

Introduction to Geology

Introduction:

Geology (word derived from Greek, Geo = Earth, logos = science) is a science that deals with the study of the Earth as a planet. Thus it includes essence of scientific studies dealing with the origin, age, and structure of the Earth on one hand and with the evolution, modification and extinction of various surface and subsurface physical features (like mountains, plateaus, plains, valleys, basins, caves and all coastal, marine and submarine forms) on the other hand.

Branches of Geology:

The field of Geology is vast and it is divided into several branches.

- **Physical Geology:** - Physical geology is concerned with the work of natural processes which bring about changes upon the earth's surface.
- **Mineralogy** :- Mineralogy includes the study of mineral composition, structures, appearance, stability, occurrence and associations.
- **Petrology**:- The study of the different kinds of rocks is known as petrology. It deals with composition, structure and origin of rocks.
- **Structural Geology**:- This branch of geology deals with the study of structures of rocks in the earth's crust.
- **Stratigraphy**:- The study of the stratified rocks especially their sequence in time, the character of the rocks and correlation of beds at different localities.
- **Palaeontology**:- Palaeontology is the science of fossils of ancient life forms and their evolution.
- **Economic Geology**:- The economic geology deals with the study of minerals, ores, and fossil fuels of economic importance.
- **Mining Geology** :- This branch of Geology is concerned with the study of application of geology to mining engineering.
- **Engineering Geology**:- The Principles and methods of geology is adopted for the purpose of civil engineering operations. Broadly speaking, Engineering Geology has two divisions.
 - a) The study of raw materials.
 - b) The study of the geological characteristics of the area where engineering operations are to be carried out such as Ground water characteristics, the load bearing capacity of rocks, the stability of

slopes, Excavation, rock mechanics etc

Scope of Geology:- in Civil Engineering.

- Geology provides necessary information about the materials at the site used in the construction of buildings, dams, tunnels, reservoirs, highways and bridges.
- Geological information is most important in planning stage, design phase and construction phase of an engineering project.

IMPORTANCE OF PHYSICAL GEOLOGY: It deals with the geological processes which bring about changes in the crust and upon the surface of the earth. It also deals with the surface features of the earth (land forms) or its topography. The earth is concentrically divided into a number of spheres viz.,
(1) Atmosphere ; (2) Hydrosphere and (3) Lithosphere .

The outermost sphere is Atmosphere which consists of several gases and vapours and envelopes the earth. Atmosphere is essentially a mixture of N_2 and O_2 with smaller quantities of vapour, CO_2 etc... Geologically atmosphere is important as the medium of climate and weather. Hydrosphere includes the natural waters of the earth ie., oceans, seas, lakes, rivers, streams and underground water. Lithosphere is the outer part of the earth's crust consisting of rocks and minerals.

The geological processes include Denudation, Deposition, Earth movements, Igneous activity and metamorphism.

Denudation: The sum of the processes which result in the general lowering of the land surfaces or when erosion takes place, fresh country rock surfaces will be exposed and this process is called DENUDATION. Denudation consists of weathering, transportation and erosion.

Weathering is the process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes. Weathering is the initial stage in the process of denudation.

Transportation is the main agency by which materials are moved by means of Gravity, running water (rivers, streams); Ice (glaciers); Wind etc..

Erosion: Mechanical disintegration or chemical decomposition of rocks and their subsequent displacement is called as erosion or erosion is the destructive process due to the effect of the transporting agents. The chief agents of erosion are running water, wind etc..

Deposition : The material is transported mechanically and deposit (eg: sand).

Earth movements include the uplift and depressions of land areas & sea floors.

Igneous activity includes emission of lavas, gases, other volcanic products etc

Metamorphism: The process by which changes are brought about in rocks within the earth's crust by the agencies of Heat, Pressure and Chemical fluids.

Thermal metamorphism : heat alone acts



Dynamic metamorphism : involves stress to break up the rocks

Regional/Dynamothermal metamorphism:

Both heat & pressure involves

Retrograde metamorphism : produces lower grade metamorphic rocks

Auto Metamorphism : chemical adjustment in newly solidified igneous rocks, brought about by a decrease in temperature .

Geological works of Rivers

A river is one of the major geological agent which carries out its work. The work is mainly divided into three stages, namely

1. River Erosion
2. River Transportation
3. River Deposition

River Erosion: Erosion means mechanical disintegration or chemical decomposition of rocks are transported from the site with the help of natural agencies like wind and running water (or) subsequent displacement. River is a powerful eroding agent and carries out its work in different ways such as hydraulic action, solution and abrasion / attrition etc.

- Hydraulic action: The physical breakdown of rocks take place naturally and greater the movement greater will be the erosion. In the initial and youth stages, the

rivers acquire more considerable kinetic energy. When such water dashes against rock forcefully, it will break and this will be more effective if

1. The rocks are already weathered.
2. They are porous and are not well cemented.
3. Those possess fractures, cracks etc.

- Solution: This process, is a part of hydraulic action which involves only chemical decay of rocks. This is an invisible process and very effective under favourable conditions.

- Attrition: This is a mechanical weathering process. When the rock fragments hit the rocks which are already exposed, abrasion take place. Thus the rock fragments during abrasion undergo wear and tear which is called attrition.

During transportation, heavier and larger materials move slowly while finer and lighter material move fast.. When attrition take place the angular edges disappear and spherical, ellipsoidal stones etc are formed after a long journey.

River Transportation: A river transports its material physically as well as in a solution form. The transport system is divided into three groups.

1. **Bed load** comprises heavier particles of sand, pebbles, gravels etc.. which are

transported mainly by their rolling, skipping, along the bottom of stream.

2. Suspended load consists of silt, fine sands, clay etc.. and such load is carried by river in its body of water in suspension. As the river is moved, the load is also carried along with it. Thus load is transported continuously without break till conditions are favourable. This type of natural suspension and separation of sediments account to their size is called Sorting.

3. Dissolved load: Material is transported in a solution condition. The ability to transport the sediments is influenced by river velocity, density etc..

River Deposition is the last phase of geological work of a river. Among the different kinds of river deposits, a few are listed below:

Alluvial cones and fans: River sediment is known as alluvium. If the deposit is spread over a small area but has a relatively steep slope, it is called an alluvial cone. On the other hand, if the deposit is spread over a large area and has a gentle slope, it is called an alluvial fan.

Placer deposits: The placer deposits are characteristically composed of heavier metals such as Gold, Platinum, Chromite, magnetite, Rutile, Ilmenite, Monazite etc. which are commonly economic minerals.

Eg: Rand placer deposit of South Africa is famous for gold.

Delta deposits: Most of the rivers reach this stage just before they merge with the sea. Rivers Ganga and Brahmaputra have built up the best deltaic regions of the world. Deltas are very fertile and valuable for agriculture.

Natural levees. During the time of floods, the river carries a very large scale of river dumps along its course on either side which are known as natural levees. Eg silt, clay .

MEANDER DEVELOPMENT

A meander in general is a bend in a (moving with smooth twists & turns) water course. A meander bend is formed when the moving water in a stream erodes the out banks and widens its valley. If the river encounters any obstacle, it shall not have the capacity to uproot it and therefore it takes a diversion and continues its downward course.. This is responsible for the formation of deposits known as placer deposits.

By virtue of its relatively weak condition the river compulsorily undergoes a number of curves or bends which makes its path zig-zag. These bends are called meanders and the phenomenon is known as Meandering. Meandering is therefore a characteristic feature of the mature stage.

In due course of time these bends become more and more acute due to deposition of sediments along the inner curve and erosion along the outer curve. Ultimately under favourable conditions such as floods, these loops are cut off from the main course of the river. Such cut off bodies of water which are



curved in plan are called **cut off lakes** or **horse shoe lakes** or **ox bow lakes**.

Delta: A delta is a landform that is formed at the mouth of a river where the river flows into an ocean, or sea. Deltas are formed from the deposition of the sediment carried by the river as the flow leaves the mouth of the river. Over long periods of time, this deposition builds the characteristic geographic pattern of river delta.

Development of delta: The favourable conditions for the formation of delta are:

1. The river should have large amount of load.
2. The river should have totally exhausted its energy at the time of its merger with the sea.
3. The oceans at the mouth of the river should not be turbulent otherwise as & when loose sediments are deposited they are washed away by the waves and currents of the sea.

During delta formation the prevailing conditions will be such that the river will be shallow and will change its direction and velocity frequently. Under such conditions deltas develop a typical structure known as **cross bedding**.

The delta will have gently incline bottom layers of fine sediments known as bottom set beds. These are overlain by steeply inclined middle layers of coarse sediments known as forest beds. Above these again gently dipping layers of the mixture of finer and coarser sediments occur. They are known as top set beds. Though all these three sets of beds are inclined towards the sea, they differ

in the amount of inclination and hence they are not parallel. Such a peculiar bedding phenomenon is known as cross bedding.

VALLEY DEVELOPMENT

VALLEYS: In geology, a valley is a depression with predominant extent in one direction. A very deep river valley may be called a **canyon or gorge**. The terms U-shaped and V-shaped are descriptive terms of geography to characterize the form of valley. Most valleys belong to one of these two main types or a mixture of them, at least with respect of the cross section of the slopes or hills.

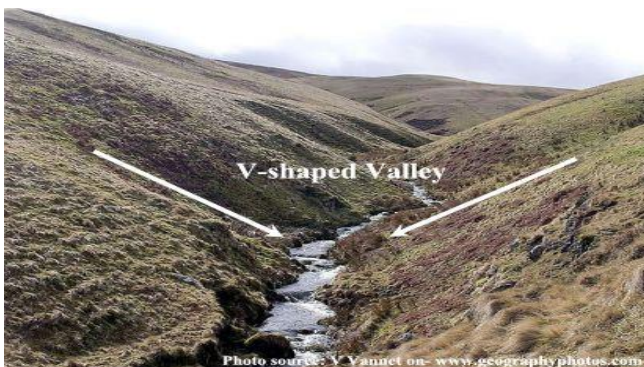
FORMATION AND DEVELOPMENT: A valley is an extended depression in the Earth's surface that is usually bounded by hills or mountains and is normally occupied by a river or stream.

Valleys are one of the most common landforms on the Earth and they are formed through erosion or the gradual wearing down of the land by wind and water. In river valleys for example, the river acts as an erosional agent by grinding down the rock or soil and creating a valley. The shape of valleys varies but they are typically steep-sided canyons or broad plains, however their form depends on what is eroding it, the slope of the land, the type of rock or soil and the amount of time the land has been eroded.

There are three common types of valleys which include V-shaped valleys, U-shaped valleys and flat floored valleys.

V-SHAPED VALLEYS/ RIVER VALLEYS: A V-shaped valley, sometimes called a river valley, is a narrow valley with steeply sloped sides that appear similar to the letter "V" from a cross-section. They are formed by strong streams, which over time have cut down into the rock through a process called down cutting. These valleys form in mountainous and/or highland areas with streams in their "youthful" stage. At this stage, streams flow rapidly down.

- An example of a V-shaped valley is the Grand Canyon in the Southwestern United States. After millions of years of erosion, the Colorado River cut through rock of the Colorado Plateau and formed a steep sided canyon V-shaped canyon known today as the Grand Canyon.
- The original natural large river valleys of the world such as Nile, Ganges, Amazon, Mississippi etc.



U-SHAPED VALLEYS/ GLACIAL VALLEYS: A U-shaped valley is a valley with a profile similar to the letter "U." They are characterized by steep sides that curve in at the base of the valley wall. They also have broad, flat valley floors. U-shaped valleys are formed by glacial erosion. U-shaped valleys are found in areas with high elevation and in high latitudes, where the most glaciation has occurred. Large glaciers that have formed in high latitudes are called continental glaciers or ice sheets, while those forming in mountain ranges are called alpine or mountain glaciers.

Due to their large size and weight, glaciers are able to completely alter topography. This is because they flowed down pre-existing river or V-shaped valleys during the last glaciations and caused the bottom of the "V" to level out into a "U" shape as the ice erode the valley walls, resulting in a wider, deeper valley. For this reason, U-shaped valleys are sometimes referred to as glacial troughs.

One of the world's most famous U-shaped valleys is Yosemite Valley in California. It has a broad plain that now consists of the Merced River along with granite walls that were eroded by glaciers during the last glaciations.

FLAT FLOORED VALLEYS: The third type of valley is called a flat-floored valley and are formed by streams, but they are no longer in their youthful stage, and are instead considered mature. The valley floor gets wider, because of the stream gradient



(moderate or low), the river begins to erode the bank of its channel instead of valley walls.

Over time, the stream continues to meander and erode the valley's soil, widening it further. With flood events, the material that is eroded and carried in the stream is deposited which builds up the floodplain of the valley. During this process, the shape of the valley changes from a V or U shaped valley into one with a broad flat valley floor. An example of a flat-floored valley is the Nile River Valley.



WEATHERING

The rock breaks and undergoes decay under the influence of the atmospheric agencies like wind, sun, frost, water and organisms, and produce soil. This phenomenon is called weathering.

(or)

Weathering is a process involving disintegration and decomposition of rocks.

- i. "disintegration" or physical breaking and
- ii. 'decomposition' or chemical decay. In nature these two processes work simultaneously.

Erosion:- 'Erosion' is a process which includes the destruction of existing rocks and removal of the product from the site of destruction. Transport is the important aspect of erosion it is usually done by water, wind or ice.

Denudation:- The combined effect of weathering and erosion is called 'denudation'.

1. Physical (or) Mechanical Weathering :-

In Physical Weathering a rock breaks into smaller pieces without any chemical change. The Principal agents of physical weathering are

- (i) Frost,
- (ii) Heating and cooling,
- (iii) Organisms.

(i) **Frost:-** When water freezes, it expands about 9 percent of its volume. In nature water enters into cracks of rocks. Upon freezing it expands and exerts great pressure on the walls of cracks. As a result, the rock breaks into pieces. This process is called "frost wedging".

(ii) **Heating and cooling :-** Heating a rock causes it to expand and cooling causes it to contract. The repeated expansion and contraction tend to develop cracks in rocks. In desert areas the coarse

grained rocks like granite, disintegrate soon into their constituent crystals and become desert sands as a result of temperature variation.

- (iii) **Organisms:-** Plants, animals and men play an important part in the disintegration of rocks. Plant roots grow into rock joints. As the roots grow thicker, they exert mechanical pressure and wedge the rock apart. Men also break rocks by making road cuts, tunneling, quarrying, mining and cultivating the land.

2. Chemical Weathering

Chemical weathering or decomposition is a process in which rocks are broken down by chemical decay of minerals. The Principal agents of chemical weathering are (i) water and (ii) Organisms.

(i) Water:

Water is the main agent of chemical weathering. Although water in pure form is inactive, it becomes a powerful chemical agent when a small amount of oxygen and carbon dioxide are dissolved in it. Rain water usually contains these gases. The main reactions involved in the chemical weathering are

- (a) Oxidation
- (b) Hydration
- (c) Carbonation
- (d) Solution.

- (a) **Oxidation :-** The oxygen present in the water in dissolved state oxidizes some minerals. Mafic minerals like

pyroxenes, amphiboles and olivines contain some iron. During weathering the oxygen unites with the iron producing insoluble iron oxides. Limonite and hematite are the common products of oxidation which impart red and yellow colours to soils.

- (b) **Hydration:-** In hydration water molecules combine chemically with minerals to produce new compounds. The formation of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) from anhydrite (CaSO_4) is a good example of hydration. Carbonation frequently operates along with hydration. The orthoclase feldspar, a mineral which is abundant in granite, is decomposed and converted into kaolin by hydration and carbonation.

- (c) **Carbonation:-** In case of carbonate rocks such as limestone, dolomite, marble. When the river water traverses in these rocks, carbonates are dissolved, resulting in the reduction of their sizes. Surface water contains O_2 and its combination with water results in the formation of carbonic acid. Production of carbonic acid lowers the pH, resulting in the attack of some of the minerals which are present in the rocks.

- (d) **Solution:-** The Process of solution and carbonation goes on together. The limestones, dolomites, rock salt, and gypsum are particularly susceptible to solution when they are attacked by water containing carbon dioxide.



(ii) Organisms:-

Many dead organisms produce organic acids as they decay. These acids increase the solvent power water. For example, the solubility of silica, alumina and iron is much greater in the presence of organic acids.

3. Biological Weathering:-

Involves breakdown of rocks by living organisms (Bacteria & Fungi). Living organisms release organic acids viz., oxalic acid, Phenolic acid, Folic acid, Acetic Acid, Humic acid etc. which cause decomposition of rocks. Some of the microorganisms penetrate into mineral crystals and remove specific ions from the inter layers.

Eg: removal of K^+ from mica layers by fungi is an example of this type.

Weathering Effect Over the Properties of Minerals & Rocks :-

- Weathered minerals exhibit change in color intensity or different colors.
- They will be less compact, and hence their specific gravity will be less.
- Their hardness will decrease so that the minerals become softer and weak.
- They become less transparent or tend to become opaque.
- The minerals lose their original shine and exhibit a due luster.
- Weathered minerals loose their internal cohesion & become easily powdered.
- Weathered rocks usually appear as brown, red & yellow colors on the surface.