Soil Nutrient Management - V

Comprehensive Course on Agriculture Optional - Paper I

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AGRICULTURE OPTIONAL

Complete Course on Agriculture (Paper I)

for UPSC CSE/IFoS/ State Service Exams

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MAJOR UNITS OF THE AGRICULTURE (PAPER I)
1. ECOLOGY AND ENVIRONMENTAL SCIENCE
2. AGRONOMY
3. WEED SCIENCE
4. FORESTRY
5. SOIL AND NUTRIENT MANAGEMENT
6. SOIL AND WATER CONSERVATION
7. AGRICULTURAL ECONOMICS
8. AGRICULTURAL EXTENSION

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UNIT 5.0 SOIL AND NUTRIENT MANAGEMENT
Topics
5.1 Soil- physical, chemical and biological properties. 5.2 Processes and factors of soil formation. 5.3 Soils of India. 5.4 Mineral and organic constituents of soils and their role in maintaining soil productivity. 5.5 Essential plant nutrients and other beneficial elements in soils and plants. 5.6 Principles of soil fertility, soil testing and fertilizer recommendations. 5.7 Integrated nutrient management. 5.8 Bio fertilizers. 5.9 Losses of nitrogen in soil, nitrogen-use efficiency in submerged rice soils, nitrogen fixation in soils. 5.10 Efficient phosphorus and potassium use. 5.11 Problem soils and their reclamation. 5.12 Soil factors affecting greenhouse gas emission.

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5.2 PROCESSES AND FACTORS OF SOIL FORMATION

The soil formation is the process of two consecutive stages.

- The weathering of rock (R) into Regolith
- The formation of true soil from Regolith
- The evolution of true soil from regolith takes place by the combined action of soil forming factors and processes.

The first step is accomplished by weathering (disintegration & decomposition)

The second step is associated with the action of Soil Forming Factors.

Rock → **Regolith** → **True soil**

Dokuchaiev (1889) established that the soils develop as a result of the action of soil forming factors.

$$S = f(P, Cl, O)$$

Further, Jenny (1941) formulated the following equation

$$S = f(Cl, O, R, P, T, \dots)$$

Where,

Cl – environmental climate

O – Organisms and vegetation (biosphere)

R – Relief or topography

P – Parent material

T- Time

... - additional unspecified factors

The five soil forming factors, acting simultaneously at any point on the surface of the earth, to produce soil

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Two groups of soil forming factors.

- **Passive**: i) Parent material, ii) Relief, iii) Time
- **Active:** iv) Climate, v) Vegetation & organism

Passive Soil forming factors

The passive soil forming factors are those which represent the source of soil forming mass and conditions affecting it. These provide a base on which the active soil forming factors work or act for the development of soil.

1. **Parent Material**

- It is that mass (consolidated material) from which the soil has formed.
- Two groups of parent material

2. **Sedentary**

- Formed in original place.
- It is the residual parent material. The parent material
- differ as widely as the rocks.

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- **Colluvium:** It is the poorly sorted materials near the base of strong slopes transported by the action of gravity.
- **Alluvium:** The material transported and deposited by water is, found along major stream courses at the bottom of slopes of mountains and along small streams flowing out of drainage basins.
- **Lacustrine:** Consists of materials that have settled out of the quiet water of lakes.
- **Moraine:** Consists of all the materials picked up, mixed, disintegrated, transported and deposited through the action of glacial ice or of water resulting primarily from melting of glaciers.
- **Loess or Aeolian:** These are the wind-blown materials. When the texture is silty - loss; when it is sand.
- **Eolian:** The soils developed on such transported parent materials bear the name of the parent material; viz. Alluvial soils from alluvium, colluvial soils from colluvium etc. In the initial stages, however, the soil properties are mainly determined by the kind of parent material.

Endodynamomorphic soils: With advanced development and excessive leaching, the influence of parent material on soil characteristics gradually diminishes. There are soils wherein the composition of parent material subdues the effects of climate and vegetation. These soils are temporary and persist only until the chemical decomposition becomes active under the influence of climate and vegetation.

Ectodynamomorphic soils: Development of normal profile under the influence of climate and vegetation. Soil properties as influenced by parent material: Different parent materials affect profile development and produce different soils, especially in the initial stages.

2. Relief or Topography: The relief and topography sometimes are used as synonymous terms. They denote the configuration of the land surface. The topography refers to the differences in elevation of the land surface on a broad scale. The prominent types of topography designations, as given in FAO Guidelines (1990) are:

Land surface	with slopes of
1 Flat to Almost flat	0 – 2 %
2 Gently undulating	2 - 5 %
3 Undulating	5 – 10 %
4 Rolling	10 – 15 %
5 Hilly	15 –3 0 %
6 Steeply dissect	> 30 % with moderate range of elevation (<300 m)
7 Mountainous	> 30% with great range of elevation (>300 m)

3. Time: Soil formation is a very slow process requiring thousands of years to develop a mature pedon. The period taken by a given soil from the stage of weathered rock (i.e. regolith) up to the stage of maturity is considered as time. The matured soils mean the soils with fully developed horizons (A, B, C). It takes hundreds of years to develop an inch of soil. The time that nature devotes to the formation of soils is termed as Pedologic Time. It has been observed that rocks and minerals disintegrate and/or decompose at different rates; the coarse particles of limestone are more resistant to disintegration than those of sandstone. However, in general, limestone decomposes more readily than sandstone (by chemical weathering).

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Weathering stages in soil formation	Stages Characteristic
1 Initial	- Un weathered parent material
2 Juvenile	-Weathering started but much of the original material still un weathered
3 Virile	- Easily weatherable minerals fairly decomposed; clay content increased, slowly weatherable minerals still appreciable.
4 Senile	-Decomposition reaches at a final stage; only most resistant minerals survive.
5 Final	-Soil development completed under prevailing Environments.

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- The soil properties also change with time, for instance nitrogen and organic matter contents increase with time provided the soil temperature is not high.
- CaCO3 content may decrease or even lost with time provided the climatic conditions are not arid
- In humid regions, the H+ concentration increases with time because of chemical weathering.

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B. Active Soil Forming Factors

The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation. These factors are climate and vegetation (biosphere).

1. Climate

Climate is the most significant factor controlling the type and rate of soil formation. The dominant climates recognized are:

1. **Arid climate:** The precipitation here is far less than the water-need. Hence the soils remain dry for most of the time in a year.
2. **Humid climate:** The precipitation here is much more than the water need. The excess water results in leaching of salt and bases followed by translocation of clay colloids.
3. **Oceanic climate:** Moderate seasonal variation of rainfall and temperature.
4. **Mediterranean climate:** The moderate precipitation. Winters and summers are dry and hot.
5. **Continental climate:** Warm summers and extremely cool or cold winters.
6. **Temperate climate:** Cold humid conditions with warm summers.
7. **Tropical and subtropical climate:** Warm to hot humid with isothermal conditions in the tropical zone.

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Climate affects the soil formation directly and indirectly: Directly, climate affects the soil formation by supplying water and heat to react with parent material. Indirectly, it determines the fauna and flora activities which furnish a source of energy in the form of organic matter. This energy acts on the rocks and minerals in the form of acids, and salt are released. The indirect effects of climate on soil formation are most clearly seen in the relationship of soils to vegetation. Precipitation and temperature are the two major climatic elements which contribute most to soil formation.

Precipitation: Precipitation is the most important among the climatic factors. As it percolates and moves from one part of the parent material to another. It carries with it substances in solution as well as in suspension. The substances so carried are re deposited in another part or completely removed from the material through percolation when the soil moisture at the surface evaporates causing an upward movement of water. The soluble substances move with it and are translocated to the upper layer. Thus rainfall brings about a redistribution of substances both soluble as well as in suspension in soil body.

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Temperature

- Temperature is another climatic agent influencing the process of soil formation.
- High temperature hinders the process of leaching and causes an upward movement of soluble salts.
- High temperature favors rapid decomposition of organic matter and increase microbial activities in soil while low temperatures induce leaching by reducing evaporation and there by favour the accumulation of organic matter by slowing down the process of decomposition.
- Temperature thus controls the rate of chemical and biological reactions taking place in the parent material.
- Jenney (1941} computed that in the tropical regions the rate of weathering proceeds three times faster than in temperate regions and nine times faster than in arctic.

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Organism & Vegetation

Organism

- The active components of soil ecosystem are plants, animals, microorganisms and man.
- The role of microorganisms in soil formation is related to the humification and mineralization of vegetation
- The action of animals especially burrowing animals to dig and mix-up the soil mass and thus disturb the parent material
- Man influences the soil formation through his manipulation of natural vegetation, agricultural practices etc.
- Compaction by traffic of man and animals decrease the rate of water infiltration into the
- soil and thereby increase the rate of runoff and erosion.

Vegetation

- The roots of the plants penetrate into the parent material and act both mechanically and chemically.
- They facilitate percolation and drainage and bring about greater dissolution of minerals through the action of CO_2
- and acidic substances secreted by them.
- The decomposition and humification of the materials further adds to the solubilization of minerals
- Forests – reduces temperature, increases humidity, reduce evaporation and increases precipitation.
- Grasses reduce runoff and result greater penetration of water in to the parent material.

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Active and Passive factors of soil formation

	Active factors	Passive factors
	The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation.	The passive soil forming factors are those which represent the source of soil forming mass and conditions affecting it.
	These are climate and vegetation (Biosphere)	These are parent material, time and relief or topography

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Soil Forming Processes: The pedogenic processes, although slow in terms of human life, yet work faster than the geological processes in changing lifeless parent material into true soil full of life.

- The pedogenic processes are extremely complex and dynamic involving many chemical and biological reactions, and usually operate simultaneously in a given area.
- One process may counteract another, or two different processes may work simultaneously to achieve the same result.
- Different processes or combination of processes operate under varying natural
- environment.
- The collective interaction of various soil forming factors under different environmental conditions set a course to certain recognized soil forming processes.

- The basic process involved in soil formation includes the following.
- Gains or Additions of water, mostly as rainfall, organic and mineral matter to the soil.
- Losses of the above materials from the soil.
- Transformation of mineral and organic substances within the soil.
- Translocation or the movement of soil materials from one point to another within the soil.
- It is usually divided into movement of solution (leaching) and movement in suspension (eluviation) of clay, organic matter and hydrous oxides

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A. Fundamental Soil forming Processes

Humification: Humification is the process of transformation of raw organic matter into humus. It is extremely a complex process involving various organisms. First, simple compounds such as sugars and starches are attacked followed by proteins and cellulose and finally very resistant compounds, such as tannins, are decomposed and the dark coloured substance, known as humus, is formed.

Eluviation: It is the mobilization and translocation of certain constituent's viz. Clay, Fe_2O_3, Al_2O_3, SiO_2, humus, $CaCO_3$, other salts etc. from one point of soil body to another. Eluviation means washing out. It is the process of removal of constituents in suspension or solution by the percolating water from the upper to lower layers. The eluviation encompasses mobilization and translocation of mobile constituents resulting in textural differences. The horizon formed by the process of eluviation is termed as eluvial horizon (A2 or E horizon). Translocation depends upon relative mobility of elements and depth of percolation.

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Illuviation: The process of deposition of soil materials (removed from the eluvial horizon) in the lower layer (or horizon of gains having the property of stabilizing translocated clay materials) is termed as Illuviation. The horizons formed by this process are termed as illuvial horizons (B-horizons, especially Bt) The process leads to textural contrast between E and Bt horizons, and higher fine: total clay ratio in the Bt horizon.

Horizonation: It is the process of differentiation of soil in different horizons along the depth of the soil body. The differentiation is due to the fundamental processes, humification, eluviation and illuviation.

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Soil Illuvation and Soil Eluvation

	Soil Illuvation	Soil Eluvation
	Illuvation is the accumulation of elevated material in lower layer is known as soil illuvation.	Eluvation is the transport of soil material from upper layer of soil to lower levels by downward precipitation of water across soil horizons.
	A soil horizon formed due to illuvation is an illuval zone or illuvial horizon.	A soil horizon formed due to eluviations is an eluvial zone or eluvial horizon.
	Illuvium includes organic matter, silicate clay and hydrous oxides of iron and aluminium	Clay depleted, contains little organic matter and high concentration of sand silt
	Dark colour soil	Light colour soil
	More fertile	Less fertile
	Rich in essential minerals	Poor in essential minerals
	Illuvation occur in B horizon	Elevation occur in E and A horizon
	Good source of organic matter	Poor source of organic matter
	Also called as WASHING IN horizon	Also called as WASHING OUT horizon

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B. Specific Soil Forming Processes

The basic pedologic processes provide a framework for later operation of more specific Processes

1. **Calcification:** It is the process of precipitation and accumulation of calcium carbonate (CaCO3) in some part of the profile. The accumulation of CaCO3 may result in the development of a calcic horizon. Calcium is readily soluble in acid soil water and/or when CO2 concentration is high in root zone.

   The process of precipitation after mobilization under these conditions is called calcification and the resulting illuviated horizon of carbonates is designated as Bk horizon (Bca).

2. **Decalcification:** It is the reverse of calcification that is the process of removal of CaCO3 or calcium ions from the soil by leaching.

3. **Podzolization;** It is a process of soil formation resulting in the formation of Podzols and Podzolic soils. In many respects, podzolization is the negative of calcification. The calcification process tends to concentrate calcium in the lower part of the B horizon, whereas podzolization leaches the entire solum of calcium carbonates. Apart from calcium, the other bases are also removed and the whole soil becomes distinctly acidic. In fact, the process is essentially one of acid leaching.

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The process operates under favourable combination of the following environments.

i) **Climate:** A cold and humid climate is most favourable for podzolization.
ii) **Parent material:** Siliceous (Sandy) material, having poor reserves of weatherable minerals, favor the operation of podzolization as it helps in easy percolation of water.
iii) **Vegetation:** Acid producing vegetation such as coniferous pines is essential
iv) **Leaching and Translocation of Sesquioxide:** In the process of decomposition of organic matter various organic acids are produced. The organic acids thus formed act with Sesquioxide and the remaining clay minerals, forming organic- Sesquioxide and organic clay complexes, which are soluble and move with the percolating water to the lower horizons (Bh, Bs).

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Aluminium ions in a water solution hydrolyze and make the soil solution very acidic. As iron and aluminium move about, the A horizon gives a bleached grey or ashy appearance.
The Russians used the term Podzols (pod means under, the zola means ash like i.e. ash-like horizon appearing beneath the surface horizon) for such soils.

To conclude, the Podzolization is a soil forming process which prevails in a cold and humid
climate where coniferous and acid forming vegetations dominate. The humus and Sesquioxide become mobile and leached out from the upper horizon s and deposited in the lower horizon.

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4. Laterization; The term laterite is derived from the word later meaning brick or tile and was originally applied to a group of high clay Indian soils found in Malabar hills of Kerala, Tamil Nadu, Karnataka and Maharashtra. It refers specifically to a particular cemented horizon in certain soils which when dried, become very hard, like a brick. Such soils (in tropics) when massively impregnated with sesquioxides (iron and aluminium oxides) to extent of 70 to 80 per cent of the total mass, are called laterites or latosols (Oxisols). The soil forming process is called Laterization or Latozation. Laterization is the process that removes silica, instead of sesquioxides from the upper layers and thereby leaving sesquioxides to concentrate in the solum.

The process operates under the following conditions.

i) **Climate:** Unlike podzolization, the process of laterization operates most favorable in warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature (25°C) throughout the year.
ii) **Natural vegetation:** The rain forests of tropical areas are favorable for the process.
iii) **Parent Material:** Basic parent materials, having sufficient iron bearing ferromagnesian minerals (Pyroxene, amphiboles, biotite and chlorite), which on weathering release iron, are congenial for the development of laterites.

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5. Gleization

The term glei is of Russian origin means blue, grey or green clay. The Gleization is a process of soil formation resulting in the development of a glei (or gley horizon) in the lower part of the soil profile above the parent material due to poor drainage condition (lack of oxygen) and where waterlogged conditions prevail. Such soils are called hydro orphic soils. The process is not particularly dependent on climate (high rainfall as in humid regions) but often on drainage conditions.

The poor drainage conditions result from:

- Lower topographic position, such as depression land, where water stands continuously at or close to the surface.
- Impervious soil parent material, and.
- Lack of aeration.

Under such conditions, iron compounds are reduced to soluble ferrous forms. The reduction of iron is primarily biological and requires both organic matter and microorganisms capable of respiring an aerobically. The solubility of Ca, Mg, Fe, and Mn is increased and most of the iron exists as Fe++ organo - complexes in solution or as mixed precipitate of ferric and ferrous hydroxides. This is responsible for the production of typical bluish to grayish horizon with mottling of yellow and or reddish brown colors.

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6. Salinization: It is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of a salty (salic) horizon. It is quite common in arid and semi-arid regions. It may also take place through capillary rise of saline ground water and by inundation with seawater in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in areas of impeded drainage.

7. Desalinization: It is the removal by leaching of excess soluble salts from horizons or soil profile (that contained enough soluble salts to impair the plant growth) by ponding water and improving the drainage conditions by installing artificial drainage network.

8. Solonization or Alkalization: The process involves the accumulation of sodium ions on the exchange complex of the clay, resulting in the formation of sodic soils (Solonetz). All cations in solution are engaged in a reversible reaction with the exchange sites on the clay and organic matter particles.

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9. Solodization or dealkalization: The process refers to the removal of Na^+ from the exchange sites. This process involves dispersion of clay. Dispersion occurs when Na^+ ions become hydrated. Much of the dispersion can be eliminated if Ca^{++} and or Mg^{++} ions are concentrated in the water, which is used to leach the soonest.

10. Pedoturbation: Another process that may be operative in soils is pedoturbation. It is the process of mixing of the soil. Mixing to a certain extent takes place in all soils. The most common types of pedoturbation are:

- **Faunal pedoturbation:** It is the mixing of soil by animals such as ants, earthworms, moles, rodents, and man himself
- **Floral pedoturbation:** It is the mixing of soil by plants as in tree tipping that forms pits and mounds
- **Argillic pedoturbation:** It is the mixing of materials in the solum by the churning process caused by swell shrink clays as observed in deep Black Cotton Soils.

5.4 Mineral and organic constituents of soils and their role in maintaining soil productivity.

Minerals

Minerals are naturally occurring solids with a definite chemical composition and crystal structure. "Solid substances composed of atoms having an orderly and regular arrangement" When molten magma solidifies, different elements present in them freely arrange in accordance with the attractive forces and geometric form. Silica tetrahedron is the fundamental building blocks for the formation of different minerals.

Different silicate minerals are ortho silicates, ino-silicates, phyllosilicates and tectosilicates. There are nonsilicate minerals also. These are different oxides, carbonates, sulphates, phosphates etc.

Minerals that are original components of rocks are called **primary minerals**. (feldspar, mica, etc.). Minerals that are formed from changes in primary minerals and rocks are called **secondary minerals (clay minerals).**

Those minerals that are chief constituents of rocks are called as essential **minerals (Feldspars, pyroxenes micas etc**) and those which are present in small quantities, whose presence or absence will not alter the properties of rocks are called accessory minerals (tourmaline, magnetite etc).

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Sr. No	Minerals	Rocks
1.	Minerals are naturally occurring inorganic solid homogeneous substance composed of atoms having an orderly and regular arrangement with definite chemical composition and a characteristic geometric form. Eg. Quartz, Orthoclase, Calcite, Olivine and Gypsum	Rocks may be defined as the mixtures of two or more minerals.
2.	Minerals are inorganic.	Rocks can contain organic matter – even fossils
3.	Minerals usually have specific shape	Rocks don't have a definite shape
4.	Minerals help in blood coagulation, in bone formation and muscle contraction, and some have nutritive value for the human body.	Rocks don't have any nutritional value.
5.	It has a regular, repeating atomic arrangement.	Rocks do not.
6.	Minerals are classified according to their chemical and physical properties, but never by the way they were formed.	The tree major categories refer to the process formation of said rocks. Igneous, sedimentary and metamorphic rocks
7.	The science that studies minerals is called mineralogy.	The science deals with the study of rocks is known as perology .

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Weathering: A process of disintegration and decomposition of rocks and minerals which are brought about by physical agents and chemical processes, leading to the formation of Regolith (unconsolidated residues of the weathering rock on the earth's surface or above the solid rocks).

(OR)

The process by which the earth's crust or lithosphere is broken down by the activities of the atmosphere, with the aid of the hydrosphere and biosphere

(OR)

The process of transformation of solid rocks into parent material or Regolith

Parent material: It is the regolith or at least it's upper portion. May be defined as the unconsolidated and more or less chemically weathered mineral material from which soil are developed.

Two basic weathering processes

Physical / mechanical

(disintegration)

Chemical

(decomposition)

In addition, another process: Biological and all these processes are work hand in hand. Depending up on the agents taking part in weathering processes, it is classified into three types.

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Weathering of Rocks

Different agents of weathering

Physical/ Mechanical
(Disintegration)

1. Physical condition of rock
2. Change in temperature
3. Action of H2O
4. Fragment & transport
5. Action of freezing
6. Alter net Wet & drying
7. Action of glaciers
8. Action of wind
9. Atmosp. electric pheno

Chemical
(Decomposition)

1. Hydration
2. Hydrolysis
3. Solution
4. Carbonation
5. Oxidation
6. Reduction

Biological
(Disintegration + Decomposition)

1. Man & animals
2. Higher plants & their roots
3. Micro organisms

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Physical weathering: The rocks are disintegrated and are broken down to comparatively smaller pieces, without producing any new substances

1. Physical condition of rocks

The permeability of rocks is the most important single factor. Coarse textured (porous) sand stone weather more readily than a fine textured (almost solid) basalt. Unconsolidated volcanic ash weather quickly as compared to unconsolidated coarse deposits such as gravels.

2. Action of Temperature: The variations in temperature exert great influence on the disintegration of rocks.

- During day time, the rocks get heated up by the sun and expand. At night, the
- temperature falls and the rocks get cooled and contract.
- This alternate expansion and contraction weaken the surface of the rock and crumbles it because the rocks do not conduct heat easily.
- The minerals within the rock also vary in their rate of expansion and contraction
- The cubical expansion of quartz is twice as feldspar
- Dark coloured rocks are subjected to fast changes in temperature as compared to
- light coloured rocks
- The differential expansion of minerals in a rock surface generates stress between the
- heated surface and cooled un expanded parts resulting in fragmentation of rocks.
- This process causes the surface layer to peel off from the parent mass and the rock
- ultimately disintegrates. This process is called **Exfoliation**

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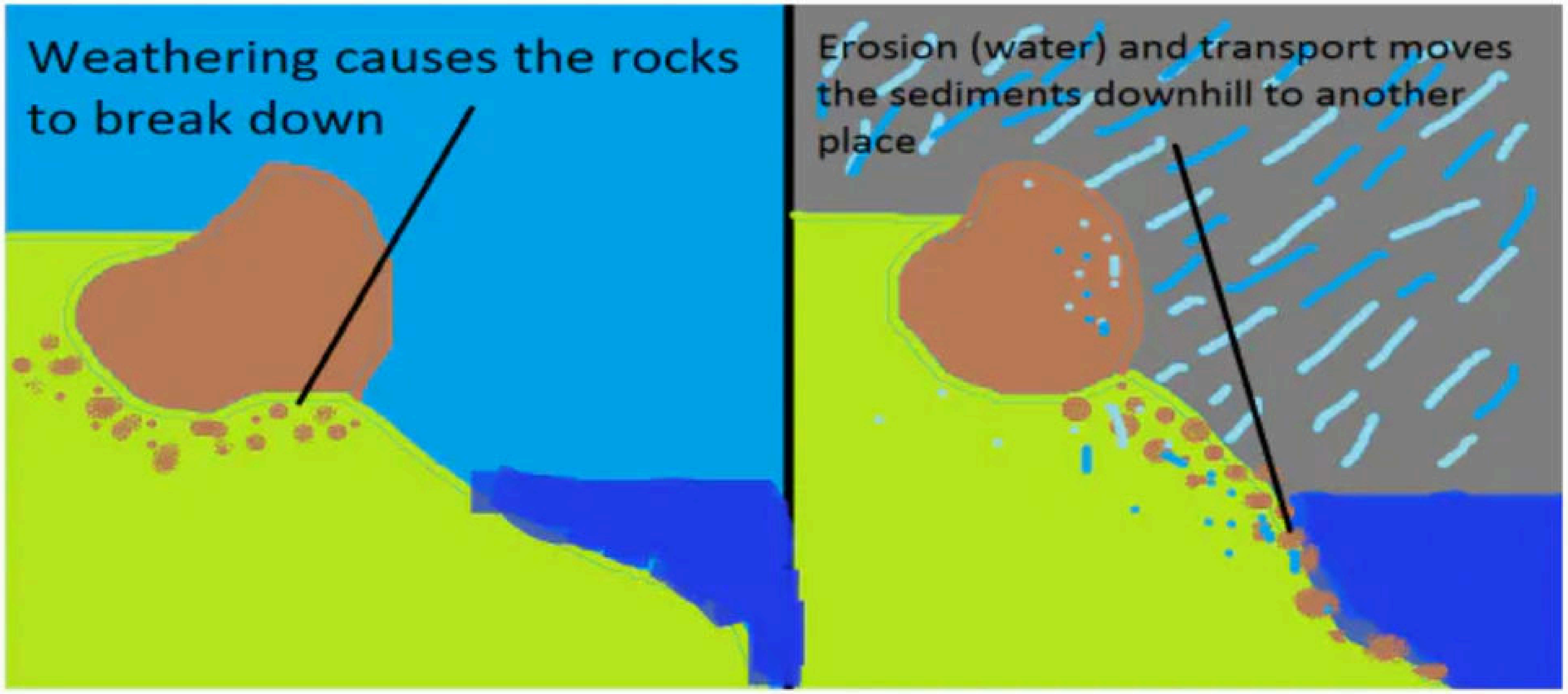
3. Action of Water: Water acts as a disintegrating, transporting and depositing agent.

i) **Fragmentation and transport:**

- Water beats over the surface of the rock when the rain occurs and starts flowing towards the ocean
- Moving water has the great cutting and carrying force.
- It forms gullies and ravines and carries with the suspended soil material of variable sizes.
- Transporting power of water varies. It is estimated that the transporting power of stream varies as the sixth power of its velocity i.e. the greater the speed of water, more is the transporting power and carrying capacity.



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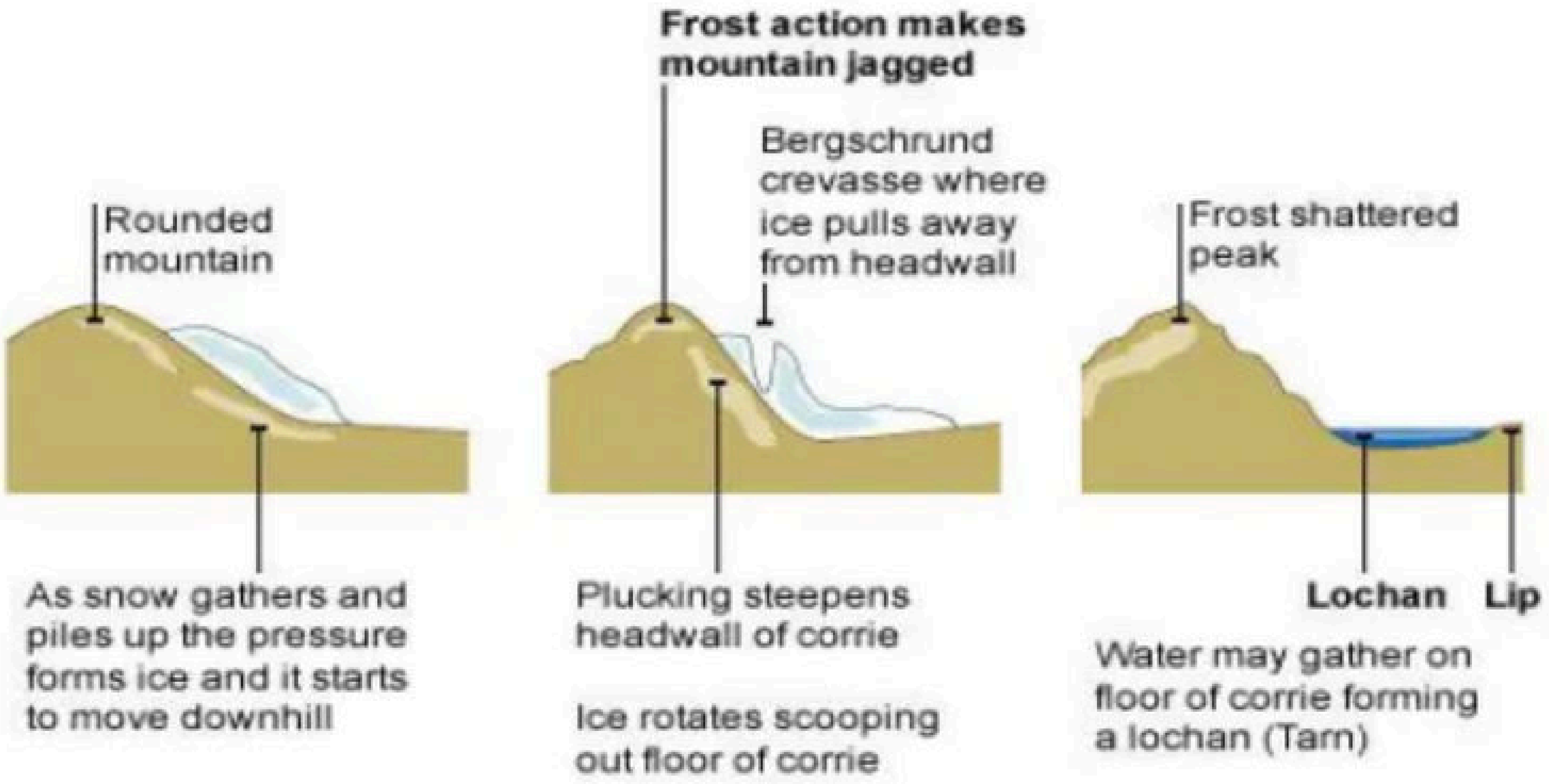
ii) Action of freezing

- Frost is much more effective than heat in producing physical weathering
- In cold regions, the water in the cracks and crevices freezes into ice and the volume increases to one tenth.

As the freezing starts from the top there is no possibility of its upward expansion. Hence, the increase in volume creates enormous out ward pressure which breaks apart the rocks



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iii) Alternate wetting and Drying

- Some natural substances increase considerably in volume on wetting and shrink on drying. e.g. smectite, montmorilonite
- During dry summer/ dry weather – these clays shrink considerably forming deep cracks or wide cracks.
- On subsequent wetting, it swells.
- This alternate swelling and shrinking/ wetting or drying of clay enriched rocks make them loose and eventually breaks

iv) Action of glaciers

- In cold regions, when snow falls, it accumulates and change into a ice sheet.
- These big glaciers start moving owing to the change in temperature and/or gradient.
- On moving, these exert tremendous pressure over the rock on which they pass and carry the loose materials
- These materials get deposited on reaching the warmer regions, where its movement stops with the melting of ice

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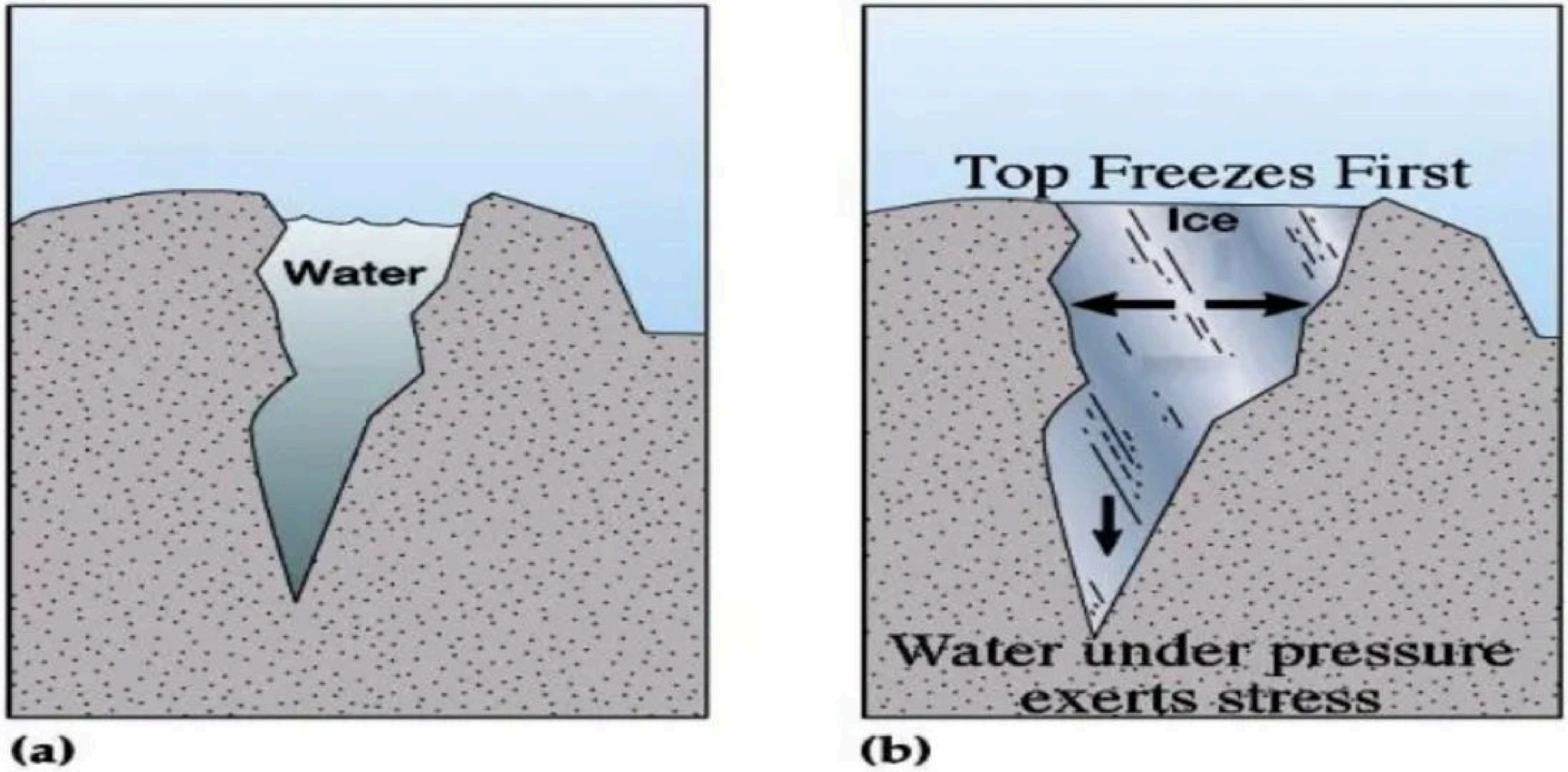

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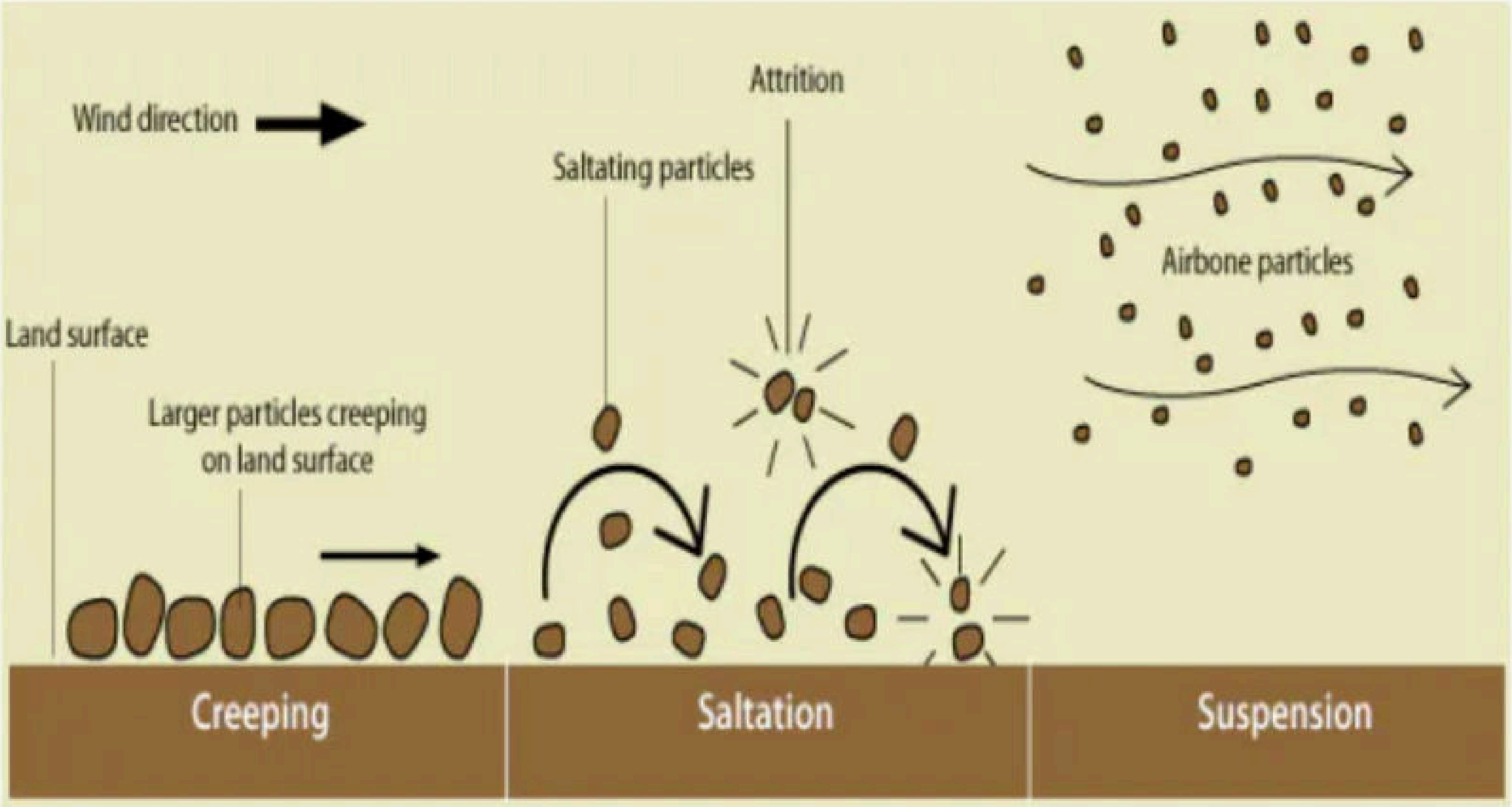
4. Action of wind

Wind has an erosive and transporting effect. Often when the wind is laden with fine material viz., fine sand, silt or clay particles, it has a serious abrasive effect and the sand laden winds itch the rocks and ultimately breaks down under its force. The dust storm may transport tons of material from one place to another. The shifting of soil causes serious wind erosion problem and may render cultivated land as degraded (e.g) Rajasthan deserts



5. Atmospheric electrical phenomenon

It is an important factor causing break down during rainy season and lightning breaks up rocks and or widens cracks.

Chemical Weathering: Decomposition of rocks and minerals by various chemical processes is called chemical weathering. It is the most important process for soil formation. Chemical weathering takes place mainly at the surface of rocks and minerals with disappearance of certain minerals and the formation of secondary products (new materials). This is called **chemical transformation.**

Feldspar + water $\rightarrow$ clay mineral + soluble cations and anions

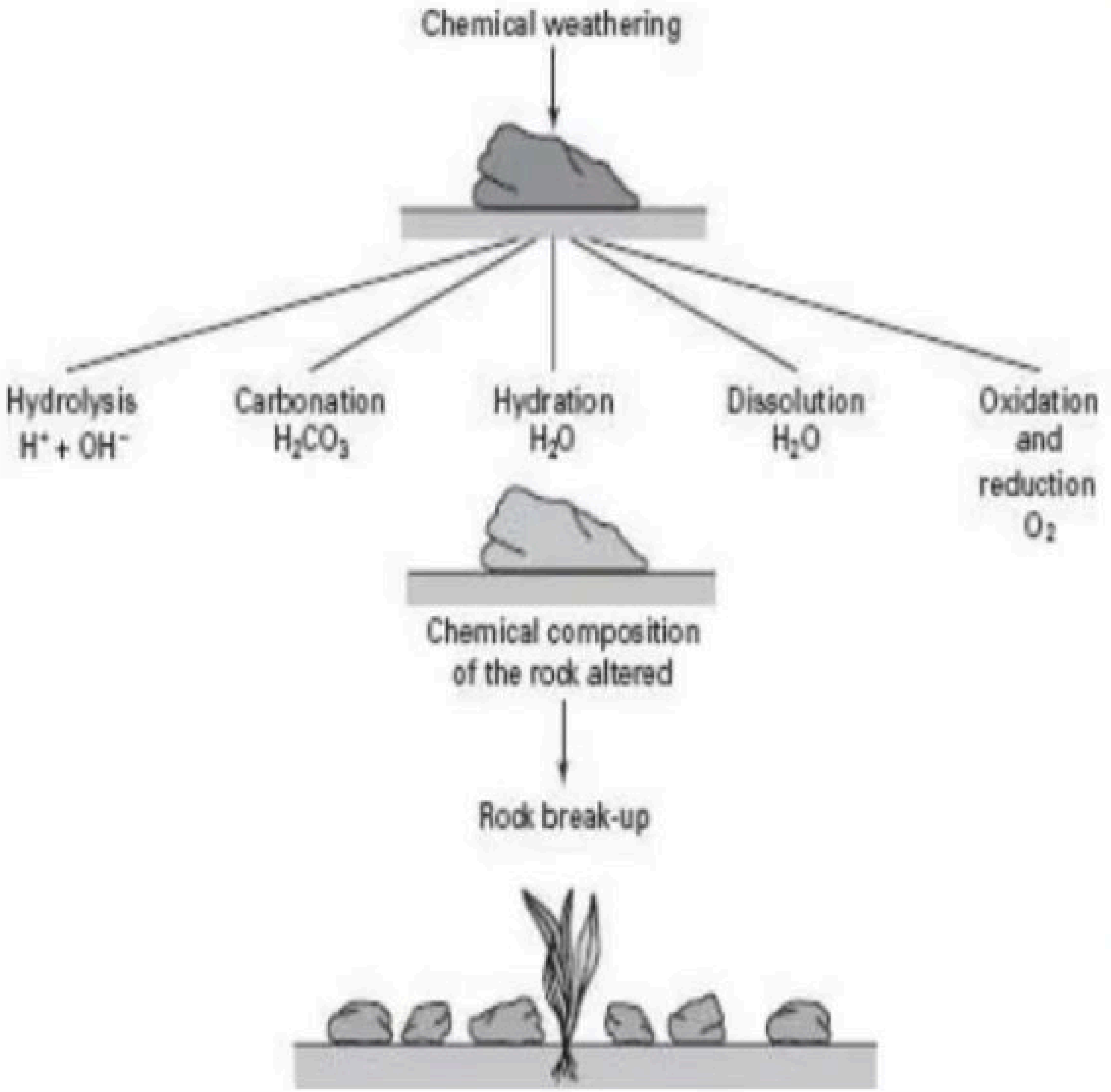
Chemical weathering becomes more effective as the surface area of the rock increases.

Since the chemical reactions occur largely on the surface of the rocks, therefore the smaller the fragments, the greater the surface area per unit volume available for reaction.

The effectiveness of chemical weathering is closely related to the mineral composition of rocks. (e.g) quartz responds far slowly to the chemical attack than olivine or pyroxene.

Chemical Processes of weathering:

1. Hydration: Chemical combination of water molecules with a particular substance or mineral leading to a change in structure. Soil forming minerals in rocks do not contain any water and they undergo hydration when exposed to humid conditions. Up on hydration there is swelling and increase in volume of minerals. The minerals loose their luster and become soft. It is one of the most common processes in nature and works with secondary minerals, such as aluminium oxide andiron oxide minerals and gypsum.



Example:

2Fe2O3+ 3HOH → 2Fe2O3.3H2O

(Haematite) (red) (Limonite) (yellow)

2. Hydrolysis: Most important process in chemical weathering. It is due to the dissociation of H_2O into H^+ and OH^- ions which chemically combine with minerals and bring about changes, such as exchange, decomposition of crystalline structure and formation of new compounds. Water acts as a weak acid on silicate minerals.

$$KAlSi_3O_8 + H_2O \longrightarrow HAlSi_3O_8 + KOH$$

(Orthoclase) → (Acid silt clay)

3. Solution: Some substances present in the rocks are directly soluble in water. The soluble substances are removed by the continuous action of water and the rock no longer remains solid and form holes, rills or rough surface and ultimately falls into pieces or decomposes. The action is considerably increased when the water is acidified by the dissolution of organic and inorganic acids. (e.g) halites, NaCl

$NaCl + H_2O \longrightarrow Na^+, Cl^-, H_2O$ (dissolved ions with water)

4. Carbonation: Carbon di oxide when dissolved in water it forms carbonic acid.

$$2H_2O + CO_2 \rightarrow H_2CO_3$$

This carbonic acid attacks many rocks and minerals and brings them into solution. The carbonated water has an etching effect up on some rocks, especially lime stone. The removal of cement that holds sand particles together leads to their disintegration.

$$\underset{\text{(Calcite) slightly soluble}}{CaCO_3 + H_2CO_3} \rightarrow \underset{\text{(Ca bi carbonate) readily soluble}}{Ca(HCO_3)_2}$$

5. Oxidation: The process of addition and combination of oxygen to minerals. The absorption is usually from O_2dissolved in soil water and that present in atmosphere. The oxidation is more active in the presence of moisture and results in hydrated oxides. (e.g) minerals containing Fe and Mg

$$4FeO \text{ (Ferrous oxide)} + O_2 \rightarrow 2Fe_2O_3 \text{ (Ferric oxide)}$$

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6. Reduction: The process of removal of oxygen and is the reverse of oxidation and is equally important in changing soil colour to grey, blue or green as ferric iron is converted to ferrous iron compounds. Under the conditions of excess water or water logged condition (less or no oxygen), reduction takes place.

$$2Fe_2O_3 \text{ (Haematite)} - O_2 \longrightarrow 4FeO \text{ (Ferrous oxide) - reduced form}$$

In conclusion, during chemical weathering igneous and metamorphic rocks can be regarded as involving destruction of primary minerals and the production of secondary minerals.
In sedimentary rocks, which is made up of primary and secondary minerals, weathering acts initially to destroy any relatively weak bonding agents (FeO) and the particles are freed and can be individually subjected to weathering.

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Physical weathering and Chemical weathering

Sr. No	Physical weathering	Chemical weathering
1.	It is the disintegration of rock, mineral and soil aggregates by the mechanical process.	It is decomposition of rock, soil and other minerals by biochemical processes.
2.	Cold and very dry environment	Wet and hot environment
3.	Disaggregation or disintegration on rocks.	Decomposition of minerals and rocks
4.	Physical change	Chemical change
5.	Agents of weathering are pressure, temperature, water, wind, gravity etc	Agents of weathering are carbon dioxide, water, oxygen, living organisms and acid rain.
6.	No change in composition of parent material	change in composition of parent material
7.	Stability of the rocks decreases	Stability of the rocks increases

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Biological Weathering

Unlike physical and chemical weathering, the biological or living agents are responsible for both decomposition and disintegration of rocks and minerals. The biological life is mainly controlled largely by the prevailing environment.

1. Man and Animals

- The action of man in disintegration of rocks is well known as he cuts rocks to build dams, channels and construct roads and buildings. All these activities result in increasing the surface area of the rocks for attack of chemical agents and accelerate the process of rock decomposition.
- A large number of animals, birds, insects and worms, by their activities they make holes in them and thus aid for weathering.
- In tropical and sub tropical regions, ants and termites build galleries and passages and carry materials from lower to upper surface and excrete acids. The oxygen and water with many dissolved substances, reach every part of the rock through the cracks, holes and galleries, and thus brings about speedy disintegration.
- Rabbits, by burrowing in to the ground, destroy soft rocks. Moles, ants and bodies of the dead animals, provides substances which react with minerals and aid in decaying process.

The earthworms pass the soil through the alimentary canal and thus brings about physical and chemical changes in soil material.

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2. Higher Plants and Roots

- The roots of trees and other plants penetrate into the joints and crevices of the rocks. As they grew, they exert a great disruptive force and the hard rock may broke apart. (e.g) pipal tree growing on walls/ rocks
- The grass roots form a sponge like mass, prevents erosion and conserve moisture and thus allowing moisture and air to enter in to the rock for further action.
- Some roots penetrate deep into the soil and may open some sort of drainage channel. The roots running in crevices in lime stone and marble produces acids . These acids have a solvent action on carbonates.

The dead roots and plant residues decompose and produce carbon dioxide which is of great importance in weathering.

3. Micro- organisms

In early stages of mineral decomposition and soil formation, the lower forms of plants and animals like, mosses, bacteria and fungi and actinomycetes play an important role. They extract nutrients from the rock and N from air and live with a small quantity of water. In due course of time, the soil develops under the cluster of these micro-organisms. These organisms closely associated with the decay of plant and animal remains and thus liberate nutrients for the use of next generation plants and also produces CO_2 and organic compounds which aid in mineral decomposition.

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SOIL ORGANIC MATTER

Substances containing carbon are organic matter. Soil organic matter consists of decomposing plant and animal residues. It also includes substances of organic origin either leaving or dead. Soil organic matter plays an important role in **deciding / maintaining soil physical conditions**. It also influences soil chemical properties especially **cation exchange capacity**. Organic matters supply the energy sources for soil micro-organisms. Soil development is another aspect which is influenced by the soil organic matter. Plant tissue is the major source. Animals are considered as the secondary sources. They attack original plant tissues, contribute waste products and leave their own bodies after death.

Factors affecting soil organic matter

1. Climate
2. Natural vegetation
3. Texture
4. Drainage
5. Cropping and Tillage
6. Crop rotations, residues and plant nutrients.

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1. Climate: Temperature and rainfall exert a dominant influence on the amounts of N and organic matter found in soils.

a) Temperature: The organic matter and N content of comparable soils tend to increase if one moves from warmer to cooler areas. The decomposition of organic matter is accelerated in warm climates as compared to cooler climates. For each 10^0C decline in mean annual temperature, the total organic matter and N increases by two to three times.

b) Rainfall: There is an increase in organic matter with an increase in rainfall. Under comparable conditions, the N and organic matter increase as the effective moisture becomes greater.

2. Natural Vegetation: The total organic matter is higher in soils developed under grasslands than those under forests.

3. Texture: Fine textured soils are generally higher in organic matter than coarse textured soils.

4. Drainage: Poorly drained soils because of their high moisture content and relatively poor aeration are much higher in organic matter and N than well drained soils.

5. Cropping and Tillage: The cropped lands have much low N and organic matter than comparable virgin soils. Modern conservation tillage practices helps to maintain high OM levels as compared to conventional tillage.

6. Rotations, residues and plant nutrients: Crop rotations of cereals with legumes results in higher soil organic matter. Higher organic matter levels, preferably where a crop rotation is followed.

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Composition of organic residues: Plant residues contain 75% moisture and 25% dry matter. This 25% is made up of Carbon (10-12%), Oxygen (9-10%), Hydrogen (1.5-2.5%), N (1-2%) and mineral matter (1-3%).

The organic matter is also classified on the basis of their rate of decomposition

1. Rapidly decomposed: Sugars, starches, proteins etc.
2. Less rapidly decomposed: Hemicelluloses, celluloses etc.
3. Very slowly decomposed: Fats, waxes, resins, lignins etc

Decomposition of soil organic matter:

Different organic residues contain different organic compounds. There is great variation in the rate of decomposition of organic residues. Sugars, starches and simple proteins are very rapidly decomposed. On the other hand, Fats, waxes and lignins are very slowly decomposed. Hemicellulose, celluloses and protein are intermediate. Even though the composition may vary the end products are more or less the same. The general reactions taking place during decomposition are

1. Enzymatic oxidation of the bulk with the release of Co2, water, energy and heat
2. Essential elements are released (N, P, S etc) and immobilized by a series of reactions.
3. Formation of compounds which are resistant to microbial action.

Molecules very resistant to microbial action is formed either through modification of compounds or by microbial synthesis

Under aerobic conditions the products formed are Co2, NH4, NO3, H2PO4, SO4, H2O and essential plant nutrients like Ca, Mg, Fe, Cu, Zn etc.

1. **Under anaerobic conditions** CH4, organic acids like lactic, propionic, butyric, NH4, various amine residues (R-NH2) H2S, ethylene (CH2=CH2) and humic substances.

A. **Decomposition of soluble substances:** When glucose is decomposed under aerobic conditions the reaction is as under:

Sugar + Oxygen →CO2 + H2O

Under partially oxidized conditions,

Sugar + Oxygen → Aliphatic acids (Acetic, formic etc.) or Hydroxy acids (Citric, lactic etc.) or Alcohols (ethyl alcohol etc.)

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Ammonification – organic N - Polypeptides – Peptides – amonoacids – NH3 or NH4

i) Ammonification: The transformation of organic nitrogenous compounds (amino acids, amides, ammonium compounds, nitrates etc.) into ammonia is called ammonification. This process occurs as a result of hydrolytic and oxidative enzymatic reaction under aerobic conditions by heterotrophic microbes.

ii) Nitrification: The process of conversion of ammonia to nitrites (NO2) and then to nitrate (NO3-) is known as nitrification. It is an aerobic process by autotrophic bacteria.

iii) Denitrification: The process, which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide, is called Denitrification. Water logging and high pH will increase N loss by Denitrification.

2. Under anaerobic conditions:

C6H12 O6 (Glucose) - Lactic acid, butyric acid Ethyl alcohol are formed Protein and other N compounds are converted into elemental N.

B. Decomposition of Insoluble Substances

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i) Breakdown of Protein: During the course of decomposition of plant materials, the proteins are first hydrolyzed to a number of intermediate products.

Aminization: The process of conversion of proteins to aminoacids.

Ammonification: The process of conversion of amino acids and amides to ammonia.

ii) Breakdown of cellulose: The decomposition of the most abundant carbohydrates.

Hydrolysis hydrolysis oxidation. This reaction proceeds more slowly in acid soils than in neutral and alkaline soils. It is quite rapid in well aerated soils and comparatively slow in poorly aerated soils.

iii) Breakdown of Hemi cellulose: Decompose faster than cellulose and are first hydrolyzed to their components sugars and uronic acids. Sugars are attacked by microbes and are converted to organic acids, alcohols, carbon dioxide and water.

The uronic acids are broken down to pentose and CO2. The newly synthesized hemicelluloses thus form a part of the humus.

iv) Breakdown of Starch: It is chemically a glucose polymer and is first hydrolyzed to maltose by the action of amylases. Maltose is next converted to glucose by maltase.

P containing organic compounds:
Various micro-organisms mineralize phospholipids and other organic P compounds in the presence of phosphates enzymets H_2PO_4 and HPO_4^{-2} depending on soil pH.

Mineralisation: The biological conversion of organic forms of C, N, P and S to inorganic or mineral forms is called mineralization.

Immobilization: The conversion of inorganic forms of C, N, P and S by the soil organism into organic forms is called Immobilization.

Factors affecting decomposition

1. **Temperature:** Cold periods retard plant growth and organic matter decomposition. Warm summers may permit plant growth and humus accumulation.
2. **Soil moisture:** Extremes of both arid and anaerobic conditions reduce plant growth and microbial decomposition. Near or slightly wetter than field capacity moisture conditions are most favorable for both processes.
3. **Nutrients:** Lack of nutrients particularly N slows decomposition.
4. **Soil pH:** Most of the microbes grow best at pH 6 to 8, but are severely inhibited below pH 4.5 and above pH 8.5.
5. **Soil Texture:** Soils higher in clays tend to retain larger amounts of humus.
6. **Other Factors:** Toxic levels of elements (Al, Mn, B, Se, Cl), excessive soluble salts, shade and organic phytotoxins in plant materials.

Role of organic matter

- Organic matter creates a granular condition of soil which maintains favourable condition of aeration and permeability.
- Water holding capacity of soil is increased and surface runoff, erosion etc., are reduced as there is good infiltration due to the addition of organic matter.
- Surface mulching with coarse organic matter lowers wind erosion and lowers soil temperatures in the summer and keeps the soil warmer in winter.
- Organic matter serves as a source of energy for the microbes and as a reservoir of nutrients that are essential for plant growth and also hormones, antibiotics.
- Fresh Organic matter supplies food for earthworms, ants and rodents and makes soil P readily available in acid soils.
- Organic acids released from decomposing organic matter help to reduce alkalinity in soils; organic acids along with released CO_2 dissolve minerals and make them more available.
- Humus (a highly decomposed organic matter) provides a storehouse for the exchangeable and available cations.
- It acts as a buffering agent which checks rapid chemical changes in pH and soil reaction.

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Organic compound and Inorganic compound

Sr. No	Organic compound	Inorganic compound
1.	These are formed from few elements like C, H, O, N, P, S and halogens.	Formed from any of more than 100 elements known
2.	These are of living origin	These are of mineral origin
3.	Exhibit covalent bonding	Exhibit ionic bonding
4.	Exhibit isomerism	Isomerism is not possible
5.	Have low melting and boiling Points.	Have high melting and boiling points.
6.	Highly combustible	Non- combustible
7.	Highly volatile	Non-volatile
8.	Low solubility in water, Highly soluble in organic solvents	Highly soluble in water but less soluble in organic solvents.
9.	These are nonconductors of Electricity	Solutions are good conductors of Electricity
10.	Reactions are slow require catalysts	Reactions are rapid, in general Do not require catalysts.

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Organic colloids and Inorganic colloids

Sr. No	Properties	Organic colloids	Inorganic colloids
1.	Origin	Decomposition of organic Matter	Weathering of rocks and minerals
2.	Composition	C, H, O (N, P, S)	Si, Al, Fe, Mg, O, OH
3.	Shape	Amorphous	Crystalline except allophone and sesquioxide clays
4.	Stability	Unstable in nature	Stable
5.	Origin of charge	pH dependent	Mostly due to isomorphous substitution and partly by soil reaction
6.	CEC	150-400 cmol kg-1	3-150 cmol kg-1
7.	Water and nutrient holding Capacity	High	Low
8.	Plasticity	Low	High
9.	Surface area m2/g	Around 900	Variable (10 to >700)

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