

Weathering and Soil Formation

Chapter 4

KEY CONCEPTS

- * Types of Rocks.
- * Weathering: meaning; factors affecting weathering.
- * Types of Weathering.
- * Soil formation as a result of weathering.
- * Soil profile; importance of soil conservation.
- * Methods of soil conservation.

The outer most layer of the earth called lithosphere is made up of various types of rocks that differ from one another in texture, structure, colour, size, mode of occurrence. Any natural mass of mineral matter that makes up the earth's crust is called a rock. The term rock refers not only to any hard solid matter like granite, but also to soft and loose particles like sand, silt and clay derived from the earth. Therefore, the term 'rock' refers to an aggregate of minerals that forms more or less a definite unit of the earth's crust. Rocks are made up of mineral elements.

TYPES OF ROCKS

On the basis of their origin, there are three main types of rocks:

1. *Igneous*;
2. *Sedimentary*; and
3. *Metamorphic*.

Igneous Rocks

The word 'igneous' is derived from the Latin word 'ignis' meaning fire. When the molten materials inside the earth's crust, i.e., magma, cools and solidifies, igneous rocks are formed. Since the igneous rocks were the first to be formed, they are called *primary rocks*. They form the basis of formation of other types of rocks.

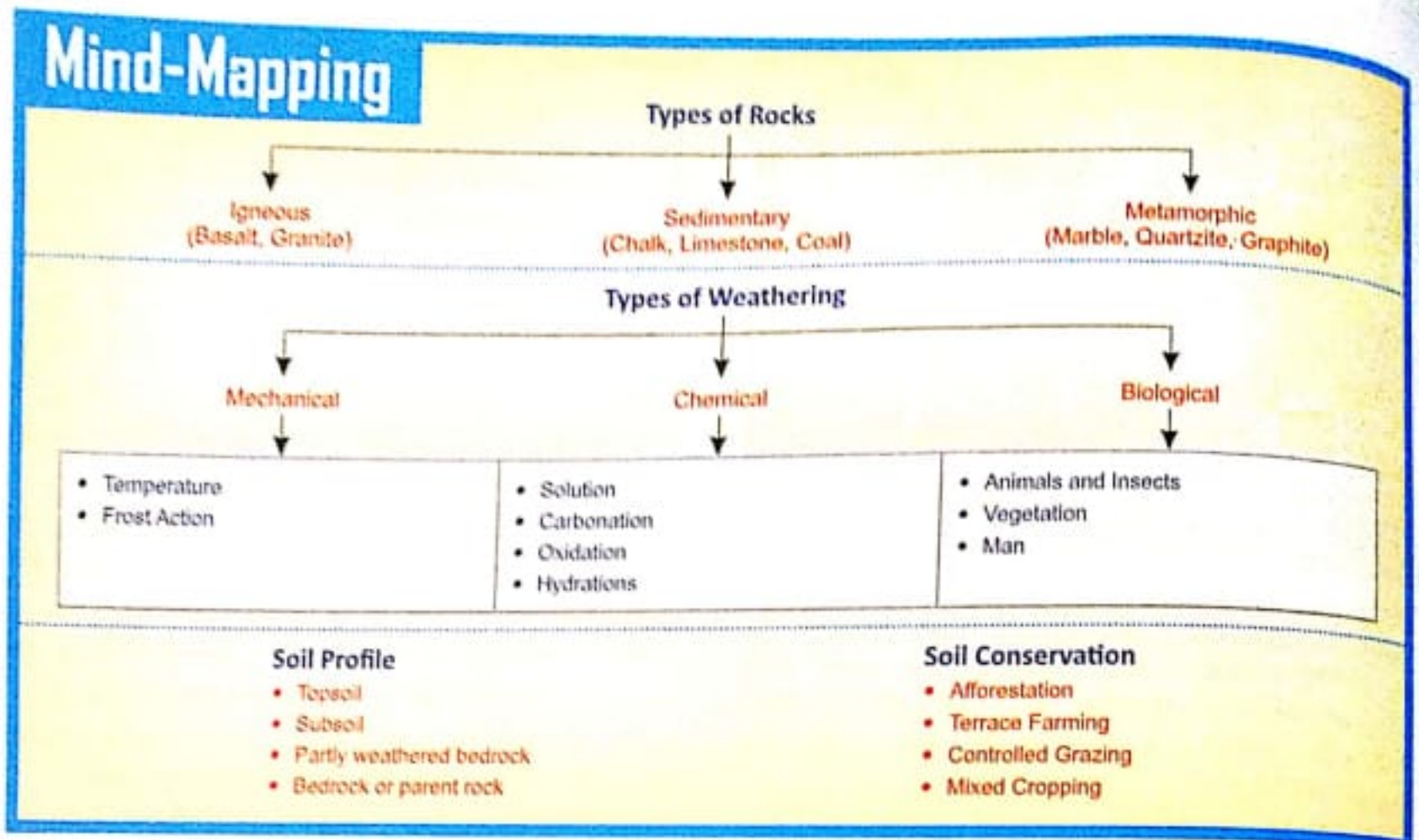
Characteristics of Igneous Rocks

- * They are hard and compact.
- * They are formed by solidification of molten magma.
- * They are granular and crystalline.
- * They are either fine grained, smooth and compact or may have large crystals with coarse texture.

Difference between Rocks and Minerals

Rocks	Minerals
1. Rocks are aggregates of mineral elements.	1. Minerals are solid inorganic substances occurring naturally.
2. A rock has no definite chemical composition.	2. Minerals have a definite chemical composition.
3. Minerals are organised to form rocks.	3. Elements are organised to form compounds which are known as minerals. An element is a pure substance.
4. Three chief types of rocks are Igneous, Sedimentary and Metamorphic.	4. Four chief mineral groups are silicates, carbonates, sulphides and metallic minerals.
5. Basalt, granite, sandstone and quartz are some important types of rocks.	5. Iron, silicon, magnesium, nickel, calcium, potassium, sodium are the minerals of the earth.





Key Points

- Rocks are aggregates of mineral elements.
- There are three main types of rocks — igneous rocks, sedimentary rocks and metamorphic rocks..
- **Weathering** is the process of breaking down of rocks by natural agents at or near the surface of the earth. It is a static process and does not involve transportation of the broken or decayed rocks.
- Weathering is of three types—*Physical, Chemical and Biological*.
- **Physical Weathering** involves disintegration of rocks without changing their chemical composition. This happens due to *temperature changes and frost action*.
- The process of chemical weathering involves *oxidation, hydration, carbonation and solution*.
- **Oxidation** involves reaction of minerals in rocks with atmospheric oxygen present in rain water which changes the colour of rocks to red, yellow or brown. The iron content in rocks reacts with atmospheric oxygen and forms iron-oxide which crumbles easily. It is then removed, loosening the overall structure of the rocks.
- **Hydration** involves expansion of minerals in the rocks due to contact with water. As a result the minerals become heavy and disintegrate.
- **Carbonation** involves conversion of calcium carbonate in the rocks like gypsum, marble and limestone into calcium bicarbonate by the action of rain water on rocks containing carbon dioxide. Calcium carbonate is soluble in water and is therefore, taken away by the ground water.
- **Solution** refers to the dissolution of rocks like limestone, rock salt or gypsum in water and their disintegration.
- **Biological Weathering** involves both the physical disintegration and/or chemical decomposition as all the biological matter is made up of oxygen and water. It is caused by animals and insects, plants and human activities.
- **Soil** is the relatively loose material on the earth's crust comprising fine particles and organic matter.
- **Soil Profile** is the vertical section of the soil showing arrangement of its different horizons or layers.
- **Soil erosion** is the removal of the topmost layer of the soil by natural process (rains, winds, etc.) or human activities.
- **Conservation** involves protection of soil by checking soil erosion.



Rows of trees (Shelter Belts) prevent soil erosion

water-logged soil, farming on land with unsuitable terrain and soil compaction by agricultural machinery, etc. make the topsoil vulnerable to erosion.

Due to these activities topsoil is disturbed and rendered devoid of vegetation cover. Overgrazing accounts for 35 per cent of the world's soil erosion while deforestation is responsible for 30 per cent of the earth's seriously eroded lands. Unsustainable methods of farming also cause 28 per cent of soil erosion.

CONSERVATION OF SOIL

Conservation of soil means protecting the soil from being eroded so that it can be used by future generations as well.

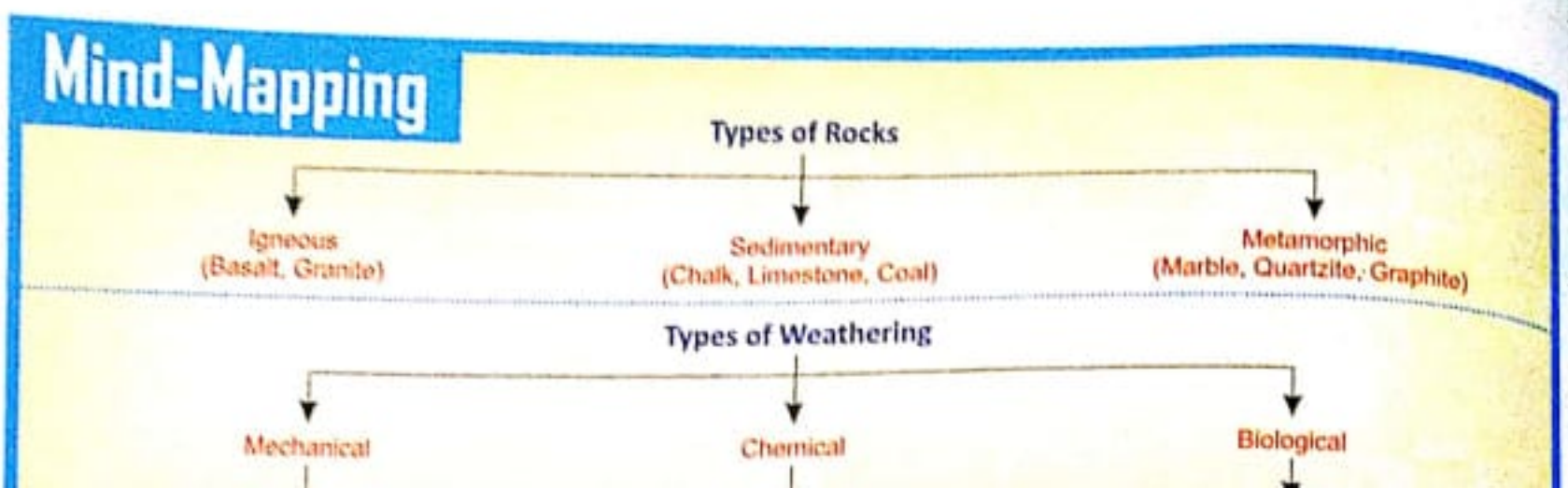
Methods of Soil Conservation

At present, the top soil is being lost at a fast rate leading to reduced fertility of the soil and thereby, low crop yield. To reduce the rate of soil erosion, we need to undertake the following conservation measures:

- * Stopping reckless cutting of trees as their roots bind the soil, thereby preventing erosion.
- * Using organic farming.
- * Using natural fertilisers like compost more than chemical fertilisers.
- * Stopping irrigating the plants using a strong flow of water, as it would wash off the top soil.
- * Checking over-irrigation of the soil to prevent salinisation and water logging.
- * Practising inter-mixed cropping so that specific nutrients do not get depleted.
- * Practising terrace farming in hilly areas to conserve soil.
- * Planting trees on slopes and constructing earthen embankments called *bunds* across slopes to prevent soil erosion.
- * Planting rows of trees along agricultural fields, called *shelter belts*.
- * Using green manure and mulch as it protects the soil.
- * Stopping overgrazing of land by animals by developing grazing lands on wastelands.



Terrace Farming on hill slopes protects the soil.



weathered bedrock and resembles the underlying parent rock.

D-horizon: This is the hard bedrock which forms the lowermost layer. But, this is generally not considered as a part of the soil.

Soil Composition

Soils are mainly divided into following types according to their composition (presence of different components in the soil) and water retaining capacity.

1. **Sandy Soil:** It is a light and porous soil containing 70-80 per cent sand particles. It is poor in nutrients and water holding capacity. Since sandy soils are coarse, they do not support plant growth.
2. **Clayey Soil:** It has fine clay particles which remain together. It has high water holding capacity and little organic matter. It is not suitable for cultivation of crops but is good for growing mango, jackfruit, black plum, etc.
3. **Loamy Soil:** It is a mixture of clay, sand particles, silt and humus. It has good water holding capacity, good aeration and good water movement. It is regarded as the best soil for plant growth. Crops grown in such soil are wheat, paddy, maize, sorghum, sugarcane, potato, etc.
4. **Silty Soil:** It has soft, smooth particles and high water holding capacity. It turns sticky with water and hardens on drying. Pulses; fibre yielding crops – cotton and jute; paddy; gram; etc. are the main crops grown in this soil.

If the amount of clay in the soil is more, then water cannot percolate down and it stays in the soil. This type of soil is known as *water-logged soil* and is not fit for cultivation of crops as the air spaces get filled with water and allow little space for the roots to breathe. Similarly, if the sand content in the soil is more, water percolates down with all the nutrients and renders the soil infertile.

All the constituents of soil provide nutrients to plants and animals and help in their growth and survival. When these plants and animals die, the nutrients are returned to the soil.

Soil Types

- * **Alluvial Soil:** It is formed by the sediments brought down by a river. It is a mixture of sand, clay and silt that is called loam. It is very fertile. It has fine particles and is found in coastal plains and deltas. The entire northern plains of India are made up of these soils. It is suitable for the cultivation of rice, wheat, sugarcane, cotton, tobacco, gram and oilseeds.
- * **Black Soil:** It is black in colour as it is formed from weathering of volcanic rocks. It is very clayey (up to 50% clay content) and has a good water holding capacity. It is found in Deccan Plateau in India. It is very fertile and suitable for cultivation of jowar, wheat, sugarcane, cotton, gram, etc.
- * **Laterite Soil:** It is reddish in colour due to the presence of iron and aluminium-oxides. It has good water holding capacity. It is not very fertile and yields crops when manures and fertilisers are added. It is suitable for growing vegetables, rice, ragi and tobacco.
- * **Desert Soil:** It is arid and sandy. It is formed as a result of wear and tear as well as mechanical weathering of rocks in deserts.
- * **Mountain Soil:** It includes forest and hill soils. It is rich in humus and is fertile. It is found in the northern and north-eastern hilly regions of India.
- * **Marshy Soil:** It is found in the continuously water-logged areas, especially in the coastal regions near the sea or near the deltas. It contains iron and varying amounts of humus.

Soil Erosion

The removal of the topmost layer of the soil is called Soil erosion. It occurs in the following ways:

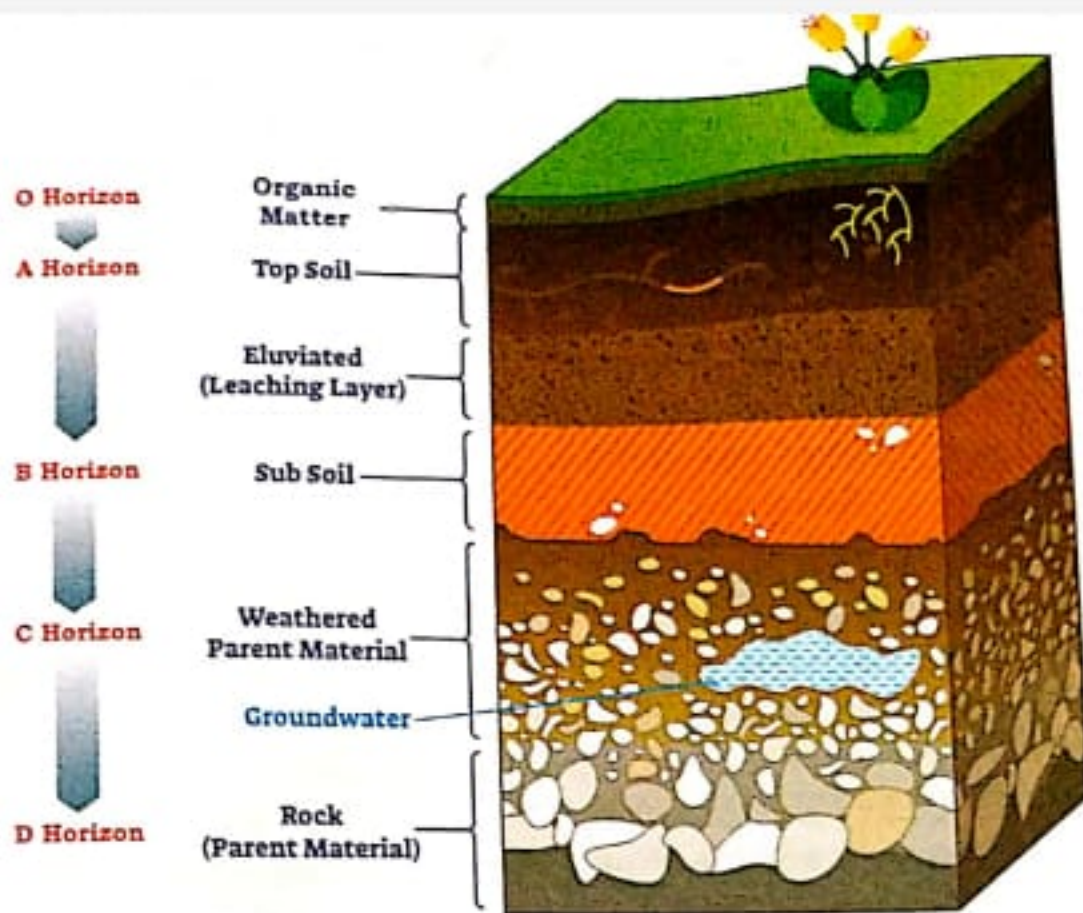
1. **Natural processes** like torrential rains, rapid flow of water along slopes, run-off, wave action, melting of snow and movement of winds.
2. **Human activities** like deforestation, mining, overgrazing, etc. Deforestation without reforestation, overgrazing by cattle, surface mining without land filling, irrigation techniques that lead to salt built-up,

Methods of Soil Conservation

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Layers of the Soil

SOIL FORMATION

Soil refers to the relatively loose material on the earth's surface comprising fine rock particles and organic matter. Soil formation is a slow process which may take about thousand years to form a thick layer of soil. It depends upon the nature of the parent rock, climate and natural vegetation.

Soil formation includes the following steps:

- * Weathering causes the break up of rocks into small pieces until they are finely broken so as to turn into fine powder.
- * The mineral particles and weathered particles are transported over long distances to other areas by water, wind or ice.
- * These transported rock particles then mix with decayed organic matter (humus), water and air to form soil. Humus makes the soil fertile.

Soil Profile

If we examine a cut hillside or the side of a freshly dug pit, we will find the presence of several layers in the soil. The soil layers which have different textures, colours, depths and chemical composition, are called *soil horizons*.

The soil horizons are arranged in a definite pattern in the soil. A vertical section of the soil showing arrangement of different soil horizons is called the *soil profile*. The different soil horizons are as follows:

O-horizon: This is the uppermost layer composed mainly of organic matter. Decomposed organic matter in this layer enhance the soil fertility.

A-horizon: This is the soft, dark and porous layer just beneath the O-horizon. It can retain water. In this layer, humus and organic material from O-horizon become thoroughly mixed with the mineral matter produced by weathering. The O-horizon and A-horizon are collectively known as **top soil**.

B-horizon: This is the denser soil layer beneath the A-horizon. It is formed due to leaching and accumulation of materials from the above layers. Organic matter and humus are less in the B-horizon. The colour of this layer may be due to presence of oxides of iron and aluminium or calcium carbonate leached from the A-horizon. It is called the **subsoil**.

C-horizon: This is the layer below the B-horizon. It is made up of small lumps of rocks produced by weathering. It consists of partly

weathered bedrock and resembles the underlying parent rock.

D-horizon: This is the hard bedrock which forms the lowermost layer. But, this is generally not considered as a part of the soil.

Soil Composition

Soil Types

- * **Alluvial Soil:** It is formed by the sediments brought down by a river. It is a mixture of sand, clay and silt that is called **loam**. It is very fertile. It has fine particles and is found in coastal plains and deltas. The entire northern plains of India are made up of these soils. It is suitable for the cultivation.



Chemical Weathering of Sandstone

chemical process. For example, rocks like feldspar are converted into kaolin.

Biological Weathering

Biological Weathering is also known as *Organic Weathering*. Its main agents are animals, insects, plants and man. In all the cases, however, both physical disintegration and/or chemical decomposition are involved. This is because all biological matter is made up of oxygen and water, the two substances that set off reactions in rocks.

- * **Animals and Insects:** Burrowing animals like rabbits, worms, moles and insects bring large quantities of fine material to the surface. These animals help to loosen the surface materials around the rocks facilitating their physical disintegration. Upon death, the decaying animals also provide many chemicals and acids for rock disintegration.
- * **Vegetation:** Roots of large trees reach deep into rocks and cause physical disintegration due to pressure. Most of vegetation, however, prevents disintegration of rocks because it binds the surface layer and does not allow exposure of rocks beneath to the elements of weathering.
- * **Man:** Man is the most active agent of both physical and chemical weathering of rocks. For example, mining, excavations, construction of roads, buildings, etc. cause physical disintegration of rocks. Agriculture, dumping of chemicals and

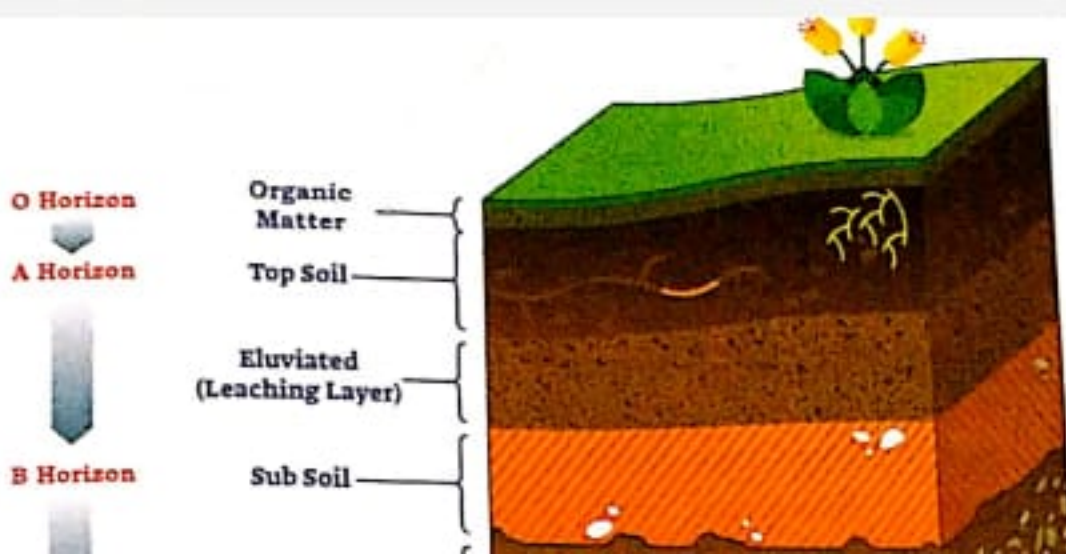
wastes underground promote both physical and chemical weathering.

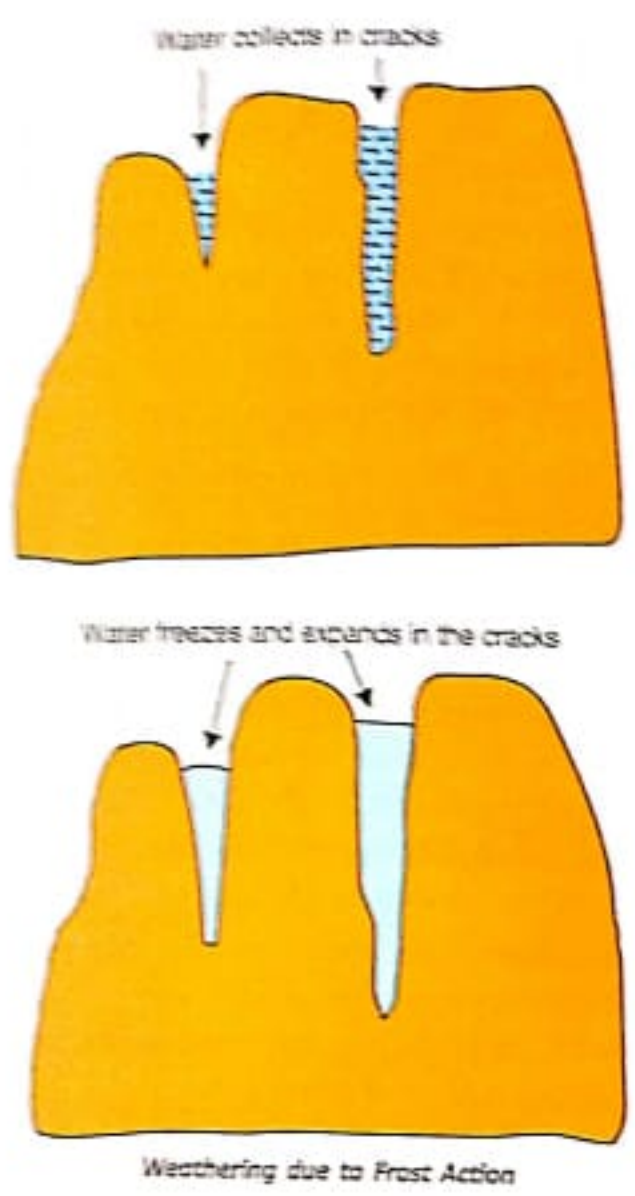
Effects of Weathering

- * The process of weathering causes exposed rock surfaces to break and crumble. In this way it prepares the material for transportation by other erosive agents such as rivers, glaciers, waves, etc.
- * Weathering plays an important role in the formation of soil. The disintegrated rock or breaking of rocks as a result of weathering is the major constituent of soils.
- * Sometimes due to gravity there is a large scale movement of loose material derived from weathering of rocks. This is known as *mass-wasting* or *mass movement*. Mass-wasting causes landslides and mudflows.
- * Sudden landslides can cause great destruction across a wide area of habitable land. Landslides can also cause floods by blocking of river channels.
- * In dry mountainous regions, where no vegetation is present to hold the soil and slopes are steep, rainfall causes mudflows. The debris is transported by streams and rivers as mud. The mudflows from great heights can bury houses and bridges, clog the stream channels and sever communication links.



Biological Weathering of Sandstone





to distinguish the different processes involved. Four main processes are — *solution, carbonation, oxidation and hydration.*

- * **Solution:** Some of the rocks and minerals such as limestone, rock-salt and gypsum are soluble in water. Those rocks get

dissolved in water and disintegrate in the form of solution.

- * **Carbonation:** Many mineral constituents of rocks such as carbon dioxide while coming in contact with water produce acidic effect on rocks. This action dissolves most calcareous rocks such as gypsum, marble and limestone. However, this action should not be mistaken for solution. In the case of carbonation, rainwater converts calcium carbonate into calcium bicarbonate which is soluble and is taken away by the ground water and thus cause disintegration of the rocks.
- * **Oxidation:** The decomposition of rocks through oxidation takes place when minerals present in the rocks react with atmospheric oxygen present in the rainwater. When the iron present in rocks comes in contact with oxygen, it is changed to iron oxide, the familiar brownish rust. The colour of the rocks change to red, yellow or brown. Iron oxide crumbles easily and is eroded more easily than the original rock. It is then removed, loosening the overall structure of the rocks and weakening them.
- * **Hydration:** In this process, expansion of minerals occurs on coming into contact with rainwater. These minerals become heavy and start disintegrating. This action, though can be termed as physical or mechanical, its effect in hydration is a

Differences between Physical and Chemical Weathering

Physical Weathering	Chemical Weathering
1. Disintegration of rocks takes place without any change in their chemical composition.	1. Minerals in rocks are dissolved or altered.
2. Factors such as temperature, moisture and pressure cause physical break-down of rocks.	2. Temperature, moisture, etc., cause minerals in rocks to dissolve in water or convert them into other minerals.
3. It takes place in hot, dry and cold areas due to rapid temperature changes.	3. It takes place in hot and humid areas due to chemical action of minerals in rocks.
4. It takes place from the surface to great depths in the rocks.	4. It mostly takes place near the surface of the earth.
5. Its agents are temperature and moisture.	5. Its agents are <i>solution, oxidation, carbonation and hydration.</i>



wastes underground promote both physical and chemical weathering.

Effects of Weathering

- * The process of weathering causes exposed rock surfaces to break and crumble. In this way it prepares the material for transportation by other erosive agents such as rivers, glaciers, waves, etc.

acids, water or oxygen and cause considerable weathering. For example, limestone can get severely acted upon by even very mildly acidic rainwater. Granite on the other hand, contains silica and remains unaffected by such agents.

Physical weathering is also dependent on mineral composition. Soft rocks weather more readily than the hard rocks. The solid crystalline rocks are quite compact with very little opening and are very resistant to entry of water into them, and can therefore resist weathering.

6. Time: The process of weathering is a time taking process. The duration of time for which a rock is exposed to weather determines the extent of weathering. Strong rocks, take longer time and undergo weathering in hundreds of years.

Chief Characteristics of Weathering

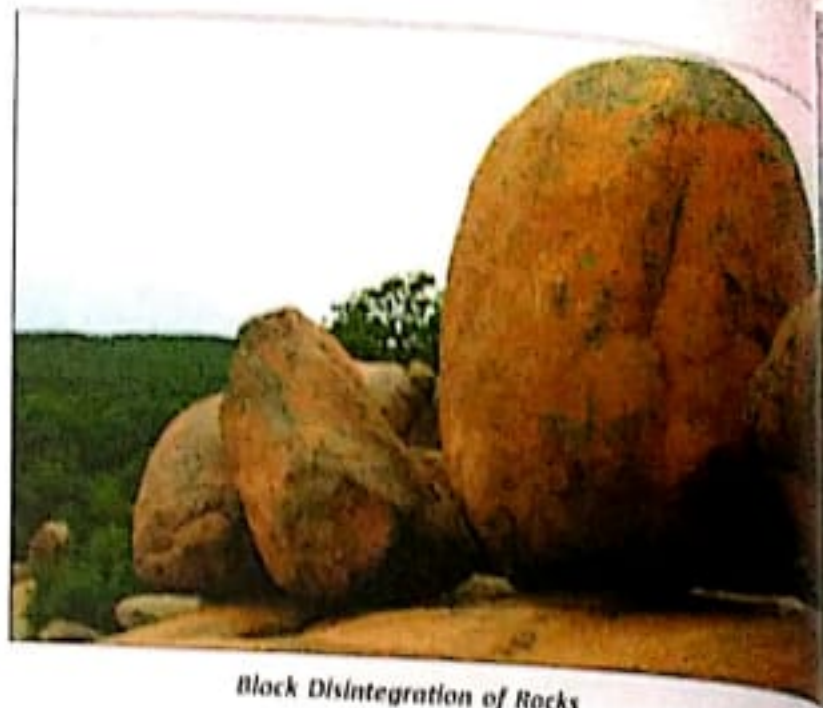
- * Weathering involves disintegration or break up of solid rock.
- * It depends on climatic elements and on the character of rocks. For example, the rock's chemical composition, hardness, texture and its permeability (allowing water to penetrate) determines the weathering pattern.
- * Weathering affects the surface of the earth.
- * Weathering causes formation of soil.
- * Weathering degrades hard massive rocks into finer material.
- * Weathering prepares rock material for transportation by agents of gradation.

TYPES OF WEATHERING

The disintegration of rocks may occur through physical forces, chemical forces, animals, insects, or by roots of plants, etc. Based on this, weathering is of three types — *mechanical*, *chemical* and *biological*.

Mechanical Weathering

Mechanical Weathering is also known as physical weathering. It involves disintegration of rocks without changing their chemical composition. The main factors responsible for physical weathering are temperature changes and frost action.



Block Disintegration of Rocks

Temperature: Weathering due to changes in temperature is more rapid in hot deserts. It is because temperature changes are sharpest in a desert. The sudden rise and fall of temperature causes expansion and contraction of rocks. The repeated action causes their breakdown. At night the temperature suddenly falls and during the day it rises suddenly. This leads to tension and splitting of rocks. The process of rock splitting continues in desert areas until the rock breaks down to constitute sand.

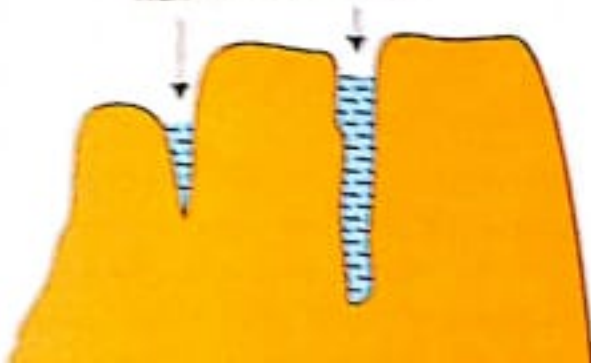
Frost Action: At high altitudes as in mountainous regions or colder places, the freezing action of water, also known as *frost action*, causes the disintegration of rocks. It happens in areas where there is lot of moisture and temperatures frequently fluctuate above and below freezing point. The cracks and joints of rocks are filled with water during day time. At night, when the temperature falls, the water in the cracks or joints freezes and its volume increases, requiring more space. This causes the widening of joints and cracks in the rocks. Repeated action weakens the rocks causing them to break along the joints.

Chemical Weathering

Chemical weathering involves the change in the composition of rocks due to chemical reaction of minerals with air and water. This type of weathering happens over a period of time.

The chemical weathering of rocks occurs in a number of ways and each one is given a name

Water collects in cracks



dissolved in water and disintegrate in the form of solution.

- * **Carbonation:** Many mineral constituents of rocks such as carbon dioxide while coming in contact with water produce acidic effect on rocks. This action dissolves most calcareous rocks such as gypsum, marble and limestone. However, this action should not be mistaken

- * Sedimentary rocks are most widespread on the surface of the earth and constitute about 75 per cent of the surface area of the globe.
- * Sedimentary rocks are soft (as compared to igneous rocks) and layered as they are formed by deposition of sediments.
- * Sedimentary rocks make extensive landforms.

Metamorphic rocks

The word *Metamorphic* is derived from 'metamorphose' which means change in form. When sedimentary and igneous rocks change their form due to high temperature and pressure they form metamorphic rocks. The rocks used in the Taj mahal at Agra are marbles metamorphosed from Dolomites. Dilwara Temple at Mount Abu is also built of similar marbles.

Original Rock undergoes changes to form Metamorphic Rock

Original Rock	Metamorphic Rock
Limestone	Marble
Sandstone	Quartzite
Shale	Slate
Coal	Graphite
Basalt	Schist
Granite	Gneiss
Dolomite/Chalk	Marble

Characteristics of Metamorphic Rocks

- * They are harder and more compact than their original form. For example, marble made from limestone is harder than limestone.
- * Most of them are impermeable i.e., they do not allow water to percolate through them.
- * They do not have fossils as fossils in sedimentary rocks get destroyed during the formation of metamorphic rocks.
- * New minerals are formed during the process of metamorphism.

WEATHERING

Weathering is the process of breaking down and decomposition of rocks but not their removal. It

is described as *disintegration or decomposition of rocks in size by natural agents at or near the surface of the earth*. It is so called because the disintegration or decomposition of rocks takes place only by being exposed. It is the change in weather conditions like temperature, moisture, precipitation that break down the rocks. Weathering is a static process. It occurs *in situ*, i.e., at the place where the rocks are present. Erosion on the other hand, is a dynamic process that involves disintegration of rocks and their transportation and finally deposition as sediments by running water, winds, glaciers and waves. Weathering cannot take place on the surface of Moon where such conditions do not exist. The footprints left on the Moon by astronauts last for millions of years.

Factors Affecting the Process of Weathering

The following are the factors that affect the process of weathering:

- 1. Climate:** It is an important factor that affects weathering through changes in temperature, precipitation and sunshine. Warm and humid places cause chemical weathering whereas cold places cause physical weathering. This is because at higher temperatures, chemical reactions take place at a faster pace. Similarly, physical weathering by frost action is most likely in cold climate.
- 2. Particle Size:** Rate of chemical weathering is affected by size of rock particles. If the rock pieces are smaller, the weathering is faster. This is because if the rock pieces are smaller, the surface area exposed to weather action is greater.
- 3. Exposure:** The extent of exposure i.e., the extent to which the rocks come into contact with the agents of weathering affects the process of weathering. In some cases, vegetation, soil, ice cover a rock and thereby, reduce the area exposed to weather action.
- 4. Slope** of the region also affects weathering. Where the slopes are steep, loose materials are displaced downhill either by gravity or by erosion resulting in continuous exposure of the fresh rock.
- 5. Mineral Composition:** The chemical properties of a rock depend on its mineral constituents. Minerals in a rock may readily react with

acids, water or oxygen and cause considerable weathering. For example, limestone can get severely acted upon by even very mildly acidic rainwater. Granite on the other hand, contains silica and remains unaffected by such agents.



Different Types of Rocks

- * The size of their crystals depends upon the rate of cooling of the molten material.
- * These rocks are less affected by chemical weathering because water does not percolate in these rocks.
- * They do not have layers. They are generally weathered by mechanical weathering.
- * Igneous rocks are associated with volcanic activity and are found mostly in volcanic regions.

The Igneous Rocks are of two types —

1. Extrusive Igneous Rocks, and
2. Intrusive Igneous Rocks.

Extrusive Igneous Rocks are formed by the cooling of molten magma on the earth's surface. The magma which is brought to the surface through fissures or volcanic eruptions, rapidly cools down and becomes solid to form rocks. Hence, such rocks are smooth, crystalline and fine grained. They are also called as *volcanic rocks*. Basalt is a common extrusive igneous rock and forms lava flows, lava sheets and lava plateaus. The Deccan Plateau is made up of basalt.

Intrusive Igneous Rocks are formed when the magma cools down slowly and solidifies within the earth's crust. They are coarse textured hard rocks with large crystals, e.g., granite, gabbro, dolomite.

Sedimentary Rocks

When igneous rocks are exposed on the surface of the earth, they are broken down by weathering and carried away by rivers, glaciers, ocean waves and winds. They are then deposited as sediments.

These loose sediments get deposited over long periods. Subsequent layers are added and due to their own weight from above, the sediments get compressed, hardened and cemented together to form *sedimentary rocks*. They are called *secondary rocks* because they are formed by the solidification of sediments of original igneous, sedimentary or metamorphic parent rocks.

Coal is a sedimentary rock and petroleum also occurs in sedimentary rocks. Coal was formed millions of years ago by the remains of plants and animals that got buried with other sediments. The high temperature and pressure under the earth's surface converted these organic remains into coal, lignite and peat. Similarly, petroleum was formed by the decay of plants and animals buried under the earth for millions of years.

Chalk and limestone are formed by the deposition of shells and skeletons of sea organisms corals, clams, oysters, etc.

Characteristics of Sedimentary Rocks

- * Sedimentary rocks are formed from materials derived from other rocks. They may also have plant and animal remains. These rocks may thus contain fossils.

- * Sedimentary rocks are most widespread on the surface of the earth and constitute about 75 per cent of the surface area of the globe.
- * Sedimentary rocks are soft (as compared to igneous rocks) and layered as they are formed by deposition of sediments.
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Home work:

Q. 1. What is rock?

Q. 2. Name different types of rocks.

Q. 3. State two difference between rock and mineral.

Q. 4. State the factors affecting the process of weathering.

Q. 5. Name the different types of weathering.

Q. 6. What is soil profile?

Q. 7. Define soil conservation.