Highlights :

- Physical and chemical processes are constantly acting on the surface of the Earth resulting into various landforms.
- Soil is a product of weathering and various factors are responsible for soil formation.

Introduction :

Weathering is a natural process of *in-situ* mechanical disintegration and/or chemical decomposition of rocks and minerals of the Earth's crust. These processes are carried out by certain physical and chemical agencies and are included under the term Geomorphic Processes. The weathered product may remain *in-situ* or get transported.

2.1 Agents of weathering :

The agencies involved in the process of weathering are atmosphere, water and organisms.

2.2 Types of weathering :

There are several processes by which rocks and minerals undergo weathering. These may be classified into two main types, viz. mechanical or physical weathering and chemical weathering.

2.2.1 Mechanical (Physical) weathering :

This is one of the most common geological processes of *in-situ* disintegration of rocks and minerals into smaller fragments without any change in chemical composition. Mechanical weathering is achieved by a number of processes and its nature depends upon the climatic conditions. These processes mainly depend on the predominance of effective agents like temperature changes (frost wedging and exfoliation), and animal/plant activity. The agents of physical weathering are described below.

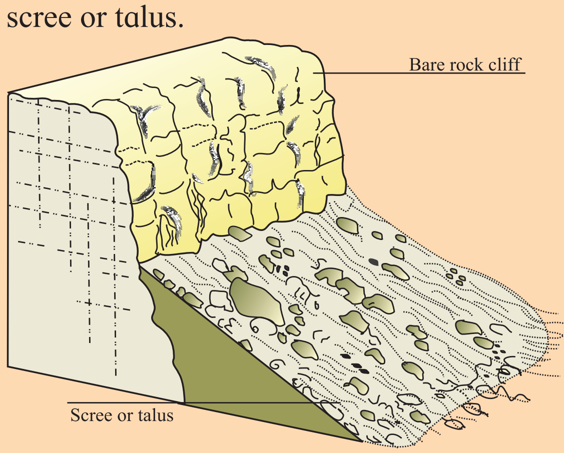
i) **Frost wedging :** The process of freezing of water and thawing of ice due to temperature changes and its effect on rocks is known as frost action. It is confined to regions in higher latitudes and altitudes.

The pores, cracks, fractures and cavities are widened due to subsequent cycles of freezing and thawing, leading to gradual disintegration of rocks. Thus, the affected rocks in such a climate become weak and get fractured.

Do you know?

When water in a fracture freezes, it exerts tremendous pressure on the walls of the fracture or joints due to increase in volume. It is estimated to be about 30,000 pounds per square inch (2109 Kg/cm^2) at 8^{o}C below freezing point.

It is observed that in mountainous region, along steep mountain slopes, such jointed blocks are dislodged from the rock body. As blocks after blocks are dislodged from the slope, they fall and accumulate at the base to form a huge deposit of angular rock fragments. Such deposits are known as scree or talus.



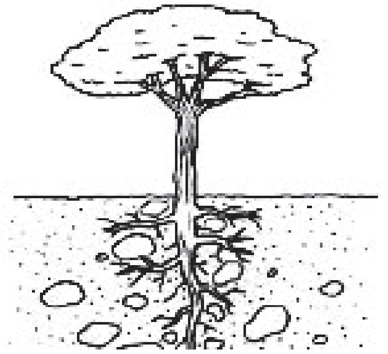
ii) **Thermal effects :** Thermal effect is more common in arid, semi-arid and desert regions where diurnal temperatures in summer and winter vary considerably. Rocks, like many other solids, expand on heating and contract on cooling.

Such repeated variations in temperature gradually break the rocks into smaller pieces, especially the top layers. Tensile stresses developed by alternate expansion and contraction are also responsible for the disintegration of the exposed rocks.

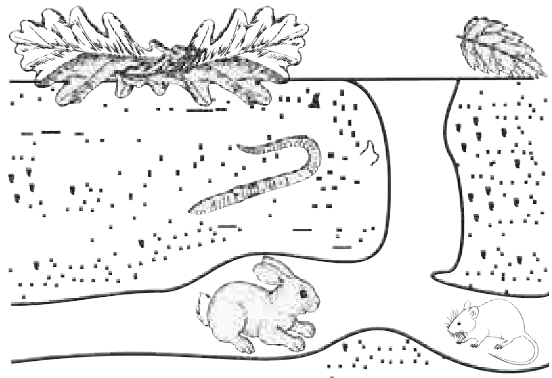
iii) Exfoliation : Exfoliation is the process by which layers peel away from the outer surface of the exposed rock. Rocks which are subjected to such a process, assume a characteristic dome shape. This dome appears like a bald central part surrounded by a number of exfoliated sheets. Exfoliation is mainly observed in plutonic rocks such as granites. When these rocks are exposed on the surface, pressure decreases due to removal of overburden resulting in expansion. This expansion causes fractures, which are generally parallel to the surface of the exposed rock and are at right angles to the direction of expansion (Fig. 2.1).

Fig. 2.1 : Exfoliation

iv) Plants and animals : Plants and various organisms also play a considerable role in rock disintegration directly or indirectly. When plant roots enter rock fractures, they exert pressure. This results in wedging apart of the rock blocks. Lichens and moss open tiny cracks in the rock and loosen the mineral grains. Man is also directly or indirectly responsible for disintegration by various activities such as quarrying and mining. Burrowing animals like earthworms and rodents engage in transferring the soil material to the surface.(Fig. 2.2 A and B).



A) Activity of plants



B) Activity of animals

Fig. 2.2 : Weathering by plants and animals

2.2.2 Chemical Weathering :

It is the process of alteration of rocks by chemical decomposition brought about by atmospheric gases and moisture. Various important chemical processes leading to decomposition of rocks are dissolution, hydration, hydrolysis, carbonation, oxidation and reduction.

Fig. 2.3 : Chemical weathering in limestone

i) **Dissolution :** Water is a universal solvent and number of minerals get dissolved in it. On saturation, precipitation of salts occurs at favourable places. The removal of soluble matter from bed rock by water is termed as leaching and residue is termed as leachates.

e. g. $CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2(HCO_3)^-$

Calcite Carbonic acid Calcium ion Bicarbonate ion

Solution is commonly the first stage in chemical weathering and it removes the most readily soluble minerals. The process depends on pH. SiO_2 is more soluble at pH > 9 while Al_2O_3 is soluble only below pH-4 and above pH-9. Limestones are insoluble in pure water but in presence of dissolved CO_2, calcium carbonate is replaced by calcium bicarbonate which is soluble in water. Calcite in limestones is among the most soluble of common rocks (Fig. 2.3)

e.g.$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$

Calcite Calcium Bicarbonate

ii) **Hydration :** It is the process whereby certain minerals absorb water into the crystal lattice, e.g. iron oxides absorb water and turn to hydrated iron oxides.

$2Fe_2O_3 + 3H_2O \rightarrow 2Fe_2O_3.3H_2O$

Hematite $\rightarrow$ Limonite

iii) **Hydrolysis :** It is a chemical reaction between the minerals and water. The H^+ and OH^- ions of water react with the ions of the mineral. In hydrolysis, water is a reactant and not merely a solvent.

e.g. The feldspars in coarse grained granite, under hydrolysis, form clay minerals. This process also involves volume expansion .

$2KAlSi_3O_8 + 2H^+ + 9H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4H_4SiO_4 + 2K^+$

Orthoclase Water Kaolinite Silicic acid

iv) **Carbonation :** This process can occur readily because bicarbonate is nearly always present in sub-surface waters and is also a major component of stream waters. Bicarbonate ion is derived from the photosynthetic fixation of CO_2 and its subsequent respiration by plant roots and bacterial degradation of plant debris.

e.g. $H_2O + CO_2 \rightarrow H_2CO_3$

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

v) **Oxidation :** It is the process of reaction with Oxygen e.g. Ferrous (reduced state) to Ferric (oxidised state).

$4FeO + O_2 \rightarrow 2Fe_2O_3$

It is the process whereby the minerals lose one or more ions or atoms in the presence of oxygen. Oxidation takes place when rock comes in contact with oxygen from air or from water i.e. oxic conditions. Ferrous iron (Fe^{2+}) of the minerals is oxidised to ferric iron (Fe^{3+}) on exposure to moist air (Fig. 2.4).

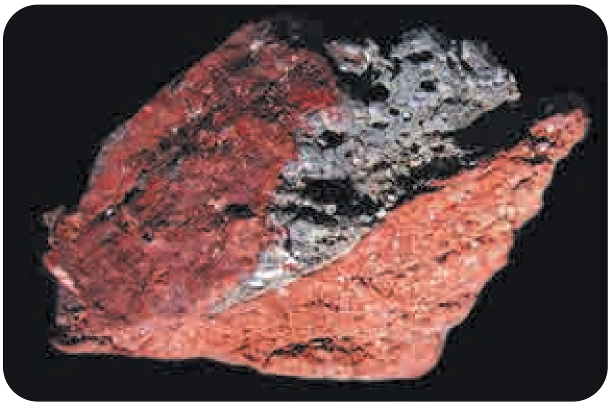


Fig. 2.4 : Oxidation in basalt

vi) **Reduction :** It is the reverse process of oxidation and usually occurs in waterlogged (anaerobic) conditions in the absence of free oxygen (anoxic conditions).

e.g. The reduction of iron to ferrous state makes it more soluble and mobile, hence water from bogs is stained brown by oxides. These oxides are further reduced in the presence of anaerobic bacteria and then converted back to ferric state as the water is aerated and the ferric oxide precipitates as Hematite (Fe_2O_3).

Table 2.1 : Chemical weathering of common minerals and their products.

<table>
<tr><td>Olivine
$(Mg,Fe)_2SiO_4$</td><td>Magnesium dissolves as bicarbonate, iron is oxidized to hematite, silica leached away.</td></tr>
<tr><td>Augite
$(Ca,Na,Mg,Fe,Mn,Ti,Al)_2(Al,Si)_2O_6$</td><td rowspan="2">Magnesium and calcium dissolve as bicarbonate, alumina and silica form clay on hydrolysis. Under extreme oxidizing conditions, silica is leached away and alumina changes to aluminium hydroxide.</td></tr>
<tr><td>Hornblende
$(Ca,Na)_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$</td></tr>
<tr><td>Biotite
$K(Mg,Fe)_3AlSi_3O_{10}(OH,F)_2$</td><td>Potassium dissolves as bicarbonate, alumina and silica form clay on hydrolysis.</td></tr>
<tr><td>Orthoclase
$KAlSi_3O_8$</td><td>Potassium dissolves as bicarbonate, alumina and silica form clay on hydrolysis, but under extreme oxidising conditions, silica is leached away and alumina changes to aluminum hydroxide and soluble silica.</td></tr>
<tr><td>Muscovite
$KAl_2(AlSi_3O_{10})(F,OH)_2$</td><td>Potassium dissolves as bicarbonate, alumina and silica form clay on hydrolysis, but under extreme oxidizing condition, silica is leached away and alumina changes to aluminum hydroxide and soluble silica. It is also a highly resistant mineral and generally does not decompose (Fig.2.5)</td></tr>
<tr><td>Quartz
SiO_2</td><td>Chemically, it is highly resistant and under normal conditions of weathering, remains unchanged. Under special conditions, quartz may be dissolved by alkaline waters.</td></tr>
</table>

2.3 Susceptibility of minerals to chemical weathering :

Minerals within rocks, exhibit varying degrees of resistance to chemical weathering. All minerals in the rock do not decompose with the same degree. Some are more susceptible, while others are resistant to chemical weathering. Apart from carbonate minerals, those minerals which crystallise from magma at higher temperature are more susceptible to decomposition. Susceptibility decreases in minerals which crystallise at lower temperatures. This leads to a regular order of susceptibility of minerals with respect to chemical weathering. Common rock forming minerals are arranged according to their resistance to chemical weathering, as shown in Goldich stability series (Fig.2.5).

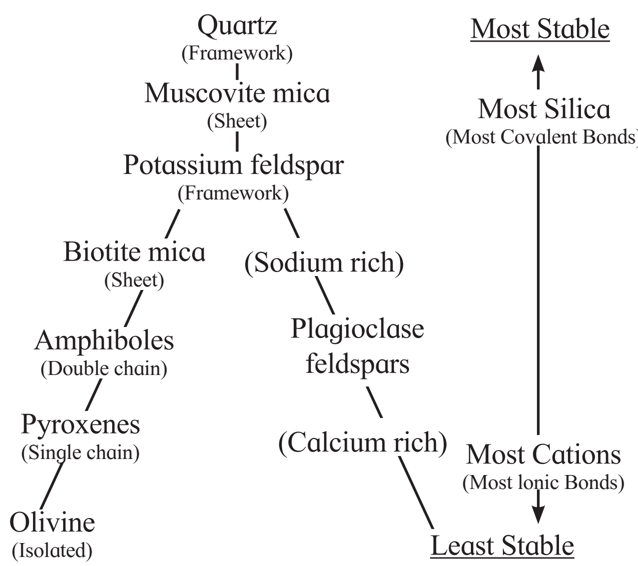


Fig. 2.5 : Goldich stability series

2.4 Factors affecting chemical weathering :

Weathering is affected by variations in factors like nature of rocks, climate, slope and surface area with time.

i) Nature of rocks : Under similar conditions of weathering, different rocks respond differently, e.g., if granite and sandstone are exposed to similar weathering conditions, granite will be more resistant to weathering than sandstone. This is because gases and moisture find easy pathways into the rock mass through the pores in sandstone. Some minerals in the rocks have different weathering susceptibility according to the Goldich stability series.

ii) Climate : The process of weathering is intimately related to the climatic conditions prevailing in an area. Same type of rocks, if exposed to different climatic conditions, show different trends and degrees of weathering. Cold and humid conditions favour both chemical and mechanical weathering, while totally dry and cold climates neither favour chemical nor mechanical weathering. In hot and humid climates, chemical weathering processes predominate, while in hot and arid climate, mechanical weathering is pronounced.

iii) Slope : Steep slope facilitates removal of broken rocks and loose material under the influence of gravity. Rocks on mountain slopes devoid of vegetation are more susceptible to weathering.

iv) Surface area : Greater the surface area, faster will be the decomposition. A non-fractured massive rock will naturally decompose rather slowly.

2.5 Spheroidal weathering :

A common feature observed along many road cuts (specially in Deccan basalt region) is the occurrence of a number of spheroidal or ellipsoidal rock boulders, surrounded by a number of concentric rings of weathered rock material (Fig. 2.6). In many cases, the central boulders present are hard and compact and show very less alteration.

Spheroidal weathering is typically shown by basaltic rocks, where three sets of joints are mutually perpendicular to each other. Such joints divide the entire outcrop of rocks into a number of cuboidal blocks of various sizes. Percolating groundwater surrounds each block and chemical decomposition starts from all sides of the block. The rate of decomposition is not the same everywhere. Along the corners of such blocks, water attacks from three sides. Along the edges, weathering occurs from two sides and along the surface only from one side. As a result, decomposition is relatively fast along the corners and slow along the surfaces. Therefore the shell of the decomposed rock is thickest along the corners and thinnest along the surface. The products of decomposition swell with increase in volume and in due course, the outer decomposed layer detaches itself from the inner undecomposed rock. The inner rock is now subjected to the same process. Repetition of this process develops a number of rings and the size of the inner undecomposed rock becomes smaller and smaller and at the same time it becomes more and more spheroidal. This unaltered rock at the centre is known as residual boulder or core stone. The entire process is known as spheroidal weathering. The iron oxides released by decomposition give a reddish or yellowish tinge to the outer decomposed shell.

Fig. 2.6 : Spheroidal weathering in basalt

2.6 Genesis of soil :

The final product of weathering is formation of soil. Soil is an important natural component of the Earth and its ecosystem. It is an admixture of organic matter, minerals, gases, liquids and organisms that together support life. Study of soil is called as 'Pedology' and the layer of soil on the surface of the Earth is known as 'Pedosphere'.

Geologists define soil as a naturally occurring material which is in the form of layers or horizons of varying thicknesses. These layers have evolved from the surface weathering of the Earth's crustal material. A typical soil consists of 50% solids (45% mineral and 5% organic matter), and ~50% voids (or pores) which are occupied by water and air.

2.6.1Soil Profile :

Given sufficient time, an undifferentiated soil will evolve as a soil profile. It consists of several layers, referred to as soil horizons. The vertical exposure of soil horizons is referred to as a 'Soil Profile'. These horizons differ in their texture, structure, density, porosity, consistency, colour and reactivity. The horizons show variable thickness and generally lack sharp boundaries. The biological influences on soil properties are strongest near the surface. The chemical influences decrease with depth. Mature soil profiles typically include three basic horizons: A, B, and C. The living component of the soil is largely confined to the O, A and B horizons (Fig. 2.7).

2.6.2 Soil Horizons :

O Horizon : It consists of thin organic layers of decaying plants, animal tissues and is saturated by water. It is the top layer in places covered by vegetation.

A Horizon : It is the top soil and consists of mostly minerals from parent material with organic matter. It is also called as mineral horizon. This is generally the most productive layer of the soil. Conservation efforts are focussed here.

B Horizon : It is rich in minerals that have leached from horizons 'O' and 'A'. The horizon is usually lighter in colour, dense and low in organic matter. It is the zone of accumulation of clays and colloids.

C Horizon : It is the zone of soil consisting of partly decomposed bedrock underlying the B horizon. It grades downwards into fresh, unweathered bedrock.

D or R Horizon : Below the C horizon, the unweathered rock basement is present. This is the bedrock horizon.

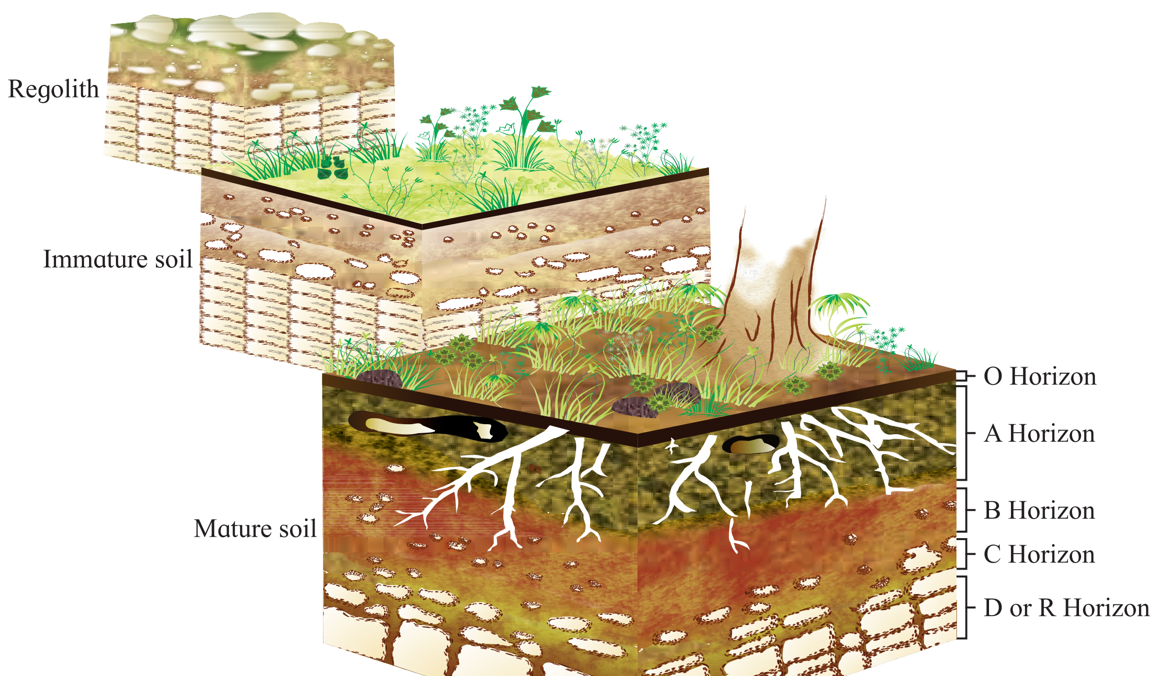


Fig. 2.7 : Soil profile development

2.6.3 Factors affecting soil formation :

Soil formation is influenced by five main factors that are intertwined in the evolution of a soil. They are: climate, organisms, topography (relief), parent material and time.

i) **Climate :** The principal climatic variables influencing soil formation are effective precipitation and temperature. Both affect the rates of chemical, physical, and biological processes. In humid tropical climates, rate of weathering and erosion is rapid.

ii) **Organisms :** Plant and animal activity produces humic acids that are powerful weathering agents.

Plants can physically as well as chemically break down the rocks. Plants stabilize soil profiles. Animal and human activites tend to increase soil erosion, by disturbing the soil profile.

iii) **Topography :** The topography or relief is characterized by the slope, elevation and orientation of the terrain. Steep slopes encourage rapid soil loss. Therefore, soils on steep terrain are shallow, poorly developed as compared to soils on gentle or flat terrain.

iv) **Parent material :** The mineral material from which a soil forms is called parent material. As the parent material is chemically and physically weathered, transported, deposited and precipitated, it is transformed into a soil.

v) **Time :** Typical reaction rates are slow, the longer a rock unit has been exposed, the more it is likely to be weathered.

2.7 Soil erosion and conservation :

Soil erosion is the displacement of the upper layer of soil. This layer is most fertile because it contains most organic and nutrient rich materials. Soil erosion takes place due to factors such as water, wind and tillage of farmland.

Soil conservation is the prevention of soil loss by erosion or reduced fertility caused by over-usage, acidification, salinisation or other chemical soil contamination processes. Slash-and-burn and other unsustainable methods of subsistence farming are practiced in some lesser developed areas. A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification.

Soil conservation is the name given to a handful of techniques aimed at preserving soil. Soil loss and loss of soil fertility re-mediated by methods of conservation like reforestation, crop rotation, contour ploughing and building terraces.

Do you know?

Black soils of Maharashtra : The soils of Maharashtra are residual, derived from the underlying basalt. These are generally called as black cotton soil (regur) which is clayey, rich in iron and moisture retentive, but poor in nitrogen and organic matter. Black soils of upland are of low fertility but they are darker, deeper, and richer in valleys. Due to their high fertility and retentivity of moisture, black soils are widely used for producing several important crops.

Activity :

1) Take a photograph of a soil profile along a road cutting pit or excavation and draw the vertical soil profile digram and describe.
2) Visit nearby soil testing lab and gather information about various properties of soils.

Summary :

- The exogenic and endogenic processes govern the Earth's surface. These processes are continuously operating as rock cycle (described in chapter 4).
- Study of soil helps to understand the composition of parent rocks and the long term climates experienced by it.

EXERCISE

Q. 1. Fill in the blanks :

1) The process of freezing and thawing of water due to temperature changes and its effect on rocks is known as................. .

2) Vertical exposure of soil horizons is referred to as a................. .

Q. 2. Fill in the blanks using the correct options :

1) Development of spheroidal weathering is independent of ....
   a) rock type
   b) chemical decomposition
   c) percolating water
   d) joints mutually perpendicular to each other.

2) Mechanical weathering is more pronounced in .... climate.
   a) hot and humid   b) hot and arid
   c) cold and humid   d) wet and humid

3) The most common type of mechanical weathering is..............
   a) sheeting
   b) thermal expansion and contraction
   c) oxidation
   d) action of burrowing organisms

4) The mineral calcite in limestone is transported in water during.............. process.
   a) oxidation   b) reduction
   c) dissolution   d) frost action

Q. 3. Choose the correct alternative :

1) Statement that is true regarding chemical weathering.
   i) All the minerals in the rock decompose with the same intensity/rate
   ii) Minerals crystallizing at lower temperature are more susceptible to decomposition.
   iii) Minerals crystallizing at higher temperature are more susceptible to decomposition.
   iv) Minerals in the rock offer same degree of resistance to chemical weathering

2) Which of the following statement is incorrect?
   i) Plants stabilize soil profiles.
   ii) Animals tend to increase erosion.
   iii) Steep slopes encourage rapid soil loss.
   iv) Study of soil is called 'Pedosphere'.

Q. 4. Find the odd one out :

1) i) The weathered product may remain *in-situ* or get transported.
   ii) Process of freezing and thawing of water gives rise to frost wedging.
   iii) Thermal effect is more common in arid, semi-arid and desert regions.
   iv) Soil is a naturally occurring material which is in the form of layers .
   a) i   b) ii   c) iii   d) iv

2) i) Temperature, wind, basalt, glaciers, organisms.
   ii) Dissolution, hydration, hydrolysis, carbonation, erosion.
   iii) O Horizon, A Horizon, B Horizon, C Horizon.
   iv) Cracks, fractures, cavities, joints.
   a) i   b) ii   c) iii   d) iv

Q. 5. Give geological terms for the following :

1) Parent material from which soil is formed.

2) Mechanical weathering of rocks due to freezing and thawing of water within fissures or cracks.

3) The process by which layers peel away from the outer surface of the exposed rock.

4) Type of weathering resulting in the formation

of concentric rings of weathered rock material surrounding a central boulder.

Q. 6. Answer in brief :

1) Discuss the role of topography in soil formation.
2) How are processes of mechanical weathering and chemical weathering complementary to each other?

Q. 7. Answer in detail :

1) Explain the process of oxidation and reduction in chemical weathering.
2) Describe the factors affecting weathering.

Q. 8. Read the following passage and answer the questions :

Panchgani is well-known for its impressive tableland, string of mesas and is a popular getaway for tourists from Mumbai and Pune. The flat-topped hills are the result of differential erosion The mesas and the tableland are built of flat-lying caprocks and are scarp-bound on all sides. The ferricrete duricrusts (or laterites) act as the caprock. The mesa tops are featureless. There is evidence of pseudo-karstic activity and mechanical disintegration of the crust rim. The broadly accordant heights of the mesas suggest that they were formed due to the breaching and fragmentation of an extensive lateritised surface and subsequent back-wearing of the cliffs The formation of mesas appears to be a three stage process: formation of lateritised surface, breaching and fragmentation of the lateritised surface by stream incision, and slope retreat and circum-denudation of isolated patches.

(Source : *Kale V. S, 2014 in Kale (edited).*)

1) Describe the process by which flat- topped hills and tableland have been created in Panchgani area.
2) What is the role of stream incision in creating a typical landscape of the Panchgani and similar such areas of Maharashtra?
3) Why does the author consider the formation of mesas as a three stage process.