurred, the land in between may sink down or may be forced to move upwards. These movements of the earth will result in the formation of the following landforms: 1. Rift valleys 2. Block Mountains
- ✓ Rift valleys: They are formed when the land between two faults sinks down. The blocks on both sides of the valley form plateaus. For example the East African Rift Valley.
- ✓ Block Mountains: They are formed when the land between two parallel faults is pushed upward. A block mountain is called horst. For example: the Afar Horst.

3. EARTHQUAKES

- ✓ The sudden shaking of the ground that occurs when masses of rock change position below Earth's surface is called an earthquake.
- ✓ The shifting of the rock releases a great amount of energy, sending out shock waves that travel through the rock, and cause the ground to shake. These shock waves, called seismic

waves by Earth scientists, may be powerful enough to alter the surface, thrusting up cliffs and opening great cracks in the ground. Earthquakes occur most often along geologic faults, which are fractures in the rocks of Earth's crust.

- ✓ Along faults, the rock masses on opposite sides of the fracture strain against each other and sometimes "slip," causing an earthquake.
- ✓ The major fault lines of the world are located at the fringes of the huge tectonic plates that make up the crust.
- ✓ Earthquakes, called temblors by scientists, occur almost continuously.
- ✓ Fortunately, most of them can be detected only by sensitive instruments called seismographs.
- ✓ A scale is used for reading is called a Richter scale.
- ✓ It gives reading from 0 (no movement) to 9 (extremely severe).
- ✓ The Richter scale measures the effect in a logarithmic scale.
- ✓ The effects of an earthquake increases significantly for each step up the scale.

Causes of Earthquakes

- ✓ Most of the worst earthquakes are associated with changes in the shape of Earth's outermost shell, particularly the crust.
- ✓ These earthquakes are generated by the rapid release of strain energy that is stored within the rocks of the crust.
- ✓ The strongest and the most destructive quakes are associated with ruptures of the crust, which are known as faults. Although faults are present in most regions of the world, earthquakes are not associated with all of them. (The kilogram of Trinitrotoluene (TNT) is a unit of energy equal to 4.184 mega joules, which is approximately the amount of energy released in the detonation of one kilogram of TNT.)
- ✓ Shock Waves: the shifting rock in an earthquake causes shock waves called seismic waves to spread through the rock in all directions. In a great earthquake, shocks may be felt by people thousands of miles or kilometers away from the center.
- ✓ Seismographs can pick up the waves on the other side of the world.
- ✓ There are two broad classes of seismic waves: Body waves and surface waves.
- ✓ Body waves travel within the body of the Earth. They include or primary waves and S secondary) waves.
- ✓ P waves spread in the crust from the point of rupture, which is called the focus of the earthquake.
- ✓ The point of which the wave originates is what we call the Earthquake focus.
- ✓ The point on the Earth's surface immediately above the focus is termed the epicenter of an earthquake.
- ✓ P waves alternately compress and expand the rock through which they pass, and vibrate in the same direction in which the waves travel.
- ✓ S waves vibrate at right angles to the direction of wave travel. These secondary waves are the location of an earthquake many thousands of miles away.

- ✓ After both P and S waves have moved through the body of the Earth, they are followed by two types of surface waves, which travel along the Earth's surface. These are named Love and Rayleigh waves, after the scientists who identified them.
- ✓ Because of their larger amplitude, surface waves are responsible for much of the destructive shaking that occurs far from the epicenter.
- ✓ Surface waves, which travel more slowly than body waves, are the most powerful shake waves.

❖ **Effects of Earthquakes**

- ➢ Cause dramatic changes at the Earth's surface.
- ➢ Changes in the flow of groundwater, landslides, and mudflows.
- ➢ Damage to buildings, bridges, pipelines, railways, embankments, dams, and other structures.
- ➢ Devastating fires.
- ➢ Tsunamis

- ✓ Most earthquakes take place on one of the two great earthquake belts that girdle the world.
- ✓ The belts coincide with the more recently formed mountain ranges and with belts of volcanic activity.
- ✓ The main earthquake belts of the world are

1. Earthquake belt circles the Pacific Ocean along the mountainous west coasts of North and South America and runs through the island areas of Asia.
   - ✓ It is estimated that 80 percent of the energy released in earthquakes comes from this belt.
   - ✓ It is called the Circum-Pacific Belt or the Ring of Fire
2. Less active belt passes between Europe and North Africa through the Mediterranean region.
   - ✓ It then runs eastward through Asia and joins the Ring of Fire in the East Indies.
   - ✓ The energy released in earthquakes in this belt is about 15 percent of the world total.
3. The Arctic Ocean, the Atlantic Ocean, and the western Indian Ocean and along the Great Rift Valley of East Africa.
   - ✓ The focus of an earthquake may classified into three

1. Shallow focus: is a quake with foci less than about 60 kilometers deep. More than 75 percent of the seismic energy produced each year from here
2. Intermediate focus: those with foci ranging from about 60 to 300 kilometers. About 12 percent of the total energy released in earthquakes comes from intermediate earthquakes,
3. Deep focus: occur from quite close to the surface down to a maximum depth of about 700 kilometers deep. About 3 percent of the total energy comes from deeper earthquakes. The deeper focus earthquakes commonly occur in Benioff zones, which dip down into the mantle at places where two tectonic plates converge. A Benioff zone extends down along the plate that is being subducted.

4. Volcanism

- ✓ Volcanism is the process by which molten rock or magma, gaseous and solid materials is forced out on the surface of the earth.
- ✓ This movement could be very slow or sudden.

- ✓ With slow movement, the materials could spread over the surrounding area gently.
- ✓ If the movement is violent, the materials will be thrown high into the sky and then fall back in the surface of the earth.
- ✓ Magma may reach the surface of the earth through Vents (holes)and Fissures(large or narrow crack)
- ✓ If lava emerges via vent, it builds up a volcano (a cone shaped mound). Fissures are large and narrow cracks or fractures in a rock.
- ✓ If the lava emerges via a fissure, it builds up a plateau. During the formation of lava plateau, there is little or no explosive activity through the fissures; lava gently spreads over large area.
- ✓ The word volcano refers to the form or structure, usually conical, produced by accumulations of erupted material.
- ✓ Volcanoes occur mainly near the boundaries of tectonic plates.
- ✓ They form along belts of tension, where plates diverge, and along belts of compression, where plates converge.
- ✓ The main volcanic belts of the world

1. Pacific ocean belt:- Nearly 1,900 volcanoes are active today or are known to have been active in historical times. Of these, almost 90 percent are situated in the Pacific Ring of Fire
2. The Mediterranean-Asian belt, which accounts for most of the world's earthquakes outside the Ring of Fire, has few volcanoes except the Indonesia and Mediterranean which have more numerous ones.
3. Oceanic volcanoes are strung along the world's oceanic ridges,
4. Great Rift Valley of East Africa.

- ❖ Based on frequency of eruption volcanic eruption can be classified into three
  1. An extinct volcano is one that is not erupting, and is not likely to erupt in the future. Example, Mount Zuqualla, Ethiopia.
  2. A dormant volcano is currently inactive but has erupted within historic times, and is likely to do so in the future. Example: Mount Kilimanjaro, Tanzania
  3. An active volcano is one that has erupted or thought to have erupted during the last 500 years. Example: Erta Ale, Ethiopia
- ❖ Volcanoes are usually classified by shape and size in the following categories
  1. Shield volcanoes are volcanoes that have a low, but broad profile created by highly fluid lava flows that spread over wide areas. The lava, usually composed of basalt, cannot build up a cone with sides much steeper than 7 degrees. The Hawaiian Islands are composed of shield volcanoes that have built up from the seafloor to the surface some 5 kilometers above.
  2. Strato volcanoes are the most common volcanic form. They are steep cones composed of alternating layers of lava and pyroclastics or rock fragments. These volcanoes are characterized by a steep profile and periodic, explosive eruptions. The lava that flows from them is highly viscous, and cools and hardens before spreading very far.

3. Cinder cone volcano is a conical hill of mostly cinder-sized pyroclastics. The profile of the cone is determined by the angle of repose, that is, the steepest angle at which debris remains stable and does not slide downhill

- ✓ Other landforms created by volcanoes include craters and calderas.
- ✓ Craters are formed either by the massive collapse of material during volcanic activity, by unusually violent explosions, or later by erosion during dormancy.
- ✓ Calderas are large, basin-shaped depressions. Most of them are formed after a magma chamber drains and no longer supports the overlying cone, which then collapses inward to create the basin.
- ✓ When magma cools and solidifies within the crust intrusive or plutonic igneous rocks are formed deep beneath the Earth's surface.
- ✓ Some of the intrusive igneous rocks include batholith, dyke, and sill
- ✓ Batholith is a very large dome shaped intrusion of igneous rock. It is located several kilometers deep in the crust, and extends over hundreds of square kilometers. Sometimes, it forms the core of a mountain.
- ✓ Sill is a near horizontal intrusion of igneous rock between two rock layers. The cooled rock forms a sheet of more or less parallel to the surrounding layers of rocks.
- ✓ Dike is formed as the magma rises up through a near vertical crack.

1.4.2. EXTERNAL (EXOGENIC) FORCES

- ✓ They are forces that shape the relief features of the earth acting on the upper surface.
- ✓ These forces include forces such as denudation, weathering, erosion transportation and deposition.
- ✓ External forces can lower the level of the land by washing it away, and this process is called denudation.
- ✓ They also can raise the level of the land by deposition.
- ✓ Denudation consists of weathering and erosion

1. **Weathering:**

- ✓ It is the breaking down or changes that rocks undergo or near the earth's surface.
- ✓ Weathering of rock rocks takes place into two forms:

a) Physical weathering b) Chemical weathering

i. Physical (Mechanical) Weathering

- ✓ Physical (mechanical) weathering occurs when a rock is broken into smaller pieces but its chemical makeup is not changed
- ✓ Its main agents (causes) are temperature changes, frost action and the action of plants and animals.
- ✓ **Thermal expansion and contraction**: All minerals expand during hot days and contract during cold nights, and some minerals expand and contract more than others.
- ✓ This process continues until the rock loosens up and breaks into pieces.
- ✓ Peel off the upper layer of rock due to variability of temperature is known as **exfoliation**.
- ✓ **The effects of frost action**: Water fills in cracks in rocks, and then freezes during cold nights. As the ice expands and pushes out on the crack walls, the crack enlarges. During the

warm days, the water thaws and flows deeper into the enlarged crack. Over time, the crack grows until the rock is broken apart.

- ✓ This process is active in mountains, producing a pile of rock pieces at the mountain base called scree.
- ✓ Frost action is very common in the winter season in the temperate zone (cold) and in some high mountains all year round
- ✓ Salt weathering occurs in areas where much salt is available or there is a high evaporation rate, such as along the seashore. Salt crystals form when salty moisture enters rock cracks. Growing crystals settle in the bottom of the crack and apply pressure on the crack walls, enlarging the crack.
- ✓ As plants develop their roots may push the rock apart.
- ✓ When **plant** roots grow into cracks in rocks, they enlarge the cracks and break up the rocks.
- ✓ Some animals burrow, and this also helps to break up rocks.

ii. Chemical Weathering (Decomposition)

- ✓ It is the decomposition of rocks into smaller pieces by chemical changes of the mineral constitute of the rock.
- ✓ Water and oxygen create two common causes of chemical weathering.
- ✓ **Hydrolysis** can occur when water flows through earth materials. The hydrogen ions or the hydroxide ions of the water may react with minerals in the rocks. When this occurs, the chemical composition of the mineral is changed, and a new mineral is formed. Hydrolysis often produces clay minerals.
- ✓ Some elements in minerals combine with oxygen from the atmosphere, creating a new mineral. This process is called **oxidation**. Some of these oxidation minerals are commonly referred to as **rust.**
- ✓ As rain water passes through the atmosphere, it takes in carbon dioxide (CO_2) and forms a weak carbonic acid. When this acid water comes into contact with rock, it begins to dissolve minerals in the rock. This process is known as **carbonation.** Limestone, for example, dissolves very quickly.

  $H_2O + CO_2 \Rightarrow$ carbonic acid $\Rightarrow$ dissolves and erodes limestone and forms caves example **Sofomer Cave**, in Bale formed by the River Weiyb and seeping rainwater
- ✓ In underground rivers, seeping rain water continues to dissolve the limestone beneath the surface, gradually forming passages and caves.
- ✓ These caves contain features such as stalactites, stalagmites and pillars.
  - ➢ A **stalactite** is a limestone column that **hangs down** from the ceiling of the cave.
  - ➢ A **stalagmite** is a limestone column that builds **upwards** from the floor of the cave.
  - ➢ A **pillar** is formed when a stalactite and stalagmite join together
- ✓ Plants absorb minerals, and decaying vegetation produces organic acid, which causes a further breakdown of minerals.
- ✓ Bacteria in the presence of water break down certain minerals in the soil.

- ✓ Leaching is a major soil-forming process. It occurs when substances are dissolved in water that percolates through soil. Such substances include soluble chemicals that move out of biological tissues into soil - for example, rainfall causes potassium and other ions to be lost by foliage.

2. **Erosion and deposition**

- ✓ Soil erosion is the movement of soil and rock particles from one place to another.
- ✓ Erosion is the transporting of weathered material by various natural forces such as moving water, wind and moving ice.
- ✓ Erosion is wearing way of the upper part of the earth's surface
- ✓ Agents of erosion
  - ➢ running water like stream and river
  - ➢ Sea wave
  - ➢ Glacier / ice
  - ➢ Wind

A. Erosion by Running Water

- ✓ Running water is all sort of water that flow over the earth's surface
- ✓ Among the external forces, running water is more powerful in shaping the surface of the earth
- ✓ Rivers are most important of agents of erosion in high land Area.
- ✓ The work of running water includes **eroding**, **transporting** and **depositing** eroded material.
- ✓ The ability of running water to erode and transport materials is directly related to its speed. Its speed determined by slope of the earth's surface.
- ✓ There rate of erosion is depends on slops in which water flow ,vegetation cover and soil type
- ✓ There are three types of running water erosion:

1. **Sheet erosion**: - occurs when surface water moves in a wide flow. This type of erosion may not be noticeable until much damage has been done.

2. **Rill erosion**: - occurs when surface water cuts relatively small channels and ditches.

3. **Gully erosion**: - 0ccurs when floods cut deep wide gorges. It can become severe where all or most of the vegetation has been removed

Stages in a Course of a River,

- ✓ The course of river from its source (head stream) to its mouth (end point) can be divided into 3 stages. These are
  - i. Upper Course (Mountain Course) (youth stage of a river)
  - ii. Middle Course (Valley Course) (maturity stage of a river)
  - iii. Lower Course (Plain Course) (old stage of a river)

i. Upper Course (Mountain Course) (youth stage of a river)

- ✓ In the upper course a river flows very fast,

- ✓ has lower volume of water and the work is primarily that of erosion or destruction,
- ✓ Features associated with in the upper course of rivers are V-shaped valley, gorge, Interlocking spurs, Rapids and Waterfalls.
- ✓ Gorge is a valley that is deep and narrow with steep walls. The rock walls are nearly vertical.
- ✓ Interlocking spurs: fingers of land that jut out in to the river valley that stream and rivers are forced to flow around in the upper course.
- ✓ Rapids: fast turbulent section of the river where the bed has relatively steep gradient
- ✓ Waterfalls are formed when water flows over hard rock which cannot be eroded easily, while soft rocks are easily eroded. l. E,g. Tis Isat

ii. Middle Course (Valley Course) (maturity stage of a river)

- ✓ The river valley becomes wider and larger.
- ✓ The river may receive waters of many tributaries, which increase the volume of water.
- ✓ Features associated middle course of river are meander, wide-floored valleys(u-shaped valley and oxbow lake
- ✓ **Meander** - a winding curve or bend of a river
- ✓ It is the winding of a river. The river makes zigzag movements.

iii. Lower Course (Plain Course) (old stage of a river)

- ✓ The river flows slowly, meandering over wide plains, and makes wide spread deposition.
- ✓ Features associated with in the lower course of river are flat floodplains, big meanders, levees, ox-bow lakes and deltas
- ✓ **Floodplains** are broad flat areas which border with the lower course of a river and are sometimes flooded by the river. They are covered with fertile alluvial soils which are deposited by the river when flooding.
- ✓ **Levees** are narrow ridges of alluvial deposits found along the bank of a river.
- ✓ **Ox-bow** lakes are crescent moon shaped lakes created formed when meanders are cut off from the main river channel.
- ✓ **Deltas** are usually triangular areas of land which are usually formed at the mouth of rivers
- ✓ The name originated from the Greek letter delta.

B. Erosion and Deposition by Sea Waves

- ✓ Waves are formed when wind moves over the surface of the sea. This causes the particles of water to move in a circular motion, which forms a wave.
- ✓ It is common in coastal area
- ✓ The work of the sea along the coast includes erosion, transportation and deposition.
- ✓ Some of these features formed along the shoreline are **beaches, spits** and **lagoons**.
- ✓ A **Beach** is a strip of land along the sea coast covered with various types of sediment.
- ✓ A **Spit** is a low-lying, narrow deposits of sand or silt attached at one end to the land moving deep into the sea in the other end
- ✓ A **Lagoon** is an area of saltwater separated from the sea by loose sandbanks...

C. Erosion by Glaciers

- ✓ It is common in polar area

- ✓ Erosion by Glaciers Processes of glacial erosion involves the removal and transport of bedrock or sediment by three main processes; quarrying, abrasion, and melts water erosion.

D. Wind Erosion and Deposition

- ✓ Wind erosion is common in desert and semi-desert areas
- ✓ Wind erosion form different landforms such as sand dunes, barchans and loess deposits.
- ✓ **Sand dune** is a small hill of sand formed by the action of the wind.
- ✓ **Barchan** is a sand hill that has a crescent-moon shape.
- ✓ **Loess deposit** is a deposition of fertile soil in the desert by wind. There are large loess deposits in North China.

Mass wasting:

- ✓ Mass Wasting refers to the down slope movements of rock, regolith, and soil under the influence of gravity.
- ✓ Actual gravity is the controlling factor for mass wasting.
- ✓ Other main factors of mass wasting are Water; the angle of the slope and the activities of people.
- ✓ Water: we know that a portion of rain water that falls on land soaks into the ground. Part of the sacked water collects into pores of the sediments. Such water could reduce the cohesion among the particles which results in lack of internal resistance. Subsequently, the materials are set in motion by the force of gravity.
- ✓ The Angle of the Slope: the steepest slope at which materials remain firm varies from 25 to 40 degrees. This depends on the size and shape of the particles. For example, the larger and more angular particles maintain the steepest slopes. If the angle is increased, the rock debris will adjust by moving down slope.
- ✓ Activities of people: e.g farming, deforestation and overgrazing of the areas.
- ✓ In different parts of Ethiopia, mass wasting occurred several times. This phenomenon resulted in the destruction of human life and properties.