Weathering

1. Introduction /definition
2. Importance of weathering process
3. Environment of weathering
4. Process of weathering
   - Physical weathering
   - Chemical weathering (decomposition)
   - Complex weathering (growth of crystals),
   - Combined effects of physical and Chemical weathering
5. Effects of organism
6. Effects of weathering

Definition of Weathering

Weathering is Physical and chemical changes within rock material that takes place as a result of its exposure to the sub-aerial environment.

Weathering is a general term for all the changes in rock material that take place as a result of the rock's exposure to the atmosphere (Sanders).

whereas the erosion is a collective term for any process of physical disintegration, chemical dissolution, or movement of affected rock material from one place to another on the surface of the earth.

Definition contd..

Geologists use the term weathering for the total of all processes acting at or near the earth's surface whereby rock undergoes physical disintegration and chemical decomposition (Strahler).

Definition contd..

Weathering is the total effects of all the various sub-aerial processes that co-operate in bringing about the decay and disintegration of rocks, provided that no large scale transport of the loosened product is involved.

The work of rain wash and wind are essentially erosional and this is excluded from weathering. But gravity transport is involved in weathering (Holmes).

Definition contd..

It is convenient to regard weathering as rock decay by agents involving little or no transport of the resulting products except by gravity, and erosion as land destruction by agents which simultaneously remove the debris (*Holmes*).

Both sets of processes co-operate in wearing away the land surface and their combined effects are described by the term denudation (latin: denudare- to strip bare)

Definition contd..

Erosion

All the destructive processes due to the effects of the transporting agents are described as erosion.

Erosion indicates changes in rocks at the earth's surface as a result of the movement of water, wind or ice.

Importance of weathering

1. It is a visible proof that geologic cycle is operating.

2. It shows how geologic material and certain kinds of energy react to bring the material into adjustment with conditions prevailing- environment, atmosphere, moisture, temperature fluctuation, organism etc.

Importance contd..

3. It converts bed rock into regolith and soil.
4. Weathering creates raw material that become sediments and sedimentary rocks- loosens to individual minerals, attack and alter individual minerals and solution.
5. It forms economic deposits
6. Importance in engineering projects.

Environment of weathering

1. Climate
2. Chemical composition of rainfall and effects of air pollution
3. Pore spaces in bed rock and regolith
4. Slope situation

1. Effects of climate

Time-averaged weather in a region is called climate. The environment of weathering depends intimately on climate, particularly on:

a. temperature
b. precipitation
c. evaporation
d. distribution and kinds of organism (effects of above)

This can be illustrated by weathering in four climatic zones:

i. Humid tropical region
ii. Humid temperature region
iii. Warm arid region
iv. Cold arid region

I. Humid tropical region: Weathering is most intense in humid tropics. They have average >20^0 C temperature and 250 cm/year rainfall. Both affects physical and chemical weathering. Each 10 ^{0}C rise in temperature doubles or triples chemical reaction. Biological activity increases as well. The cover of vegetation is dense and complete. No ice and snow are present.

II. Humid and Temperate (e.g. North America): Temperature is less than in humid tropical region. Temperature is more variable. In winter snow and ice are present.

iii. Warm arid: Temperature is high and has large span. Rainfall is scanty and evaporation exceeds rainfall. As a result water is drawn up out of regolith. Chemical process without water is inhibited and only few specialized plants can live. So in deserts rocks may endure for many thousand of years without changing very much.

iv. Cold arid: (Permafrost). Little liquid water is present for chemical reaction or for plant. It is cold and dry.

2. Chemical composition of rainfall

Rain water is not pure as distilled water but contains may dissolved ions.
From sea water it picks of ions of salt (NaCl or halite). Other elements which are dissolved in rain water are N_2, $_{O2}$, SO_2, C_{O2}, CO. Organic compounds are also present which may be derived from sea water or organic compounds released into atmosphere by land plants. These substances make rain water slightly acidic solution.

Therefore the rain water is very active chemically and is a source of natural fertilizers and plant food. Rain water also contains microflora consisting of bacteria and tiny spores and seeds of plants.

The corrosive effects of rainfall have been increased greatly as a result of industrial pollution. The most corrosive pollutant gas is SO_2 which is released in the atmosphere by burning coal and fuel oils and smelting of sulphide minerals. It ultimately forms H_2SO_4

Pore space in bed rock and regolith

The environment of weathering extends beyond the open surface of the earth. It also includes pore spaces of bed rock and regolith.

Pore spaces: They are found between minerals, along joints, faults, and other cracks and partings. In regolith pore spaces are found between framework particles.

Slope Situation

a. Height of the slope
b. Angle of slope
b. Direction of inclination with respect to sunlight and rain bearing wind.

Process of weathering

Weathering processes can be divided into those:
a. that involve physical activities
b. that include chemical activities.

Basically, the physical activities do the breaking and the chemical processes do the altering. But they overlap each other. For example, water acts physically and chemically.

Thus we discuss weathering under five heading:

1. Dual effect of water molecules
1. Physical
2. Chemical
3. Complex
4. Effect of organism

Agents of weathering

1. Physical agents
2. Chemical agents
3. Biological agents

The geological work accomplished by weathering is of two kinds:

1. Physical or mechanical changes (due to temperature change, frost action, organisms).
2. Chemical changes-in which minerals are decomposed, dissolved, loosened by water, CO_2, O_2 of atmosphere and soil waters and by organisms.

Dual effect of water molecules

In weathering water is more important than any other single substance or process. It is abundant, occurs in three stages as solid, liquid, gas and Chemically highly active.

Mechanical effect of water

The main physical effect of water is expansion on freezing. As the temperature of water reaches 0 ^{0} C randomly arranged water molecules will organize into characteristic lattice. Freezing water expands about 9 % with such force that rocks can break. 150 kg/cm^2 during freezing on walls of crack.

Chemical effect of water

Its major chemical effect is related to its uneven distribution of electrical charge. Water can detach and surround ions from mineral lattice. e.g. NaCl. Each water molecule act much like a tiny dipole magnet.

Physical weathering (Disintegration) or Mechanical weathering

It refers to processes that break apart rocks without altering their chemical composition. Although we discusses physical weathering as a separate processes, weathering processes work together. Also, a physical change may result from either physical process or chemical process. For example, mechanical breakage can result from

a. Physical thermal effects or
b. From crystallization of minerals

The chief effect of physical weathering is to break rocks into smaller fragments and eventually into individual mineral particles. Each new break in a rock increase the surface area, thus creating more spacing for chemical activities.

The geological work accomplished by weathering is of two kinds:

a. Physical or mechanical changes in which materials are disintegrated by temperature changes, frost action, organisms

b. Chemical changes in which minerals are decomposed, dissolved and loosened by water, O_2 and CO_2 of atmosphere and soil water, organisms and product of their decay.

Thermal effect

Disintegration by temperature change:

1. Frost action in high altitude
a. frost wedging
` **b. frost heaving**

2. Desert Repeated heating and cooling (heat expansion) of material (alternate heating and cooling)

Types of Physical weathering

a. Granular disintegration: The physical separation of the individual mineral particles of a rock from one another is a process named granular disintegration. The rocks crumble easily.

b. Sheeting joints, exfoliation: By unloading or uneven pressure which cause the rock to fracture. The splaying of bodies of bedrock along sheeting joint is exfoliation.

c. Thermal effects: Frost wedging and heat expansion

Where temperature are extreme and fluctuate. The presence of moisture accentuates thermal effects. In cold climate at 0^0 C volume increase (expands by 9 %). The growth of ice crystal can produce:

1. **Frost heaving- the lifting of overlying particles in regolith.**
2. **Frost wedging- the prying apart of solid bed rock.**

Frost wedging is most vigorous at high altitude where alternate freezing and thawing results from temperature fluctuations during the day and night.

Heat expansion (Thermal effect):

In deserts sounds developed by heat expansion and crack. But if very dry, little effect is seen. Moisture affects better:

CHEMICAL WEATHERING (DECOMPOSITION)

Chemical weathering which changes the composition of rock materials, is known as decomposition. Decomposition basically involves two processes i.e. alteration and solution.

In order to understand how decomposition works we must consider chemical processes and geologic material together. Because a given chemical process exerts different effects on different materials.

processes involved in chemical weathering

1. **Oxidation: It is the addition of oxygen to another element. The elements in rocks that are most easily oxidized are *iron* and *sulphur* (found in sulphides). The iron-oxide minerals that form during chemical weathering are coloured red, yellow, orange or brownish. If copper minerals are oxidized, green and blue minerals form.**

As in other process, oxidation proceeds more readily if water is present. Oxidation in desert is slow compared with oxidation where the rocks are exposed to water.

Many rocks contain pyrite (FeS_2) an iron sulphide. which is easily oxidized. During oxidation of pyrite,, the iron forms limonite and the released sulpher may collect as an element or may combine with water to create H2SO4 a powerful chemical agent.

$FeS_2+nO_2+mH_2O \rightarrow FeSO_4$ (first stage, unstable)$\rightarrow$ $Fe_2(SO4)_3$ (second stage, unstable)$\rightarrow$ $Fe_2O_3\ nH_2O$ (most stable)

Other sulphides too are easily oxidized. Where copper minerals are present, oxidation may be responsible for creating ore deposits.

Oxidation of organic matter

Natural organic matter can be classified into two large categories:

1. First cycle organic matter
2. Polymerized organic matter

The first cycle organic matter consists of the kinds of material manufactured by organisms. Polymerized organic matter designates materials in which carbon and hydrogen ions have formed long chains. Such chains are solids.

Most forms of first cycle organic matter have such a great affinity for oxygen that they will unite with any oxygen that is available and even use up the total supply. The end products of the oxidation of organic matter are carbondioxide gas and water. When CO2 is dissolved in water, it forms a weak acid (carbonic acid), which can attack minerals.

$CO_2+H_2O \rightarrow H_2CO_3$ (carbonic acid)

Solution: ($H^+ + HCO3^-$)

$2H_2CO_3+2CaCO_3 \rightarrow 2Ca\ (HCO3)_2$

2. Dissolution:

Water is capable of detaching and surrounding ions from mineral lattices, i.e. it is capable of dissolving some solid rocks. Layers of rocksalt are so easily dissolved that they are exposed only in the driest regions.

Dissolution can begin as soon as water comes in contact with minerals of regolith or bedrock. If the water remains in the ground for several months, its chemical load increases may fold. Leaching is a process of removal of mineral by dissolution in water.

3. Hydrolysis or hydration:

Hydration involves the action of water or mineral i.e. absorption of water by mineral. Hydrolysis involves the combined action of water and carbondioxide on rock.

An important process in the weathering of silicate minerals is their combination with water, or hydrolysis. In this process water attacks the crystal lattice of silicates. Some of the OH^- ions from the water becomes part of the crystal lattice of the weathered silicates to form clay minerals. They are the chief secondary-alteration products of weathering.

$6H_2O + CO_2 + 2KAlSi_3O_8$ (orthoclase) $\rightarrow Al_2Si_2O_5(OH)_4$ (clay mineral)+ $4SiO(OH)_2$ (silicic acid)+ K_2CO_3 (removed in solution)

$H_2O + CO_2 + NaAlSi_3O_8$ (albite) $\rightarrow Na_2CO_3$ + ...
$H_2O + CO_2 + CaAl_2Si_2O_8$ (anorthite) $\rightarrow Ca(HCO_3)_2$ + ...

$H_2O + CO_2 + Ca(Mg.Fe)(SiO3)_2$ (diopside pyroxene) $\rightarrow 2SiO(OH)_2$ (silicic acid) + soluable carbonates of Ca, Mg, Fe

$CaSO_4$ (anhydrite) $+2H_2O \rightarrow CaSO_4.2H_2O$ (gypsum)

Fe_2O_3 (hematite) + n $H_2O \rightarrow Fe_2O_3$. n H_2O (limonite)

Feldspars weather so readily into clay minerals that only rarely do feldspars appear as survival products in the regolith.

During the weathering of feldspars to clay minerals, Na, Ca and K ions are leached from the feldspar lattice and go into solution.

When Al_2O_3 and Fe_2O_3 are also present (e.g. in biotite, augite, hornblende) clay and chloritic minerals and limonite remains as residual products. In the presence of oxygen, limonite is also precipitated from solution containing $Fe(HCO_3)_2$

4. Carbonation

CO_2 gas which is present in the atmosphere and is a byproduct of the oxidation of organic matter, readily dissolves in water to form a weak acid, carbonic acid.

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (carbonic acid)}$$

The reaction between carbonic acid and minerals is carbonation. Carbonate minerals, especially calcite dissolves easily in carbonic acid.

$CaCO_3 + H_2CO_3 \rightarrow Ca^{++} + 2(HCO_3)^-$ (bicarbonate ion complex, dissolved and removed by water) $\rightarrow CaH(CO_3)_2$ (calcium bicarbonate)

Many kinds of rocks are affected by this process because calcite is a common mineral in many rocks.

5. Exchange reactions

An exchange reaction is the exchange of +ve ions between compounds resulting in the formation of new compounds. For example sulphuric acid (H_2SO_4) and calcite in the presence of water exchange ions to produce gypsum and carbonic acid.

$H_2O + H_2SO_4 + CaCO_3 \rightarrow CaSO_4.H_2O$ (gypsum) + H_2CO_3 (carbonic acid)

H_2CO_3 will react with $CaCO_3$ again by carbonation.

COMPLEX WEATHERING

Here we describe growth of crystals and the combined effects of chemical and physical weathering.

Growth of crystals: The water circulating in the regolith contains various elements dissolved. If this water evaporates, its dissolved minerals crystallize as solids. These crystal lattice grow and exert large force on their surroundings. When minerals crystallize in pore space they cement the sediment and form sedimentary rocks. When the minerals crystallizes along cracks, they pry rocks apart just as ice does.

Common minerals whose growth can wedge apart rocks are gypsum and halite. Gypsum (hydrated calcium sulphate), is particularly troublesome where limestone or marble is exposed to sulpher dioxide (SO_2).

H_2SO_4 will react with calcite in the limestone or marble to form gypsum. As gypsum crystals enlarge in the cracks, they cause pieces of rock to flake off from buildings.

Halite also creates problem. Salty underground water in desert during intense evaporation brings water up and crystallizes the salt and the rock crumbles.

COMBINED EFFECTS OF CHEMICAL AND PHYSICAL WEATHERING

As feldspars are converted to clay minerals by hydrolysis, the mineral fabric of the rock swells. Such swelling may be strong enough to break the rock.

If a cube of rock is undergoing hydrolysis and breaking, the effects appear first at corners where the three surfaces join.

The next place is along edge where two planes meet. The last places affected are sides. The original cube becomes more and more spherical. The weathering then proceeds inward evenly from all directions.

The end result is the series of more or less regular sheets or shells peel off like the layers of an onion. (Spheroidal weathering, Spheroidal joints).

Effects of Organism

The weathering created by organism is both :

1. **Chemical**
2. **Physical**

Lichens and bacteria break down organic materials and this liberates acids which attack silicate minerals. The growth of lichens on exposed bed rock is the first stage in the conversion of that bedrock into regolith.

Other organic materials affect the acidity of the waters and thus greatly influence the chemical environment of weathering.

Plant roots follow fractures in rocks, they grow where they can find water. Growing roots widen the cracks, as they grow they cause considerable damage to side walls, walls and foundations.

Effects of weathering

1. **Differential weathering**
2. **Talus: it is a weathered rock debris at the bottom of a steep mountain, cliff or slope**
3. **Deposition of economically valuable minerals (weathering residue)**

Weathering Residue

In dry areas the coating of chemically weathered material may not be more than a thin film. But where rain and soil water can soak deeply into rocks, weathering may proceed deep 15-30 m e.g. granites in an area of high rain and high heat.

Laterite

Hydroxide of calcium and iron, silica and various carbonates and sulphates. Rain water redissolves them but hydroxide of aluminum and Fe are left in highly insoluble states. The resulting reddish-brown deposit is called laterite.

Soils

Without weathering, the earth will be rocky, barren and lifeless.

Regolith gives rise to soil.

Soil is defined as the upper part of the regolith that is capable of supporting the growth of rooted plants. Soil consists of :

Solids, Liquids and Gases

All of which must be in proper balance. Soil is a dynamic product, it is alive with complex chemical, physical and biological activities.

Factors involved in the origin of Soil

- **a. Parent material (kinds of regolith)**
- **b. Behavior of water**
- **c. Organic material, such as bacteria, humus, and organic acids and**
- **d. Time**

These factors work together to form distinctive zones in the profile of a soil.

a. Parent material: It provides mineral nutrients, shelter and moisture for plant growth. Regolith may be residual or transported. Regolith may be formed by processes other than weathering:

1. **Volcanic tephra**
2. **Talus (down slope gravity transport of particles that break loose from bed rock)**
3. **Glacial grinding of bed rock.**

Soil Zone and soil profile

The conversion of the upper part of the regolith (whether residual or transported) into soil creates layers. They vary in colour, texture and composition. They are called soil zones (horizons).

A matured soil displays two distinctive zones called A (upper) and B (lower), collectively known as *Solum.* The solum overlies the parent regolith or subsoil (residual or transported) called zone C. If it is residual, the lower boundary is extended to bed rock. The bed rock is called zone R.

Soil Zones

Zone A	**zone of leaching**
Zone B	**zone of accumulation**
Zone C	**subsoil**
Zone R	**bed rock**

Zone A: The uppermost layer in the soil profile, is the top soil. It typically contains varying amounts of humus and has usually undergone a certain amount of leaching.

Zone B: Contains considerable amount of clay and iron but little organic material.

Zone C: It is largely composed of slightly altered parent rock which grades downwards into the bed rock.

CLASSIFICATION OF SOILS

Soil scientists classify soils according to the prevailing climate in which they are developed and the vegetation which is associated with them.

1. Laterites (lateritic soil or latosoils): Typical of moist tropical regions which support jungle vegetation, usually red or yellow in colour. Laterites contain large amount of clay, yet are relatively porous. They are high in Fe, Al and low in SiO_2. Iron and aluminum ores are formed in extreme cases.

2. Pedalfers: (pedo- soil, Greek word, Al - aluminum, fe - iron). Found in temperate and humid climates, heavy vegetation and high in Fe, Al.

3. Pedocals (Ca): Contains relatively large amount of $CaCO_3$. It is formed in areas of low rainfall and relatively high temperature and support grass and bush.

4. Bog soil: It is humus due to intense bacterial activity.