2

EARTH'S INTERIOR AND ITS MATERIAL

The earth is the only known planet with developed life in the universe. Like most of the celestial bodies, the earth is spherical in shape. You also know that hot water and molten lava eject out from the earth's interior. This indicates that the temperature below the earth's surface is very high. World's deepest mining is limited only to the depth of less than 5 kilometers. These activities can be explained by getting a better understanding of Earth's interior. As we know that the land features seldom retain any fixed form. Their shape is constantly changing. One group of exogenetic forces includes those which weaken and disintegrate the rocks at their original location. The second group consists of indogenetic forces which remove the disintegrated rocks from high lands and deposit them in the Low lands. These two processes have been responsible for disintegrating rocks and shaping new landforms. They are also partly responsible for the formation of soil, which is very important for us.

In this lesson, we will study about the earth's interior and the materials that form the upper portion of the earth's crust. You will also learn about, weathering and its types, the process of gradation and the significance and formation of soils.

OBJECTIVES

After studying this lesson, you will be able to:

- explain the limitations of direct observations of the earth's interior;
- compare the different layers of the earth's interior with reference to thickness, temperature, density and pressure;
- distinguish between rock and mineral;

- classify rocks according to their mode of formation;
- describe the economic significance of rocks;
- explain the term weathering and describe its types with suitable examples;
- explain the various gradational processes changing the face of the land;
- differentiate between degradation and aggradations;
- relate weathering with soil formation and
- explain the various factors contributing to soil formation;

2.1 EARTH'S INTERIOR

It is not possible to know about the earth's interior by direct observations because of its huge size and the changing nature of its internal composition. Through mining and drilling operations we have been able to observe the earth's interior directly only up to a depth of few kilometers. The rapid increase in temperature below the earth's surface is mainly responsible for setting a limit to direct observation inside the earth. The temperature in the earth's interior is so high that it can even melt any tool used for drilling. This fact also restricts deep drilling, thus causing hindrance to direct observation of the materials of the earth's interior.

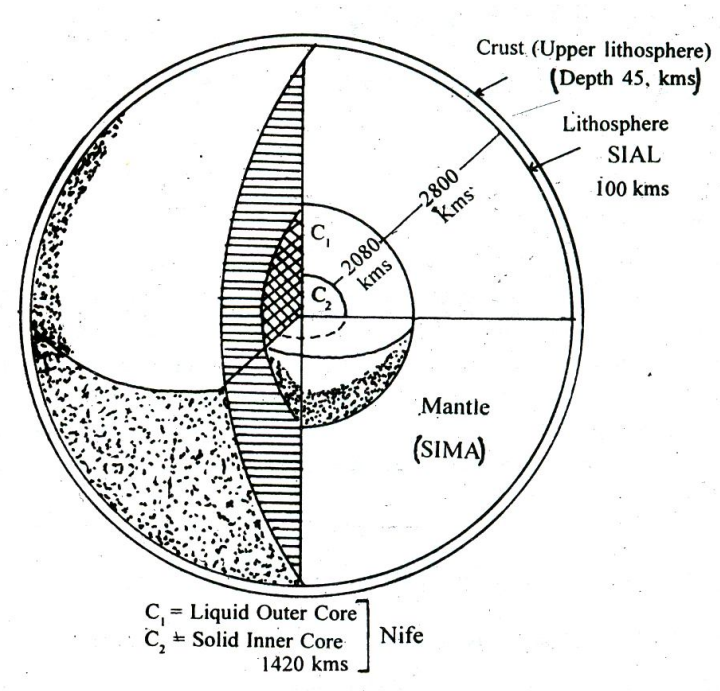


Fig. 2.1 Concentric Zones showing layers of the Earth's interior

The huge size of the earth and increasing temperature with depth has set a limit to direct observation of the earth's interior.

2.2 STRUCTURE OF THE EARTH'S INTERIOR

The above diagram (see fig. 2.1) shows the concentric layers of the earth's interior. The innermost layer surrounding the earth's centre is called core, which is about 3500 kms in radius. Core is the most dense layer of the earth with its density range from 9.5 to 14.5 and sometimes even higher. It is composed mainly of the iron and nickel thus commonly known as **Nife**. (Nickel+Ferrum). Core consists of two sub-layers. The inner one is solid (C_2 of fig. 2.1) and the outer one is semi-liquid (C_1 of fig. 2.1). The layer surrounding the core is known as mantle, a rock shell about 2900 kms thick and is composed of basic silicates. Major constituent elements of mantle are magnesium and silicon, hence, this layer is termed as **Sima** (Silica+Magnesium). The density of this layer varies from 3.3 to 5.7. Mantle is surrounded by the outermost layer of the earth, known as lithosphere and its density varies from 2.70 to 2.95. Major constituent elements of lithosphere are silica (Si) and aluminium (Al), thus this layer is termed as Sial (Silica+Aluminium). The outermost part of the lithosphere in known as crust, normally about 8 to 40 kms thick.

- Core, mantle and crust are the three main concentric layers of the earth's interior.
- Core is the innermost layer and has the highest density. It is made up mainly of nickel and iron.
- Mantle is the layer lying between the core and lithosphere. Its major constituents are silicon and magnesium.
- Crust is the outermost layer of the earth and is mainly composed of silicon and aluminium.

INTEXT QUESTIONS 2.1

1. Give the most important factor limiting direct observation of the earths interior to a few kilometers

   _____

2. Name the three layers of the earth's

   (a)_____(b) _____(c) _____

3. Name the innermost layer of the earth.

   _____

4. What is the density of the core?

   _____

5. Which layer includes the earth's crust?

6. Name the thinnest layer of the earth

2.3 TEMPERATURE, PRESSURE AND DENSITY OF THE EARTH'S INTERIOR

Temperature

Rise in temperature with increase in depth is observed in mines and deep wells. These evidences along with molten lava erupted from the earth's interior, support that temperature increases towards the centre of the earth. The different observations show that the rate of increase of temperature is not uniform from the surface towards the earth's centre.

It is faster at some places than at others. In the beginning this increase is at an average rate of 1^0C for every 32 metres increase in depth. At such a constant rate of increase in temperature, at 10 km depth, the temperature will be approximately 300^0C and at 40 km depth it will be 1200^0C. At this rate, earth's interior should be in a molten state. Yet it is not so because the rocks buried under the pressure of several km thickness of overlying rocks melt at higher temperature than similar rocks at the surface. A basaltic lava rock which melts at 1250^0C at the surface will melt at 1400^0C at 32 km depth. The extra heat required for melting is produced by radioactivity. It is the result of breakdown of atomic nuclei of minerals emitting radiant energy in the form of heat from the rocks. .

The behaviour of earthquake waves is another evidence for this phenomenon. They further confirm that the composition of different layers is as variable as is the rate of change of temperature. While in the upper 100 km, the increase in temperature is at the rate of 12°C per km, in the next 300 km it is 20°C per km but is only 10^0C per km below it. Thus the rate of increase of temperature beneath the surface decreases towards the centre. The temperature at the centre is estimated to lie somewhere between 3000°C and 5000^0C.Such a high temperature inside the earth may be due to chemical reactions under high pressure conditions and disintegration of radio active elements.

Pressure

The pressure also increases from the surface towards the centre of the earth due to huge weight of the overlying rocks. Therefore in deeper portions, the pressure is tremendously high. The pressure near the centre is considered to be 3 to 4 million times the pressure of atmosphere at sea level. At high temperature, the material beneath will melt towards the central part of the earth. This molten material under tremendous pressure conditions acquires the property of a solid and is probably in a plastic state.

Density

Due to increase in pressure and presence of heavier materials towards the earth's centers, the density of earth's layers also goes on increasing. Obviously the materials of the innermost part of the earth are very dense as already stated.

INTEXT QUESTIONS 2.2

1. What is the temperature at the centre of the earth?

   _____

2. How much is the pressure at the earth's centre?

   _____

3. Why does the density increase towards the centre of the earth?

   _____

2.4 MATERIALS OF THE EARTH'S CRUST

The outermost part of lithosphere is called crust. This is the most significant part of the earth because it is occupied by humans. The material of the crust is made up of rocks. The rocks are of different types. They are hard like granite, soft like clay and loose like gravel. Rocks have a great variety of colour, weight and hardness.

Rocks are composed of minerals. They are aggregates or physical mixture of one or more minerals. Minerals on the other hand are made up of two or more elements in a definite ratio. They have a definite chemical composition. Crust is made up of more than 2000 minerals, but out of these, 6 are the most abundant and contribute the maximum to this uppermost part of the earth. These are feldspar, quartz, pyroxenes, amphiboles, mica and olivine.

Granite is a rock and its constituent minerals bound together are quartz, feldspar and mica which make it a hard rock. Change in the ratio of these minerals give rise to granites of different colours and hardness. The minerals containing metals are called metallic minerals. Haematite, a major iron ore is a metallic mineral. Ores are metallic minerals which can be profitably mined. Rocks are of immense economic importance to us.

2.5 TYPES OF ROCKS

Rocks differ in their properties, size of particles and mode of formation. On the basis of mode of formation rocks may be grouped into three types:

(a) Igneous

(b) Sedimentary and

(c) Metamorphic

Igneous Rocks

The word igneous is derived from the Latin word 'ignis' meaning fire. Igneous

rocks are formed by the cooling of highly heated molten fluid material, known as magma. The word magma is derived from a Greek word which means 'dough'. It requires a greater quantity of heat to melt the rocks under overlying pressure than at the surface. We do not know the exact depths at which magma forms but probably it is formed at different depths not exceeding 40 km. Molten rocks produce an increase in volume which is responsible for causing fractures or cracks in the crust. The overlying pressure gets weakened along these openings, thus forcing out the magma through them. Otherwise it can't escape due to great overlying pressure.

When magma is ejected to the surface, it is called lava. Igneous rocks are formed from solidified molten magma below or on the earth's surface. As they comprise the earth's first crust and all other rocks are derived from them, these are called the parent of all rocks or the 'primary rocks'. In simple words, all rocks can be described as of igneous origin because at one time or another, they were erupted to the surface: A younger series of igneous rocks is still being formed. About 95% of the volume of outermost 16 km of the earth is composed of them. These are largely hard and massive because of their magmatic origin and are crystalline in appearances.

On the basis of their mode of occurrence, igneous rocks can be classified as : extrusive or volcanic rocks and intrusive rocks.

(i) Extrusive igneous rocks are formed by cooling of lava on the earth's surface. As lava cools very rapidly on coming out of the hot interior of the earth, the mineral crystals forming these rocks are very fine. These rocks are also called volcanic rocks. Gabbro and basalt are very common examples of such rocks. These rocks are found in volcanic areas. Deccan plateau's regur soil in India is derived from lava.

(ii) Intrusive igneous rocks are formed when magma solidifies below the earth's surface. The rate of cooling below the earth' s surface is very slow which gives rise to formation of large crystals in the rocks. Deep seated intrusive rocks are termed as plutonic rocks and shallow depth intrusive rocks are termed as hypabyssal. Granite and dolerite are common examples of intrusive rocks. From this point of view, therefore, igneous rocks can, in accordance with their mode of formation, be classified as (a) Plutonic, (b) Hypabyssal and (c) Volcanic rockmasses. The huge blocks of coarse granitic rocks are found both in the Himalaya and the Decean Plateau.

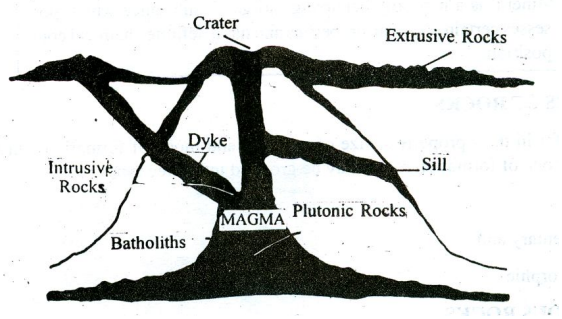


Fig. 2.2 Igneous Rocks

Let us look at the Fig. 2.2. It illustrates that magma, on cooling, produces rocks of different shapes and sizes, depending on the space available after it forces itself into the crust. Common forms of instrusive igneous rocks are batholiths, sills and dykes etc. Batholiths are huge masses of solidified magma. They vary in size; some are as much as several hundred kilometers across and thousands of kilometers thick. They generally form the core of the major mountains, as shown in this diagram. Their irregular dome shaped roofs sometimes appear on the surface after erosion of millions of years. *Sill* is the horizontal intrusion of solidified magma between the layers of pre-existing rocks. *Dyke* is similarly a more or less vertical formation from few metres to several kilometers in length and from few centimeter to hundreds of metres in thickness.

On the basis of chemical properties, igneous rocks are classified into acidic and basic rocks. These are formed as a result of solidification of acidic or basic lava. Acidic igneous rocks are composed of 65% or more of silica. These rocks are light coloured, hard and very strong. Granite is an example of an acidic rock. Basic igneous rocks contain less than 55% of silica and have more of iron and magnesium. These rocks are dark coloured and weak enough for weathering. Gabbro, basalt and dolerite are examples of basic rocks.

- Igneous rocks are formed by the solidification of hot molten material called magma or lava.
- Extrusive igneous rocks are formed by cooling of lava on the earth's surface e.g. basalt, gabbro.
- Instrusive igneous rocks are formed by solidification of magma below the earth's surface, e.g. granite.

INTEXT QUESTIONS 2.3

1. Define the term mineral.

   _____

2. Give the names of any three minerals which are found extensively on the earth's crust.

   _____

3. Give a term for each of the following

   (i) Deep seated intrusive igneous rock.

   _____

   (ii) A hot sticky molten materia1 erupted on the earth's surface.

   _____

4. How are dykes and sills formed?

   (i) _____

   (ii) _____

5. Tick (√) the correct answer

   (i) Igneous rocks are formed due to

   (a) cooling (b) heating (c) neither cooling nor heating

   (ii) Which one of the following is an example of intrusive igenous rock?

   (a) Granite (b) Basalt (c) Gabbro

   (iii) Primary rocks are the result of

   (a) sedimentation (b) solidification (c) metamorphism

Sedimentary Rocks

These rocks are formed by successive deposition of sediments. These sediments may be the debris eroded from any previously existing rock which may be igneous rock, metamorphic or old sedimentary rock. Sedimentary rocks have layered or stratified structure. The thickness of strata varies from few millimeters to several metres. So these rocks are also called stratified rocks. Generally, these rocks have some type of fossil between their strata. Fossil is the solid part or an impression of a prehistoric animal or plant embedded in strata of sedimentary rocks. Sedimentary rocks are widely spread on the earth surface but to a shallow depth.

The individual rock particles are first broken from rocks and then transported by running water, ocean currents, glaciers or even by wind from one place to another. The process by which rock forming material is laid down is called sedimentation or deposition. It may settle in calmer waters of lakes or oceans or at places where the transporting agent has no longer enough energy to carry them farther. These are identified as riverine, lacustrine (formed by lake), glacial or aeolian (formed by wind) sedimentary rocks with reference to their deposition near rivers, lakes, glacier or deserts respectively.

The sediments are often loose, unconsolidated, soft rock material, in the beginning like sand and clay, but in course of time they get hardened to a compact material by excessive pressure and cementation to form sedimentary rocks. The deposition of sediments in the beginning is generally horizontal but it may get tilted afterwards due to movements in the earth's crust. Sandstone, shale, limestone and dolomite are examples of sedimentary rocks.

Sediments get sorted by the transporting agents. Sediments of different sizes may get bound by cementing material under suitable conditions. Conglomerate is an

example of such a sedimentary rock. This type of formation of consolidated material is termed as mechanically formed sedimentary rock. The consolidation of organic matter derived from plants and animals forms sedimentary rocks of organic origin. Coal and limestone are organic sedimentary rocks. The sediments may also result from chemical reaction. Direct precipitation of minerals from their solution in water may give rise to sedimentary rocks of chemical origin. Gypsum, rock salt and nitre are examples of such sedimentary rocks.

Huge folded mountains of the world like Himalayas, Andes etc. are made up of sedimentary rocks. All the alluvial deposits of the world are also due to sedimentary accumulations. All river basins, particularly their plains and deltas, e.g. Indo-Gangetic plain and Ganga-Brahmaputra delta are good examples of sedimentary accumulations.

- Sedimentary rocks are formed by the successive deposition of sediments.
- These rocks have layered structure, therefore they are also known as stratified rocks.
- Fossil is the solid part or an impression of a prehistoric animal or plant embedded in sedimentary rocks in which they are buried.

Metamorphic Rocks

Most rocks in mountainous regions show an evidence of change. All these in course of time become metamorphic or changed forms of rocks. Metamorphic rocks are formed under the influence of heat or pressure on sedimentary or igneous rocks. Tremendous pressure and high temperature change the colour, hardness, structure and composition of all types of pre-existing rocks. The process which bring about the change is known as Metamorphism and the ultimate products, formed due to operation of such processes are defined as the Metamrphic rocks.

Temperature, pressure stress and access of chemically reactive substances are the main agents, which are responsible for metamorphism. Heat causes the minerals to recrystallise in the rock. The process of change by heat is called thermal or contact metamorphism. When molten magma or lava comes in contact with surrounding rocks, it bakes them and changes them into metamorphic rocks. Similarly the formation of metamorphic rocks due to tremendous pressure is known as dynamic or regional metamorphism. Slate, gneiss, schist, marble and diamond are good examples of metamorphic rocks. Metamorphic rocks are hard and tough in comparison to the parent rocks from which they are formed. Examples of metamorphic rocks are given in the table 2.1 with their parent rock from which they have been formed.

Table 2.1

Parent Rock and its Metamorphic Changed Form

NAME OF THE ROCK	TYPE OF ROCK	NAME OF THE METAMORPHIC ROCK
Limestone	Sedimentary Rock	Marble
Dolomite	Sedimentary Rock	Marble
Sandstone	Sedimentary Rock	Quartzite
Shale	Sedimentary Rock	Slate
Slate	Metamorphic Rock	Phylite/Schist
Coal	Sedimentary Rock	Graphite/Diamond
Granite	Igneous Rock	Gneiss
Phyllite	Metamorphic Rock	Schist

Different types of metamorphic rocks are found all over the world. In India, marble is found in Rajasthan, Bihar and Madhya Pradesh, whereas slates are available in plenty in Orissa, Andhra Pradesh and Haryana. In Kangra and Kumaun regions of Himalaya, slates of different colours are found.

- Metamorphic rocks are formed by the effect of heat or pressure on sedimentary or igneous or even metamorphic rocks.
- Thermal metamorphism is the process by which a rock under-goes change as a result of great heat.
- Dynamic metamorphism is the modification of rock, by tremendous pressure during extensive earth movements.

2.6 ECONOMIC SIGNIFICANCE OF ROCKS

Man has been interacting with the surface of the earth since long. With time and advancement in technology he is making different uses of rocks and minerals. The importance of rocks is given below:

(a) **Soils:** Soils are derived from rocks. Soils provide suitability for that agricultural products that provide food for mention and provide raw material for many industries.

(b) **Building Material:** Rocks are the source of types of building material directly or indirectly. Granite, gneiss, sandstone, marble and slates are extensively used in the construction of buildings. Tajmahal is made of white marble, Red Forts of Delhi and Agra, are made of red sandstone. Slates are used for roof purposes in different parts of India.

(c) **Mineral Source:** Minerals are the foundation of the modern civilization. Metallic minerals provide all metals ranging from very precious gold, plati-

num, silver, copper to aluminium and iron. These metals are obtained from different rocks.

(d) **Raw Material:** Certain rocks and minerals are used as raw material for many industries. In cement industry and limestone kilns different type of rocks and minerals are used for production of finished goods. Graphite is used in crucible and pencil manufacturing as raw materials.

(e) **Precious Stones:** Precious stones and metals are obtained from different metamorphic or igneous rocks. Diamond is a precious stone used in jewelry and is a metamorphic rock. Similarly other precious stones like gems, rubies and sapphires are obtained from different type of rocks.

(f) **Fuel:** Fuel in the form of coal, petroleum, natural gas and nuclear minerals are derived from different rocks.

(g) **Fertilizer:** Fertilizers are also derived from some rocks. Phosphatic fertilizers are obtained from phosphorite mineral found in abundance in some parts of the world.

- Rocks and minerals are the main source of all metals, precious stones, solid fuel and raw materials for industries.

INTEXT QUESTIOS 2.4

1. What are rocks?

_____

2. Classify rocks.

_____

3. Give single term for each of the following

   (i) Process of the formation of metamorphic rock due to pressure.

   _____

   (ii) Rocks which contain strata.

   _____

   (iii) Rocks formed by the effect of heat or pressure on sedimentary or igneous rocks.

   _____

   (iv) Sedimentary rocks deposited in lakes

   _____

4. Tick (√) the correct answer;

   (i) Marble is

(a) a sedimentary rock (b) an igneous rock (c) a metamorphic rock (d) a plutonic rock

(ii) An example of sedimentary rock is

(a) granite (b) marble (c) sandstone (d) basalt

2.7 WHAT IS WEATHERING?

Weathering is the general term applied to the combined action of all processes that cause rock to disintegrate physically and decompose chemically because of exposure near the Earth's surface through the elements of weather. Among these elements temperature, rainfall, frost, fog and ice are the important ones. Weathering begins as soon as rocks come in contact with one or more than one elements of weather on the surface of the earth. In nature, generally both the disintegration and decomposition act together at the sametime and assist each other. We must remember that the weathered material (i.e. disintegrated and decomposed) lie in situ (i.e. at its original position). In this process no transportation or movement of material is involved other than its falling down under the force of gravity.

- Weathering is the process by which exposed rocks are disintegrated and decomposed in situ (i.e their original position).

2.8 TYPES OF WEATHERING

We can recognize three types of weathering?

1. Physical Weathering
2. Chemcial weathering
3. Biotic weathering

PHYSICAL WEATHERING

When the rocks are broken up into smaller fragments without any chemical change in their composition, it is called physical weathering. The term mechanical weathering is also used for physical weathering.

Physical weathering takes place in different ways in different types of areas. They have been explained here with examples.

(a) Block disintegration

We all know that the successive heating and cooling causes expansion and contraction of the rocks. In hot desert regions, day temperatures are very high while nights are very cold. This high diurnal range of temperature causes successive expansion and contraction of the rocks which tend to enlarge the joints. Finally the rocks disintegrate into smaller blocks. This process is known as block disintegration.

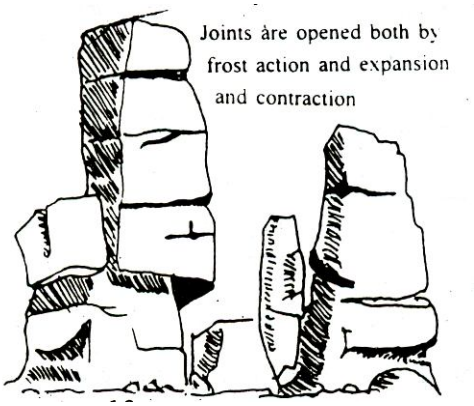


Fig. 2.3: Block Disintegration

(b) Exfoliation

Rocks are generally poor conductors of heat. As a result of intense heating the outer layers of the rock expand rapidly while the inner layers remain almost unaffected by heat. Due to successive expansion and contraction, the outer layer of the rock subsequently peels off from the main mass of the rock in the form of concentric shells. The peeling of rocks in layers by this process is very similar to the peeling of successive layers of an onion. The process is called exfoliation. Almost all rounded forms of dolerite blocks of rocks in Singhbhum district of Bihar are due to this process. Granite domes of Mahabalipuram, particularly *'Krishna Ka Laddu'* and those near Jabalpur on Madan Mahal Hill are good examples, of exfoliation.

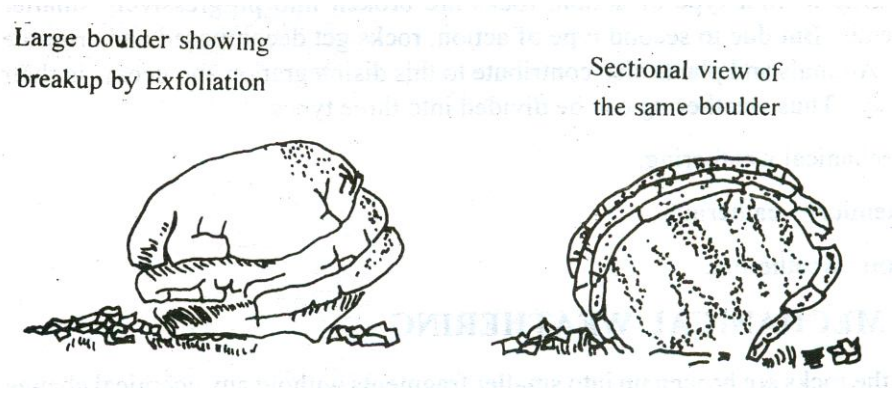


Fig 2.4 Peeling of Layer of the Rock

(c) Frost Action

One of the most important physical weathering processes in cold climates is frost action, the alternate freezing and melting of water inside the joints of the rocks, splits them into fragments. This is because conversion of water into ice increases the volume of water by 10 percent. In cold regions rocks are disintegrated into small particles through this process. It is called frost action.

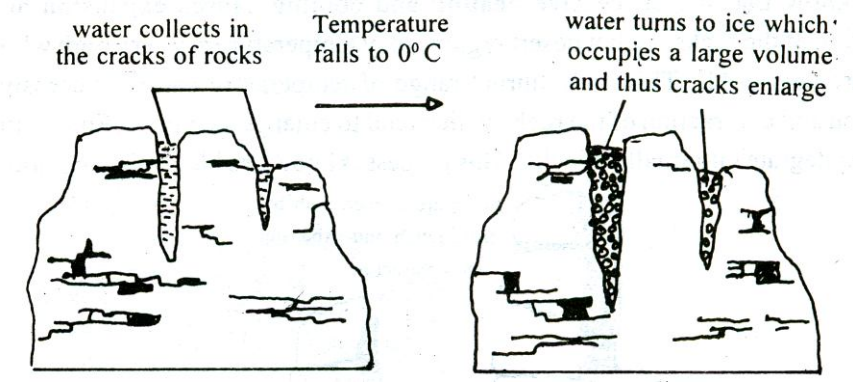


Fig 2.5 Frost Action

- disintegration of rocks into smaller fragments without any change in their chemical composition is called mechanical weathering.
- The rapid heating and cooling of the rocks creates a series of joints and cracks which lends to breaking up into smaller blocks. This process is known as block disintegration.
- A weathering process by which the outer layers of the rock peel out in concentric cells due to difference of temperature in the outer layers is called exfoliation.
- Breaking up of rocks due to freezing of water in the rock joints and cracks, in very cold regions, is called frost action.

INTEXT QUESTIONS 2.5

1. Name three types of weathering.

   (a) _____ (b) _____ (c) _____

2. In which areas is mechanical weathering more pronounced?

   _____

3. Give appropriate technical terms for each of the following statements:

   (a) Peeling of successive layers of rocks like the layers of an onion

   _____

   (b) Widening of joints and cracks due to alternative freezing and melting of water in them

   _____

(c) Disintegration of rocks without any change in their chemical composition

CHEMICAL WEATHERING

Chemical change in the rocks through formation of new compounds or formation of new substances is called chemical weathering. Chemical processes include oxidation, hydrolysis, and acid solution.

- Decomposition of rocks by chemical processes with the help of water and atmospheric gases is called chemical weathering.

Chamical weathering involves four major processes:

(a) Oxidation

This is the process in which atmospheric oxygen reacts with the rock to produce oxides. The process is called oxidation. Greatest impact of this process is observed on ferrous minerals. Oxygen present in humid air reacts with iron grains in the rocks to form a yellow or red oxide of iron. This is called rusting of the iron. Rust decomposes rocks completely with passage of time.

(b) Carbonation

This is the process by which various types of carbonates are formed. Some of these carbonates are soluble in water. For example, when rain water containing carbon dioxide passes through pervious limestone rocks, the rock joints enlarge due to the action of carbonic acid. The joints enlarge in size and lime is removed in solution. This type of breakdown of rocks is called carbonation.

(c) Hydration

This is the process by which water is absorbed by the minerals of the rock. Due to the absorption of water by the rock, its volume increases and the grains lose their shape. Feldspar, for example, is changed into kaolin through hydration. Kaolin on Vindhyan Hills near Jabalpur has been formed in this manner.

(d) Solution

This is the process in which some of the minerals get dissolved in water. They are therefore removed in solution. Rock salt and gypsum are removed by this process.

- Chemical weathering involves the process of oxidation, carbonation, hydration-and solution.

INTEXT QUESTION 2.6

1. In which region is chemical weathering more effective?

_____

2. Which process is involved when gypsum gets dissolved in water?

_____

3. Which process of chemical weathering causes rusting of iron?

_____

4. Which, chemical action is predominant in limestone region?

_____

BIOTIC WEATHERING

Biotic weathering is carried out by plants, animals and man.

(a) Plants

Plants contribute to both mechanical and chemical weathering. The roots of the plants penetrate into the joints of the rocks. They grow longer and thicker. In this manner they exert pressure on the rocks and the rock joints are thereby enlarged and break into smaller fragments.

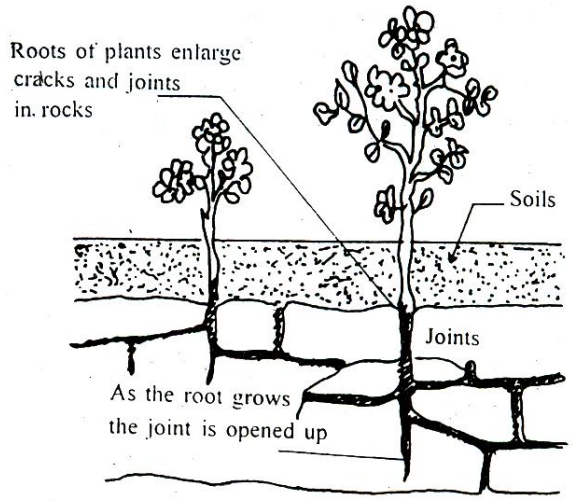


Fig. 2.6 Effect of Vegetation on Rocks

(b) Animals

Burrowing animals like earthworms, rats, rabbits, termites and ants break-down the rocks. These disintegrated rocks can easily be eroded or removed

by wind etc. Hooves of animals break the soil and thus assist soil erosion. The role of earthworms and termites is of special significance. According to scientists, there is a possibility of occurrence of about 1,50,000 earthworms in an acre and they can convert 10 to 15 tonnes of rock mass into good soil and bring it to the surface.

(c) Man

Human beings play a very important role in weathering of various rocks. Man breaks a large amount of rocks in the course of his activities, like agriculture, construction of houses, roads etc. He quarries for mining minerals, thus helps in weathering by breaking, weakening and loosening the rocks.

- Biotic agents like plants, animals and man also contribute to physical and chemical weathering.

INTEXT QUESTIONS 2.7

1. Which important matter is formed by weathering?

   (a) _____(b)_____(c)_____

2. Where does humus in soils come from?

   _____

3. Give examples of two activities of man helping in weathering.

   (a) _____(b)_____(c)_____

2.9 WEATHERING AND SOIL

We have studied the process of weathering and have learnt how different types of land features are produced in areas of different types of climate through this process. Weathering also plays an important role in formation of soil which provides basis for agriculture and world's food supply.

Mechanical weathering of the surface rocks disintegrates the rock and converts it into a fine powder. These small particles are deposited in layers with the help of water. biotic weathering produces humus. This organic matter is formed through the action of plants and animals which helps in the formation of soil. Various processes of weathering help in giving different colours and properties of soil.

- The process of weathering contributes significantly to soil formation besides disintegrated of rocks.

2.10 GRADATION

Exogenetic forces are constantly working to bring about leveling or the gradation of land. They attempt to achieve a condition of balance between erosion and deposition which mean a graded position. The above forces operate through the process called the process of gradation. Agents of gradation like rivers, glaciers winds, sea waves and underground water perform their task with the help of the triple action of weathering, erosion and deposition. The leveling down of elevated portions of the earth's surface is done by erosion. The filling up of depressions is done by deposition of the eroded material transported by the external agents of gradation as spoken earlier.

We have studied that the endogenetic forces of the earth give rise to major landforms on the earth surface and the exogenetic forces level them down.

The work of gradation has two components (a) degradation and (b) aggradation.

(a) Degradation

When rocks are removed by scraping, scratching and cutting as a result of the process of erosion, thereby lowering the elevation of the land, it is called degradation. Degradation, first of all includes the work of weathering that is the movement of scarped and scratched material aided by the great force of gravity. It also includes the work of erosion implying the transportation of the rock material by an agent of gradation. The increase in the movement of rock- debris increases both its erosional and transportational capacities.

(b) Aggradation

Filling up of low-lying areas of depression by eroded material is called deposition. Deposition starts when the agents of gradation lose their force or have obstruction in their way. As a result eroded material is deposited in depressions which not only creates new landforms but also modifies the existing ones.

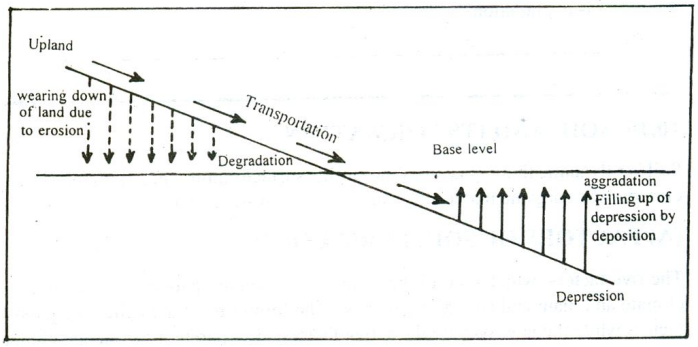


Fig. 2.7 Process of Gradation

Let us now look at the figure. It explains the total process of gradation and its two components-degradation and aggradation. It shows the elevated portions continuously being lowered by weathering and erosion. The debris consisting of the eroded material is transported and deposited in the low lying areas. The surface of the lower areas on the other hand is raised through deposition of this debris. Finally, the position of a uniform or near uniform level is achieved. The process of gradation is not performed by a single agent. It is rather a result of the work of all agents of gradation acting simultaneously. It is however possible for a single agent of gradation to be more active in particular area or at a particular time.

- Levelling and smoothening of land surface is called gradation includes both degradation and aggradation.
- The weathering of the land surface by erosion is called degradation and raising or filling up of depressions by deposition is called aggradation.

INTEXT QUESTIONS 2.8

1. Which process is involved in the levelling of the earth's surface?

   _____

2. Which two processes constitute gradation?

   (a)_____(b)_____

3. Which term is used for raising or filling up of depressions by depositing?

   _____

4. What is degradation?

   _____

2.11 SOIL AND ITS FORMATION

Soil is the uppermost layer of the land surface that plants use and depend on for nutrients, water and physical support.

(A) FACTORS OF SOIL FORMATION

The five factors, which control the formation of soil are parent rock, relief, time, climate and plant and animal organisms. The former three are called the passive factors while the later two are the active factors. The parent material and climate are the most important because these two affect the other factors.

(a) Parent rock

A soil is derived from the underlying rock or the parent rock material con-

taining different minerals. The parent rock gets broken into tiny pieces and is decomposed slowly by physical and, chemical weathering. It furnishes inorganic mineral particles of the soil. The parent rock also influences the rate of soil formation, the chemical composition, colour, texture, structure, mineral content and fertility.

(b) Relief

Topography of an area affects the degree of erosion of the parent rock material and the rate of surface run off of water. thus, the relief affects directly and indirectly the processes involved in soil formation. Steep slopes are subjected to more rapid run-off of surface water than the gentle slopes. Therefore, there is less infiltration of water on steeper slopes, which retards soil forming processes. In addition, rapid run-off on steep slopes often erodes their surface faster than soil can develop. It is because of this that the mountainous topography develops coarse, thin and infertile soil and the plain areas have rich well developed fertile soils.

(c) Time

The soil forming process is very slow. A well developed soil results as an end product of physical, chemical and biological processes operating collectively for a very long period of time.

(d) Climate

It is by far the most important factor in the sense that over a long period of time it not only tends to reduce the difference caused by the parent material but also influences biological activities within the soil. Due to this factor two different parent materials may develop the same type of soil in one type of climatic region. For example, granite and sandstone have developed into sandy soil in dry Rajasthan desert. On the other hand, two different types of soils may develop from the same parent material in two climatic regions. For example, the crystalline granites have developed laterite soils in monsoon regions and non laterite soils in sub humid regions.

The process of weathering, its effectiveness and the type of plant and animal organisms in a region are directly linked with the seasonal change of temperature and distribution and nature of precipitation. Hence, climate plays an important role in soil forming processes.

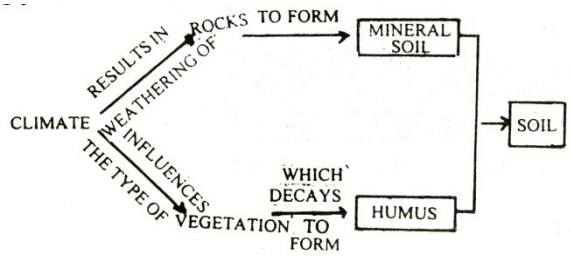


Fig. 2.8 Factors of Soil Formation

(e) Plant and Animal Organisms

Plants and animals play an active role in transforming parent materials into a mature soil. Dead plants and animals contribute to the organic content of the soil. The process of decay, added by bacterial action, transforms organic matter into humus. Humus is responsible for the fertility of the soil. It also enhances water retention capacity of the soil. This organic material helps the soil to support plant life. The plant cover in turn protects rich upper layer of the soil from erosion by increasing the proportion of rainfall entering into the soil rather than running off the surface. It also prevents greater evaporation of soil moisture by its thick canopy, thus allowing soil to mature and become fertile.

- The climate, plant and animal organisms are the active factors of soil formation.
- The parent material, relief and time are the passive factors of soil formation.

(B) SOIL HORIZONS

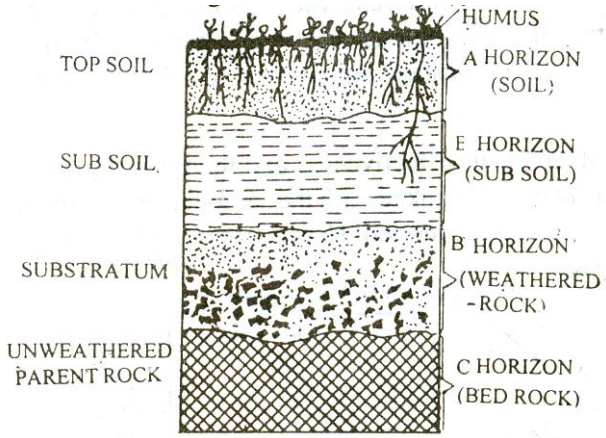


Fig. 2.9: Soil Horizons and Bedrock

A layer of soil which lies more or less parallel to the surface and has fairly distinctive soil properties is known as soil horizon. Soil horizons are distinctive layers found in soils that differ in physical or chemical composition, organic content or structure. The display of horizons on a cross section through the soil is termed as soil profile.

Let's review briefly the main types of horizons and their characteristics.

Four main horizons are important - A,E,B and C. The A horizon is the upper most horizon and rich in organic matter. Next is the E horizon. Clay particles and oxides of aluminum and iron are removed from the E horizon by downward seeping water, leaving behind pure grains of sand or coarse silt. The B horizon receives the clay particles, aluminum and iron oxides, as well as organic matter washed down from the A and E horizons. Beneath the B horizon is the C horizon, which is not considered part of the soil. If consists of the parent mineral matter of the soil.

- Soil profile is the arrangement of the soil into layer like horizons which are physically, chemically and biologically different from each other.

INTEXT QUESTIONS 2.9

1. Name two active factors of soil formation.

   (a)_____(b)_____.

2. Name the three passive factors of soil formation.

   (a)_____(b)_____(c)_____.

3. Fill in the blanks with appropriate word given in the blanks below: (organic material, inorganic mineral particles, biological activities).

   (a) The parent material provides _____ within the soil.

   (b) The climate of a region influence _____ within the soil.

4. Give the Geographical term for each of the following.

   (a) The dynamic, upper layer of earth's crust composed of solid liquid and gaseous substances.

   (b) A vertical arrangement of different layers of soils.

   (c) The horizon of soil rich in humus.

   (d) The horizon of soil ,that accumulates soil colloids.

2.12 SOIL EROSION

The removal of soil at a greater rate than its replacement by natural agencies (water, wind etc.) is known as soil erosion.

(a) Type of Soil Erosion

Soil erosion is of four types: wind erosion, sheet erosion, rill erosion and gully erosion.

(i) Wind Erosion

Winds carry away vast quantity of fine soil particles and sand from deserts and spread it over adjoining cultivated land and thus destroy their fertility. This type of erosion is known as wind erosion. It takes place in and around all desert regions of the world. In India, over one lakh kilometers of land is under Thar Desert, spread over parts of Gujarat, Haryana, Punjab and Rajasthan states. These areas are subject to intense wind erosion.

(ii) Sheet Erosion

Water when moves as a sheet takes away thin layers of soil. This type of erosion is called sheet erosion. Such type of erosion is most common along the river beds and areas affected by floods. In the long run, the soil is completely exhausted due to removal of top soil and becomes infertile.

(iii) Rill Erosion

The removal of surface material usually soil, by the action of running water. The processes create numerous tiny channels (rills) a few centimeters in depth, most of which carry water only during storms.

(iv) Gully Erosion

When water moves as a channel down the slope, it scoops out the soil and forms gullies which gradually multiply and in the long run spread over a wide area. This type of erosion is called gully erosion. The land thus dissected is called bad lands or ravines. In our country, the two rivers Chambal and Yamuna are famous for their ravines in U.P. and M.P. states.

The controlling factors in the last two types of erosion are the velocity and amount of surface run off, the erodability of the soil, nature of slope, the texture and structure of the soil, nature of precipitation and vegetation cover. The speed and frequency of winds or dust storms and vegetation cover are the controlling factors in wind erosion. Seawaves are responsible for eroding soils along the coasts formed by weak rocks such as limestone etc. This type of erosion is wide spread along Kerala coasts. Substantial soil erosion is also caused by changing river channels and snowfall specially in river basins and hilly regions.

- The removal of soil material naturally or by human action is called soil erosion.
- Soil erosion is of four types : wind erosion, sheet erosion, rill erosion, gully erosion.
- Factors influencing soil erosion are velocity and amount of surface run off, nature of slope, texture and structure of soils and frequency and speed of winds.

2.13 SOIL CONSERVATION

Soil is one of the most important natural resources, which sustains different types of lives directly or indirectly. Moreover, soil forming is a slow natural process. The process of soil erosion not only destroys this wonderful gift of nature in a shorter span of time, It creates new problems like floods, damage to roads and rail bridges, hydro electric projects, water supply and pumping stations.

Soil conservation constitutes those methods which prevent soil from being removed. The methods to control soil erosion of different types in different parts of the world are as under:

(a) Protection of forests : Indiscriminate felling of trees in the forests has been one of the major causes of soil erosion. Since roots of the trees hold the soil material together, it is desirable to protect these trees from such felling. This has led governments to declare forests as reserved in which felling of trees has been banned. This method of soil conservation is most suited to all types of landscapes. Forests are also harbinger of rain which increases the process of soil formation.

(b) Afforestation : Planting of trees along river courses, waste lands and mountainous slopes is another method of soil conservation. It reduces excessive erosion taking place in these regions. Afforestation is also effective in controlling wind erosion along the desert regions. Tree plantation along desert boundary stops swallowing of agriculture land by desert sands. In our country large scale planting of trees is being carried out in Rajasthan, Haryana, Gujrat and Punjab to control the extension of Thar Desert.

(c) Flood Control : During rainy season, the amount of water in rivers, increases exceedingly which in turn increases soil erosion. Dams are being constructed to control floods and consequently the soil erosion. This can also be done by diverting river water to dry regions through canals and by other well planned methods of water conservation.

(d) Planned Grazing : Over grazing on hill slopes has helped loosening and washing away of soils in these areas. If grazing is carried out in a planned way it will reduce soil erosion by protecting vegetation cover in these areas which are comparatively more prone to soil erosion.

(e) Bunding: Construction of bunds or obstruction is applied in lands affected by gully erosion. This method is not only helpful in controlling soil erosion but also in maintaining soil fertility, conserving water resources and levelling of sloping lands.

(f) Terracing: To conserve poorly developed thin soils on mountain slopes, terracing is another method. Terracing refers to the construction of terraces across the slope in a mountainous region. This helps in controlling soil erosion and using water resources of these areas economically and effectively for growing different crops on these terraces.

(g) Contour Ploughing : This method of soil conservation is most suited to areas having rolling landscape. Ploughing and tilling of land along the contour levels in order to cause furrows to run across the landslope reduces the rate of soil erosion. This method is also applied to maintain the fertility and soil moisture.

(h) Adoption of Strip Farming: This method is most suited in rolling plains and regions situated in arid and semiarid regions. Field are divided into strips and the fanning in one year is done on one strip while the other strip is left uncultivated. The grassy vegetation cover of the left strip controls soil erosion and maintains fertility of soils. Next year, the process is reversed.

(i) Crop Rotation: Crop rotation refers to a systematic succession of different crops cultivated in a given piece of land in order to avoid exhaustion of the soil. Thus, rotation of crops is applied to conserve the fertility of soil from over cultivation of growing continuous crops from where population pressure is more on limited agricultural lands. This method is applied in most of the countries of the world.

(j) Reclamation of Lands: Soil erosion is also being controlled by levelling lands gullied down by water channels and converted in to waste lands or ravines. This methods of soil conservation is most suited in river basins and hilly terrains. Vast areas have been levelled in Chambal and Yamuna ravines, in our country.

- Soil conservation methods include protection of forests, afforestation, bunding, reclamation of lands; controlling floods, over grazing; terracing, strip farming, contour ploughing and crop rotation.

INTEXT QUESTIONS 2.10

1. Fill in the blanks with the appropriate words given in the brackets:

   (a) The complete removal of soil cover is known as _____ (Gullying, wind, sheet erosion)

   (b) _____is the best suited method of soil conservation in desert outskirts, (strip farming, afforestation, bunding)

   (c) Sheet erosion is mostly caused by _____(foods, rains, deforestation).

2. Give the geographical term for each of the following:

   (a) Removal of soil material naturally or by man's action.

   (b) Removal of soil by water channel.

   (c) Planting of trees in deforested lands.

   (d) Removal of soil by dust storms.

   (e) Tilling of land along the contour levels.

WHAT YOU HAVE LEARNT

Earth is a spherical body. The direct observations into its interior are limited to a depth of a few kilometers. Temperature, pressure and density increase from the earth's surface to its centre. Earth's interior is divided into three concentric layers; Crust, mantle and core. Crust is the thinnest and outermost layer, mantle middle one whereas core is the innermost and the most dense layer of the earth. The material of the crust is composed of rocks. Rock is composed of one or more minerals. Minerals have a definite chemical composition. On the basis of their mode of formation, rocks are classified into three types - igneous, sedimentary and metamorphic. Igneous rocks are formed by the solidification of molten lava or magma. Granite, basalt and gabbro are examples of igneous rocks. Molten material solidified beneath the earth's surface to form intrusive and above the earth surface to form extrusive igneous rocks. Sedimentary rocks are formed by the consolidation of sediments. These are layered and may contain fossils. Shale, limestone and sandstone which are examples of sedimentary rocks. Metamorphic rocks are formed by the effect of heat or pressure on any pre-existing rock. Rocks are of immense use to us. They provide precious metals and stones, building material and fuel etc. for our use.

Landforms undergo a constant change. The exogenetic forces act upon them to make the surface level.

The rocks undergo various types of changes in their own location under the process of weathering. The rocks become weak due to the impact of the weather elements - temperature, moisture, frost etc. They develop cracks and disintegrate into small boulders, pebbles or fine fragments. This is called mechanical weathering. This type of weathering is more pronounced in areas of hot and dry or very cold climates. Rock minerals undergo chemical changes due to the effect of water and gases as a result of oxidation, carbonation, hydration and solution. This is called chemical weathering. This type of weathering is more important in areas of warm and humid climates. Plants, animals, insects and men are the agents of biotic weathering and they contribute to both mechanical and chemical weathering.

Soil is a natural resource of unestimated value to man as he gets his food, clothing and other things directly or indirectly from it. Soil is a thin layer of loose inorganic and decayed organic matter covering the earth's surface. Differente factors such as parent materials, climate, plants and animal organism, water and time along with processes such as mechanical, chemical and biological are responsible in making this valuable resource. Mature soils develop a profile which constitutes four horizons, each having different characteristics.

Soil erosion is a natural process of destruction and removal of soil material from its place. Running water, winds, sea waves and glaciers are the most active agents of

erosion. Erosion of soils takes place in four ways viz., wind erosion, sheet erosion, rill erosion and gully erosion. Removal of soil cover depends on velocity and speed of water, nature of slope, texture and structure of soils, frequency of dust storms and nature of precipitation. Man through his misdeeds, has also helped natural forces in increasing the problem of soil erosion. Methods to prevent soils from being eroded constitute soil conservation. These methods are protection of forests, afforestation, contour ploughing, terrace and strip farming, bunding, flood control, etc.

TERMINAL QUESTIONS

1. What are the limitations of direct methods in the determination of the earth's interior?
2. Draw and label a diagram showing earth's interior and its density and depth of each layer.
3. Distinguish between a rock and a mineral with suitable examples.
4. Discuss the classification of various types of rocks on the basis of their mode of formation. Support your answer with examples.
5. Explain in brief the economic significance of rocks and minerals.
6. Compare the processes of formation of metamorphic and sedimentary rocks.
7. What is weathering? Name the different types of weathering.
8. How does chemical weathering take place?
9. Differentiate between
   (a) Disintegration and Decomposition
   (b) Degradation and Aggradation
   (c) Oxidation and Solution
10. Explain the process of gradation.
11. How does man become an important agent of weathering?
12. Explain the following processes of weathering by drawing simple diagrams:
    (a) Block disintegration
    (b) Frost action
    (c) By plant action
13. Give a brief account of soil profile. Illustrate your answers with a diagram.
14. Discuss various factors responsible for soil formation.

16. What is soil erosion ? Explain the different ways in which soil is eroded. Discuss the various methods being used to conserve soil.

ANSWER TO INTEXT QUESTIONS

2.1

1. Rapid increase of temperature below the earth's surface
2. (a) Lithosphere (b) Mantle (c) Core
3. Core or Nife
4. More than 11.0
5. Lithosphere
6. Lithosphere

2.2

1. 3000^0C to 5000^0C
2. 3 to 4 million times the atmospheric pressure at sea level.
3. Due to immense pressure of overlying rocks and the presence of heavier materials.

2.3

1. Mineral is a naturally occurring inorganic substance which posseses physical properties and has a definite chemical composition. 2. Feldspar /Quartz/ Pyroxenes/Amphiboles/Mica/Olivine 3. (i) Plutonic rocks (ii) Lava 4. (i) When the magma cools in their sheets in vertical fractures within the earth's crust dykes are formed and (ii) when it solidifies in horizontal starta it is called a sill. 5. (i) cooling (ii) Granite (iii) Solidification

2.4

1. Rocks are aggregates of Minerals and are the individual units constituting the crust of the earth. 2. Igneous, Sedimentary and Metamorphic rocks. 3. (i) Dynamic metamorphism (ii) Sedimentary rocks/Stratified rocks (iii) Metamorphic rocks. (iv) Lacustrine 4. (i) a metamorphic rock (ii) Sandstone.

2.5

1. (a) Physical weathering (b) Chemicals weathering (c) Biotic weathering.
2. In dry and very cold regions.
3. (a) Exfoliation (b) Frost action (c) Physical weathering.

2.6

1. In warm and humid regions.
2. Solution

3. Oxidation
4. Carbonation

2.7

1. (a) Plants (b) Animals (c) Man.
2. The cracks in rocks are widened and the rocks are broken.
3. (a) Agriculture (b) Mining

2.8

1. Gradation
2. (a) Degradation or lowering down of raised surfaces.
   (b) Aggradation or raising up of low lying areas.
3. Aggradation.
4. Lowering down of raised portions through erosion of material.

2.9

1. (a) Climate (b) Plant and animal organisms
2. (a) Parent rock (b) relief or topography (c) Time
3. (a) Inorganic mineral particles (b) Biological activities
4. (a) Soil (b) Soil profile
   (c) Top soil (d) zone of weathered parent rock

2.10

1. (a) Sheet erosion (b) Afforestation (c) Floods
2. (a) Soil profile (b) Gully erosion
   (c) Afforestation (d) Wind erosion
   (d) Contour ploughing

HINTS TO TERMINAL QUESTIONS

1. The rapid increase of temperature below the earth's surface. Mining activity restricted to few kilometres. High temperature melts drilling tools.
2. See Fig. 2.1 - Concentric zone showing layers of Earth's interior.
3. Rock is the solid part of the crust composed of minerals. They are aggregates or physical mixture of one or more minerals for e.g. granite. Minerals are inorganic substances made up of one or more elements in a definite ratio, e.g. feldspar. Change in the ratio of minerals gives rise to different rocks.
4. Igneous rocks, sedimentary rocks and metamorphic rocks (give definition of each with examples of each type of rock).
5. See economic significance of rock (para 2.6)

6. Sedimentary rocks are formed due to weathering, erosion and deposition of rock fragments of older rocks which become hard due to compaction, chemical changes or cementation of organic matter, whereas metamorphic rocks are formed due to the pressure and high temperature of the magma when it comes in contact with both igneous and sedimentary rocks.

7. Weathering is a process by which rocks are disintegrated and decomposed in situ. See para 2.7.

8. See para 2.8 under "Chemical weathering".

9. (a) disintegration of rock of physical breaking up or shattering of rock under the influence of temperature or frost action. Decomposition is due to chemical change by which rock minerals break up or get dissolved. Give example of each type.

   (b) See para 2.10 (a) and (b)

   (c) See para 2.8 (a) and (d) under "Chemical Weathering".

10. See para 2.10 (a) and (b) and Fig. 2.7

11. See para 2.8 (c) biotic weathering.

12. See Fig. 2.3, 2.5 and 2.6.

13. Points to be discussed in detail include:

    Meaning of soil profile-refer to 2.11 Section B. Answer is to be illustrated with the help of Fig. 2.9.

14. Points to be elaborated - parent rock, relief, time, climate and plant and animal organism (Active and non-active factors) Importance of each of these points should be highlighted (Refer 2.11 Section A).

15. Soil erosion refer 2.12 Section

    Types of soil erosion - wind erosion, sheet erosion, gully erosion (Refer 2.15 Section)

    Methods to conserve soils - Protection of forests, afforestation, flood control, planned grazing, reclamation of lands, bunding, terracing, contour ploughing, strip farming, crop rotation (Refer to 2.13 Section).

3

DYNAMIC SURFACE OF THE EARTH

In the previous lesson, we have learnt that the interior of the earth is very hot. Earthquakes and volcanoes are concentrated along a few narrow belts. The type and density of rocks of the crust are variable. The surface features are dynamic in character. This dynamism is due to two forces — endogenetic and exogenetic. Endogenetic forces are those which are caused from below the surface. Due to this, an area may get elevated or gets submerged. These forces try to make the surface irregular while exogenetic froces are those which operate from above the surface. They try to eliminate the irregularities of the surface through the process of denudation about which we will be reading in lesson. In this lesson we will be studying about the endogenetic forces.

OBJECTIVES

After studying this lesson, you will be able to :

- define isostasy;
- describe the variation in relief features on the earth's surface;
- explain the isostatic adjustment by various experiments;
- explain the views of Airy and Pratt and distinguish between the ideas of both;
- explain the concept of continental drift;
- enumerate the evidences of continental drift;
- explain the concept of plate tectonics;
- identify and locate different plates on the world map;

- explain the mechanism of plate movement;
- identify various plate boundaries and associated features;
- explain the distribution of land and water on the globe and
- associate earthquakes and volcanoes with plate boundaries.

3.1 CONCEPT OF ISOSTASY

The term "Isostasy" is derived from "Isostasios", a word of Greek language meaning the state of being in balance. You already know and must have seen that the mountain have many peaks and relatively great heights. Similarly plateau and plain have flat surfaces. They have moderate and lower height, respectively. On the contrary oceanic beds and trenches have greater depths. There is a great difference in height among these features. You also know that the earth is rotating while keeping perfect balance among its various features. Thus, our earth is considered to be in isostatic equilibrium.

Example:- Suppose you are holding one stick each in your both hands vertically with varying heights, say 5' and 15' and you are moving in a particular direction. Do you have any difficulty in maintaining a balance in congruence with your body as well as two sticks together? Definitely, smaller stick will be easy to make a balance than the longer one. It is just because of the centre of gravity. The centre of gravity with smaller stick will be nearer to your holding hand in comparasion to the longer stick. In the same way smaller surface features like plains are more stable than the tall mountains.

A. Isosatic Balance: views of Airy

Airy, a geologist, considered the density of different columns (plains, plateaus, mountains, etc.) to be the same. Hence, he proposed the idea of **'uniform density with varying thickness'**. We know that the upper crust of the earth is made up of lighter material. In this layer, silica and aluminium are found in abundance, hence it is known as 'Sial'. It is less denser than the lower one. Airy assumed that the Sialic crust is floating over the Sima (silica and magnesium, lower denser layer). Crustal layer is uniform in terms of density with varying length of columns. Therefore, those columns are projecting down into the asthenosphere depending upon the proportions of the column. It is due to this reason that the root has developed or the sima has been displaced from below.

To prove this concept, Airy took an example of wooden blocks of various sizes and immersed them into water (Figure 3.1). All blocks are of same density. They get immersed differently in proportion to their sizes. In the same way higher features with great height seen on the surface of the earth have deeper roots whereas short in length has shorter roots beneath. It is the concept of root which is sustaining the higher elevation. He is of the openion

that the landmasses are floating like a boat in the substratum (magmatic asthenosphere). According to this concept, the root beneath the Mt. Everest would be 8848X8 = 70784 metre below the sea level. On this bases Airy has been criticized that the root is not possible to be at such a great depth. Because the root material will melt due to higher temperature found at that depth.

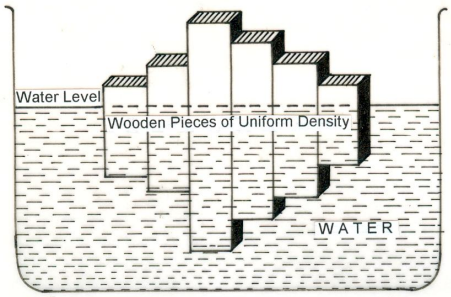


Fig. 3.1(a) :Illustration of the concept of Airy on isostasy

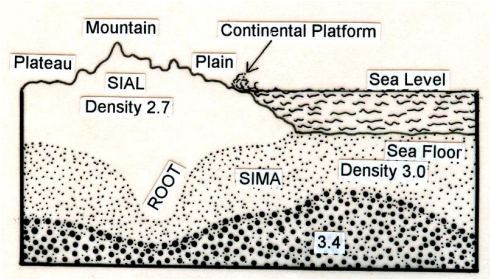


Fig. 3.1(b) : Condition of Isostary (based on A. Holmes and D.L. Holmes)

B. Isostatic Balance: views of Pratt

Pratt considered landblocks of various heights to be different in terms of their density. The taller landmass has lesser density and smaller height features to be denser. In other words, there is an inverse relationship between height and density. If there is a higher column, density will be lesser and if there is a shorter column, density will be higher. Assuming this to be true, he accepted that all blocks of different height get compensated at a certain depth into the substratum. In this way a line is being demarcated above which there is equal pressure with varying heights. Thus, he denounced the root concept of Airy and accepted the 'concept of a level of compensation'. For proving his concept he took a number of metal bars of varying density with same weight and put them into mercury (Figure 3.2). In this way they form a line by all those bars, which he regarded to be the level of compensation.

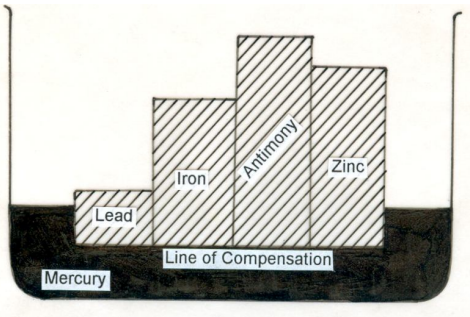


Fig. 3.2a Experiment of the concept of Pratt on Isostasy.

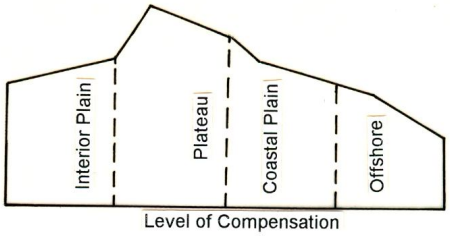


Fig. 3.2b. Illustration of Lithospheric block being compensated

Differences between the views of Airy and Pratt

The differences between the views of Airy and Pratt can more clearly be presented in a tabular form:-

	Views of Airy	Views of Pratt
1.	Uniform density of crustal material.	Varying density of crustal material.
2.	Varying depth upto which root penetrates.	Uniform depth upto which crustal material reaches.
3.	Deeper root below the mountain and smaller beneath plain. (Figure 3.1)	No root formation, but a level of Compensation. (Figure 3.2)

C. Global Isostatic Adjustment

It is quite apparent that there is no complete isostatic balance over the globe. The earth is unstable. Endogenetic forces often disturb the crustal balance. The regular earthquakes and volcanic eruptions along a particular belt do not signify any balance but a sort of adjustment is needed continuously. Endogenetic forces and their tectonic effects are the causes of imbalance on the surface but nature always tries to make an isostatic adjustment with itself.

Exogenetic forces are trying to eliminate the differences on the surface of the earth and in this process they are peeling off, transporting down to far flung places, and depositing them. In this process, isostatic balance is maintained by the underneath flowage of material by subsidence at the place of deposition and upliftment at the peeling of place in their proportion to the denudation (Figure 3.3).

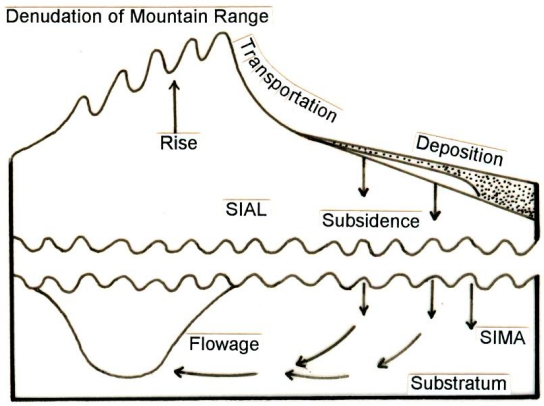


Fig. 3.3 : Mechanism of isostatic adjustment

INTEXT QUESTIONS 3.1

Fill in the blanks:-

1. Isostasy means _____.

2. Airy considered the density of different columns to be _____.

3. Pratt considered landblocks of various height to be different in terms of their _____.

4. According to Airy there is _____ root below the mountain and _____ beneath plain.

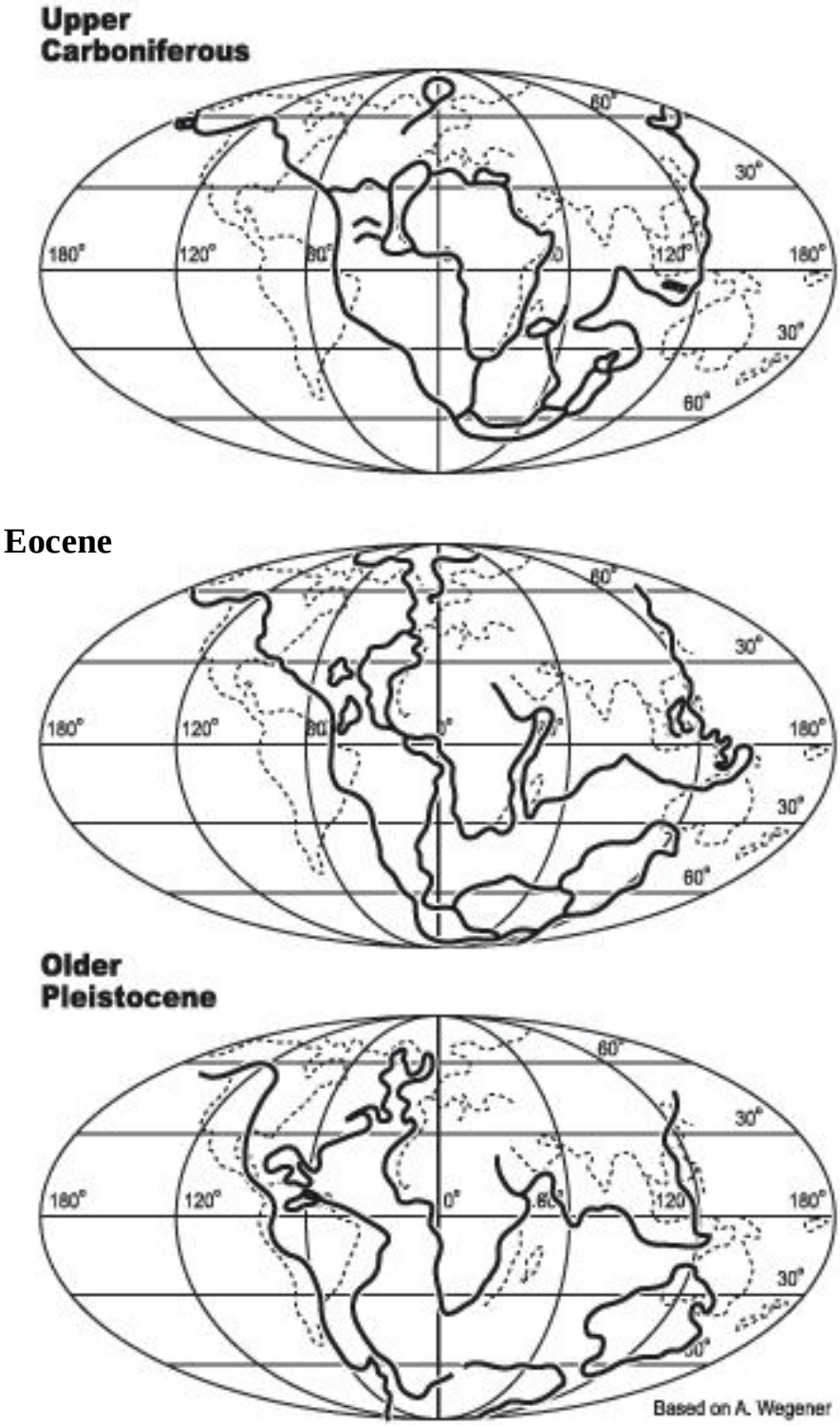
5. Pratt postulated the concept of _____ root formation but a _____ of compensation.

6. Endogenetic forces often _____ the crustal balance.

7. Regular earthquakes and volcanic eruptions along a particular belt does not signify _____ but a sort of continuous_____ _____.

3.2 CONTINENTAL DRIFT

According to Alfred Wegener, the entire landmass of the globe was together about 280 million years ago. It was termed as Pangea, a super continent. The huge water body surrounding the Pangea was known as Panthalasa. From 280 to 150 million years ago, Pangea was broken latitudinally into northern and southern parts known as Laurasia (Angaraland) and Gondwanaland, respectively. Both of them drifted away and in between a shallow sea emerged by filling up the water from Panthalasa. It was known as Tethys sea. Later on Laurasia and Gondwanaland rifted and finally drifted to form the present day distribution of land and water on the earth (Figure 3.4).



Pangea

Fig. 3.4 Pangea

Evidences of Drift

Wegener gave a number of evidences in support of the unification of land-mass in geologic past. They are such which cannot be negated even today.

a. Jig-saw-fit:- Eastern coast of South America is identical to Western coast of Africa which fits to a certain depth in the ocean. To a certain extent coastal areas and continental shelves have been modified by oceanic waves through denudation (Figure 3.5)

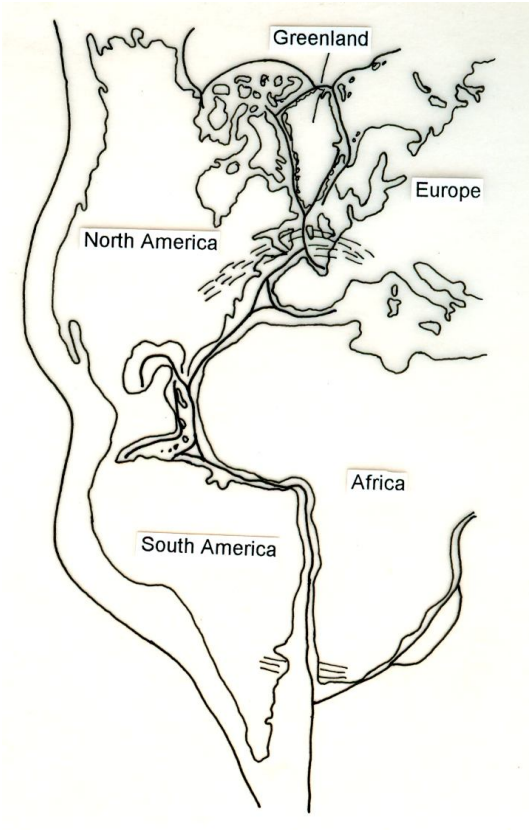


Fig. 3.5 Wegners map of continental drift-Fitting of the continents bording the Atlantic Ocean

b. Geological similarities:- The mountain systems of Southern Atalantic coast in South America and Africa show the similarity of the extension in both continents.

c. Coal and Vegetation evidences:- The distribution of coal and vegetation over South America, Africa, India and Australia proves that they were together in geological past. The classical glacial deposits during carboniferous period over these landmasses resemble each other which tells the story of togetherness. Today they lie in different climatic zones.

Apart from above evidences put forward by Wegener, other evidences (known later) are also there which support the idea of continental drift.

d. Evidences from paleomagnetism :– Paleomagnetism is the study of the direction of pole through ages. Magnetically susceptible minerals like haematite, pyrhotite magnetite etc. get aligned with the magnetic pole of the earth and recorded in the solidification of magma during that time. It is found that periodic changes have occurred and poles have wandered which is not possible for the entire earth. Hence, it is the twist and turn of the landblock and not for the entire earth which has again explained that the continents have shifted their positions.

e. Sea floor spreading :– Along the mid Atlantic ridge, magma comes out at the sea bed and gets solidified. A new zone is formed and this process is continuing since millions of years. It is leading for diversion of continental block, and hence the size of the Atlantic ocean is increasing which is termed as sea floor spreading. It is the classical example of the shifting of continents. The explanation of continental drift through sea floor spreading and the study of paleomagnetism is commonly known as Plate Tectonics. (Figure 3.6)

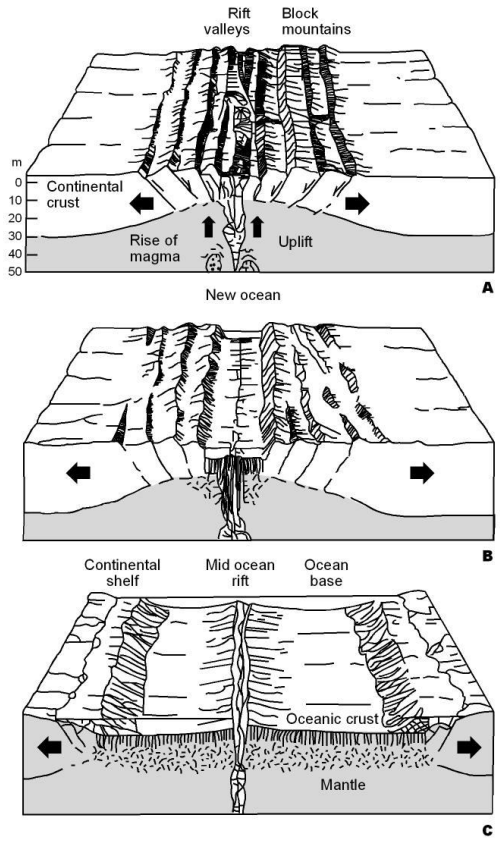


Fig. 3.6 Stages in continental rapture and the opening-up of a new basin

INTEXT QUESTIONS 3.2

1. Fill in the blanks:-
   a. Alfred Wegener termed the supercontinent as _____.
   b. Premordial ocean was known as _____.
   c. Pangaea was broken into two _____ in the north and _____ in the south.
   d. North and South America drifted towards _____.
   e. Tethys sea emerged between _____ and _____ by filling up of the water of _____.
2. Name three evidences of continental drift put forwarded by Wegener -
   a. _____
   b. _____
   c. _____
3. Name two evidences of continental drift, but not mentioned by Wegener
   a. _____
   b. _____

3.3 PLATE TECTONICS

The uppermost outer solid and rigid layer of the earth is called crust. Its thickness varies considerably. It is as little as 5 km thick beneath the oceans at some places but under some mountain ranges it extends upto a depth of 70 km. Below the crust denser rocks are found, known as mantle crust. This upper part of mantle upto an average depth of 100 km from the surface is solid. This solid mantle plus upper crust form a comparatively rigid block termed as lithosphere. Mantle is partially molten between 100 to 250 km depth. This zone is said to be asthenosphere, also known as Mohr discontinuity, a simplification of Mohorovicic, the name of the seismologist who discovered it. All these things you have already read in the previous lesson.

The lithosphere is broken into several blocks. These blocks are known as plates, which are moving over asthenosphere. There are seven major plates. (Figure 3.7)

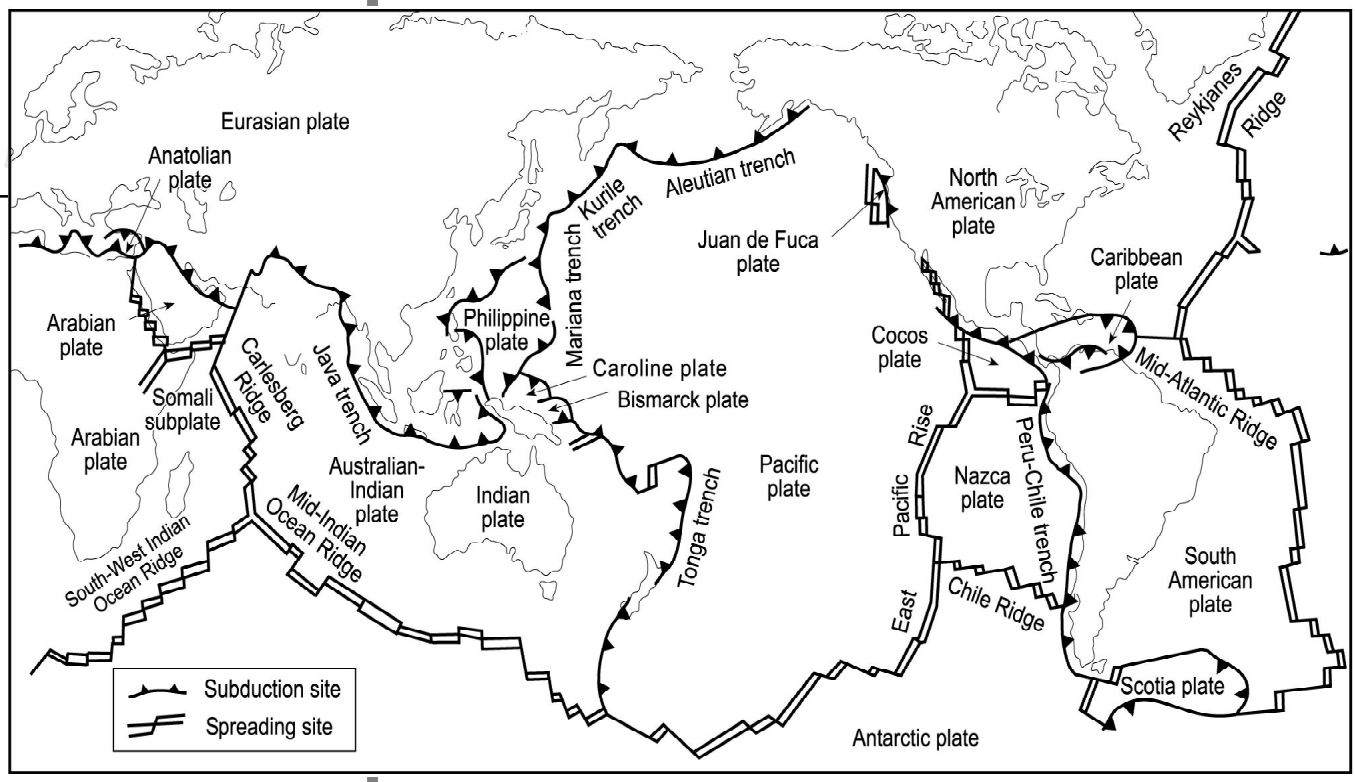


Fig. 3.7 Tectonic plates, spreading sites and subduction sites

1. Eurasian plate,
2. African plate,
3. Indo-Australian plate,
4. Pacific plate,
5. North American plate,
6. South American plate and
7. Antarctic plate.

Apart from these major plates minor plates are about 20 in number, a few important among them are :-

Arabian plate,
Philippine plate,
Cocos plate,
Nazca plate,
Caribbean plate,
Scotia plate, etc.

The major and minor plates constitute the whole surface of the earth.

Plate tectonics is a method or way of understanding the land-water distribution of the earth. Tectonics is a sort of movement of plates. Through the movement,

internal forces are explained which are responsible for the distribution of earth's crust, formation of mountain chains and distribtion of earthquakes and volcanism.

Mechanism of plate Movement

Arthur Holmes, a British geologist, in 1928 – 1929, proposed that convectional currents exist underneath the lithosphere. The centre of convectional current is not exactly known, but it is believed that it has an average depth of about 100 to 250 km below the surface. The inception of the current is initiated by heat generation due to radio-active minerals. Due to integration and disintegration of atomic minerals heat is produced and hence the melting of surrounding rocks. In this way currents start operating. These currents are classified into rising and falling with divergence and convergence activities, respectively.

With rising convectional current, transport of hot and viscous matter takes place upwardly. After reaching about 100 kms below the surface that current gets diverged leading to split into the upper part. The molten material penetrates into the split and thus creation of new surface and the draft of the mammoth plate in opposition direction. It happens below the mid-oceanic ridge. On the other hand two sets of diverging thermal convectional currents brings two plates together and it is called convergent boundary where subduction takes place. Plates of lithosphere are constantly in motion because of convectional currents. Their relative motion depends upon the force operating over them.

Plate boundaries are very important and significant structural features. Boundaries are very distinct and easy to identify. They are associated with newly formed mountain systems, oceanic ridges and trenches. Plates are moving continuously and have relative direction of movement. Based on the direction of movement three types of plate boundaries can, easily, be identified. (Figure 3.8)

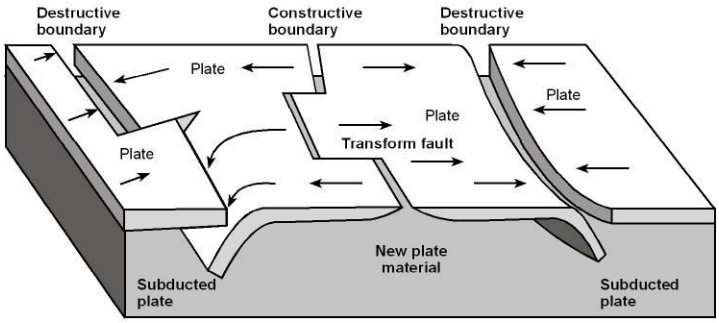


Fig. 3.8 Types of plate boundaries

(i) Divergent boundary
(ii) Convergent boundary
(iii) Fracture or transform boundary fault

The convectional current are caused due to radio-activity. These currents get diverted on approaching the crust layer. Diverging currents produce tension at the contact-zone of crust leading to fracture. Maganatic material penetrates into the fractroges and gets solidified. This continuous process pushes the blocks in opposite direction and creates a new zone, known as “zone of construction”.

At convergent boundary, two adjacent plates come further and further closer to each other and collide. When both sides are of continental nature, a mountain formation is evident. When one of the two is continental and the other maritime again mountain comes into being along the boundary. In this case, continental plate overnides the maritime. When both plates are of maritime, both of them break, subduct and penetrate below and, hence, trenches are formed. Along this boundary earthquakes and volcanic activities are prominent. In all these three situations, surface area is reduced, therefore, this is also known as “zone of destruction”.

Transform fault is the one when two adjacent plates slide past each other. Direction of movement may be along or against but they move parallel to each other. Therefore, neither there is any construction of fresh area nor it has any destruction. Hence, it is known as “zone of preservation”.

Plates are not a permanent features but they vary in size and shape. Plates can split or get welded with adjoining plate. Almost all tectonic activities occur along the plate boundaries.

Prior to the advent of plate tectonic theory, the continental drift theory which was proposed by Wegener was criticized, particularly about the forces. In fact, it was outrightly rejected inspite of apparent evidences. But further reserches about the material of sea floor and paleomagnetism supported the theory but the proposition of plate tectornic theory in 1960’s has solved the problem of the mechanism of movement.

Plate Tectonics Vs Earthquakes and Volcanoes

The distribution of earthquakes and volcanoes over the globe (Figure 3.9) clearly reveals that they are strongly associated with the boundaries of plates. Plate boundaries are the zones where every sort of tectonic activity does take place. The release of energy created because of the movement of plates is manifested in this zone in the form of earthquakes and volcanic eruption.

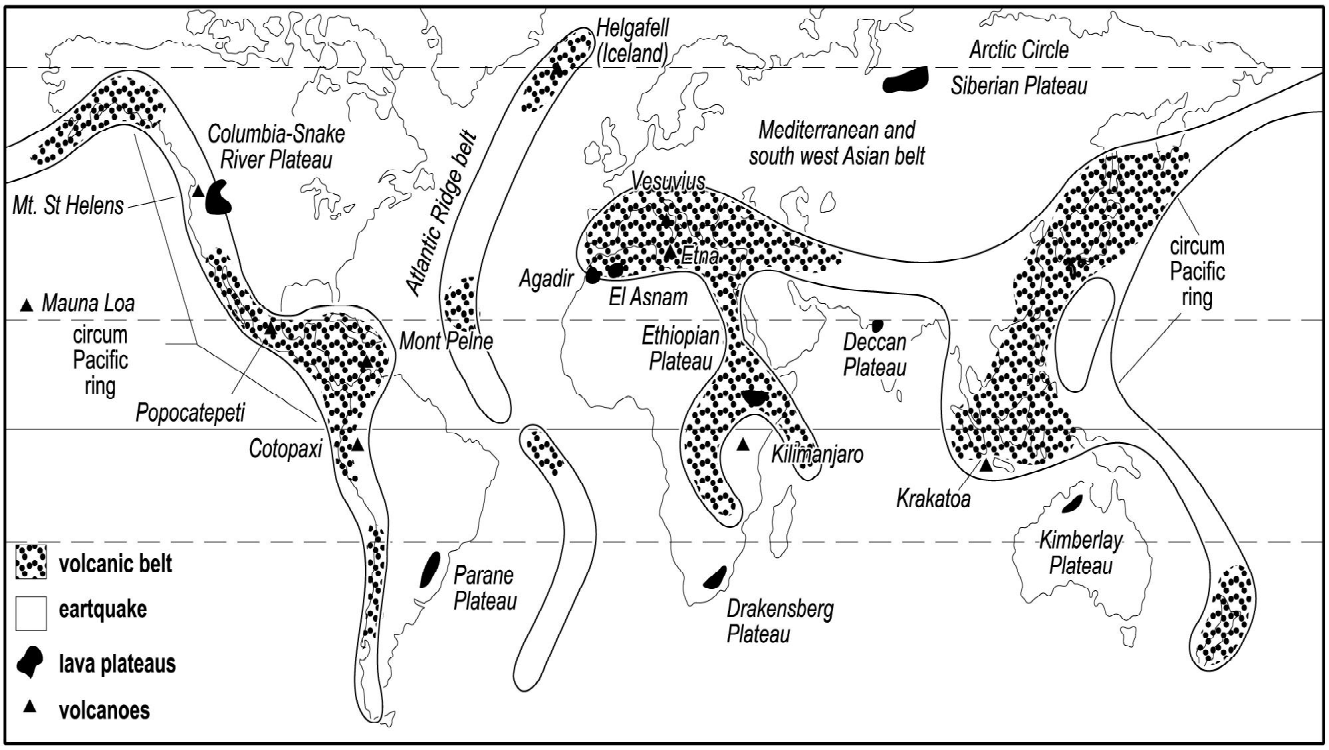


Fig. 3.9 The Major Earthquake and volcanic belts of the world

INTEXT QUESTIONS 3.3

1. Fill in the blanks:-
   a. The uppermost outer _____ layer of the earth is called _____.
   b. Crust and upper part of mantle upto an average depth of _____ is _____.
   c. Lithosphere includes _____ and _____.
   d. Tectonics is sort of _____ of lithospheric plate.
   e. The concept of convectional current was first explained by _____ in _____.
   f. Convectional currents are classified into _____ and _____; they _____ and _____, respectively.
   g. Plate boundaries are associated with _____, _____ and _____.
2. Name seven major plates
   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

f. _____

g. _____

3. Name some important minor plates –

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

4. Enumerate different types of plate boundaries

a. _____

b. _____

c. _____

WHAT YOU HAVE LEARNT

The surface of the earth is dynamic. This dynamism is due to the forces operating from inside the surface (endogenetic forces) as well as on the surface/atmospheric forces (exogenetic forces). It is existing on the earth while itself is rotating and revoling. The surface is irregular. Hence, a sort of dynamic equalibrium is always in operation which is termed as isostasy. Apart from many scholars the views of Airy and Pratt are more distinct. Airy propounded the idea of uniform density of all rocks on the surface but has its roots depending upon the height of the column. A greater root will be found beneath the higher and lofy body of mountains and having smaller root under lower columns like plateau or plain. Pratt accepted that the rocks found on the earth have different densities. At a particulars depth, the weight of all columns of varying height will be compensated. Hence, higher column of mass will have lower density and lower column will have higher density. Therefore, both of them are explaining the same problem of isostatic balance, but with different perspective.

The distribution of land and water on earth surface is not static. It has changed, it is changing and it will change in future too. This changed position is said to be continental drift in crude way which was conceived by Wegener, but the mechanism explained by him was not scientific. Therefore, his ideas of continental drift was denounced inspite of his strong unfutile and testifying evidences.

With the concept of convectional current theory of Holmes and proposition of plate tectonics, a new thinking came in understanding the surface of the earth. Study on paleomagnetism as well as sea floor spreading have supported the plate tectonics theory. According to this theory, the earth surface is made up of several broken blocks of enormous size with great depth considered to be a plate. There are seven bigger size plates and twenty seven smaller size plates. As per the concept of convectional current, their movement takes place in three possible ways. First, two adjacent plates move away (divergent) and where a new zone is constructed. Second, two adjacent plates come closer (convergent) and get subducted and where a zone is destroyed. Third, in which two adjacent plates slide past each other (fracture) where the margins of both plates are preserved. Because of these different tectonic activities, earthquakes and volcanoes are associated with plate margins.

TERMINAL QUESTIONS

1. What is isostasy?
2. Explain the concept of isostasy according to Airy.
3. Explain the isostatic balance of the earth as proposed by Pratt.
4. Differentiate the ideas between Airy and Pratt.
5. Discuss the isostatic balance at global level.
6. Discuss the evidences of continental drift.
7. What is plate? Explain the mechanism of plate movement.
8. Discuss the activities at plate margins.
9. Describe the distribution of earthquakes and volcanoes with the help of plate boundaries.

ANSWERS TO INTEXT QUESTIONS

3.1

1. the state of being balance
2. same
3. density
4. deeper, lower
5. no, level
6. disturb
7. any balance, adjustment is needed.

3.2

1. a. Pangeea
   b. Panthalasa
   c. Laurasia (Angaraland), Gondwanaland
   d. West
   e. Angaraland, Gondwanaland, Panthalasa
2. a. Jig-saw-fit
   b. geological similarities
   c. coal evidences
3 a. evidences from paleomagnetism
   b. sea floor spreading

3.3

1. a. solid and rigid, plate
   b. 100 km, solid
   c. upper solid mantle, crust
   d. movement
   e. Arthur Holmes, 1928-29
   f. Rising, falling; diverge, converge
   g. Newly formed mountain systems, oceanic ridges, trenches
2. a. Eurasian plate
   b. African plate
   c. Indo-Australian plate
   d. Pacific plate
   e. North American plate
   f. South American plate
   g. Antarctic plate
3. a. Arabian plate
   b. Philippine plate
   c. Cocos plate
   d. Nazca plate
   e. Caribbean plate
   f. Scotia plate

4. a. divergent boundaries
   b. convergent boundaries
   c. fracture or transform fault/boundaries

HINTS TO TERMINAL QUESTIONS

1. Please refer to section 3.1
2. Please refer to section A of 3.1
3. Please refer to section B of 3.1
4. Please refer to section C of 3.1
5. Please refer to section 3.2
6. Please refer to section 3.2, Evidence of drift.
7. Please refer to section 3.3
8. Please refer to section 3.3
9. Please refer to section 3.3