Chapter-Weathering and Erosion

Weathering- Weathering is the process which tends to break and decompose rocks and minerals in places, under the influence of the Earth's atmospheric agents like sun, frost, waters and organisms and produce soil. Weathering is an in – situ process, i.e. "with no movement".

Erosion- It is the process by which the weathered rock materials are removed from their site of destruction by transportation and deposided elsewhere. Agents of transportation are water, wind or ice.

Denudation- It is the combined action of weathering and erosion by which the overall lanforms at the earth surface are weared off.

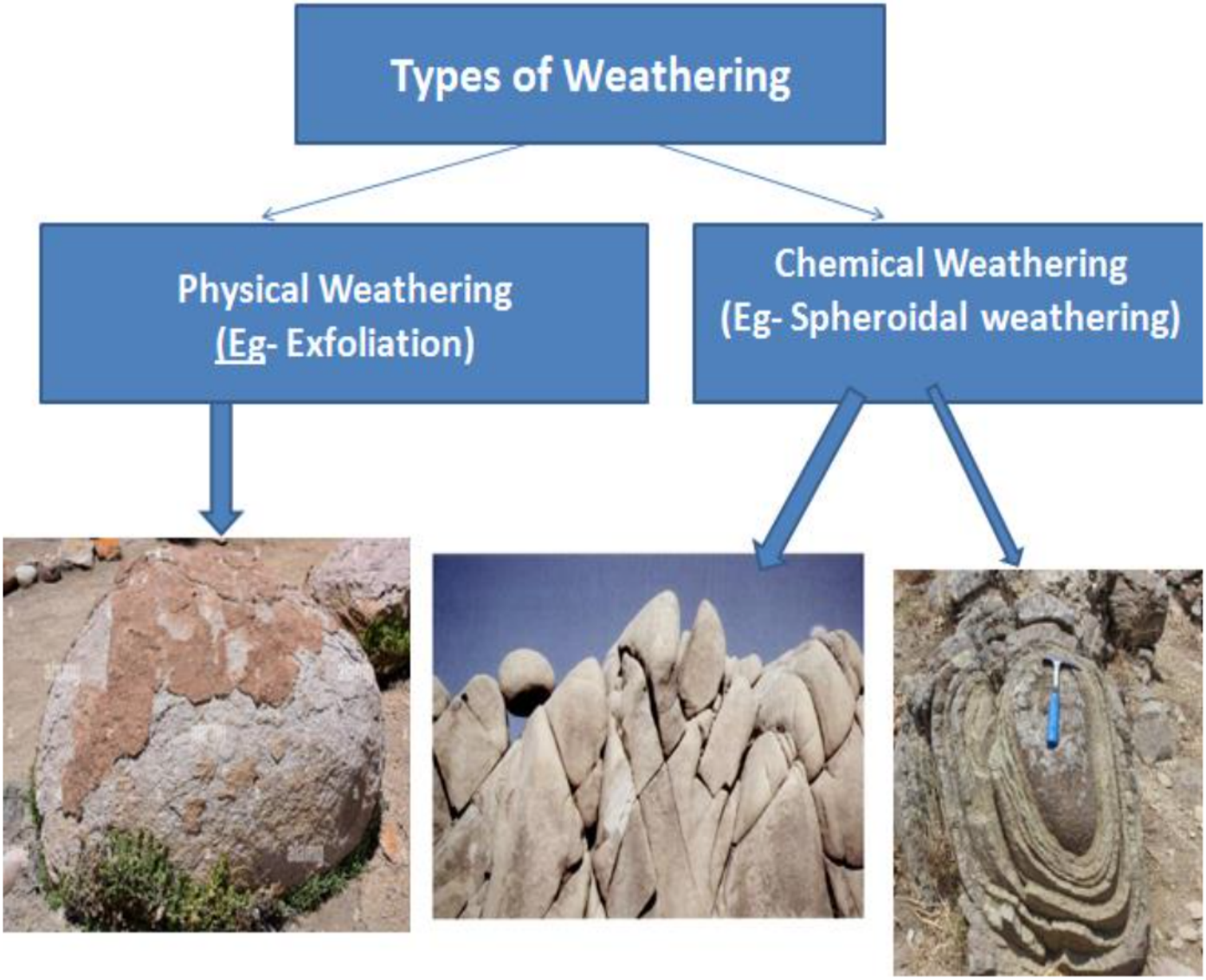

Fig- Types of weathering (Source- Google search)

1. Physical Weathering

- Is also known as Mechanical weathering.
- Mechanical weathering is the physical breakdown or disintegration of rocks into smaller pieces without any chemical change in the composition of the minerals present in the rock.
- But the disintegrated rocks pieces increase the amount of surface area for chemical weathering agents to act upon.

1.1. Principal Agents of Physical Weathering

a) Frost
b) Heating & Cooling
c) Organisms
d) Waves and wind

1.2.Action of Different Agents of Physical Weathering on Rocks –

a). **Frost wedging-** One of the most common mechanical actions is frost shattering. It happens when water enters the pore spaces within rocks in cold regions. As the temperature lowers the water freezes into ice (that expands about 9%more that equal volume of water) and causes cracks to develop in the rocks. With continued process of frost weathering the whole rock body gets disintegrated into smaller fragments. This process is collectively called as frost shattering, frost-wedging or freeze-thaw weathering.

b). Exfoliation &Thermal cracks –Exfoliation is the process by which separation of successive thin shells, or spalls, from massive rock such as granite or basalt takes place. It is common in regions that have moderate rainfall. The thickness of individual sheet or plate may be from a few millimetres to a few metres.

Thermal cracks- Mechanical/physical weathering is also caused by thermal stress which is the successive expansion and contraction effect on the rocks caused by changes in temperature or successive heating and cooling. Due to uneven expansion and contraction, the rocks crack apart and disintegrate into smaller pieces.

c) Root wedging- Like frost wedging, **root wedging** happens when plant roots penetrates within bedrock and with time as the plant grows the root also grows in size that exerts pressure on the rock due to which it leads to development of cracks within the rocks. These cracks act as weak zones that result in the rock to finally disintegrate into fragments. Occasionally these roots may become fossilized. **Rhizolith** is the term for these

roots preserved in the rock record .Boring organisms such as earthworms, termites, and ants are other biological agents that induce weathering similar to root wedging.

d). **Salt expansion**, which works similarly to frost wedging, occurs in areas of high evaporation or near-marine environments. Evaporation causes salts to precipitate out of solution and grow and expand into cracks in the rock. Salt expansion is one of the causes of **tafoni**, a series of holes in a rock. Tafoni, cracks, and holes are weak points that become susceptible to increased weathering. **Hopper crystal** [sodium chloride (NaCl)] describes a square-shaped regular crystal, commonly made of salt, preserved in rock.

2. Chemical Weathering

- Chemical weathering does not break rocks into smaller fragments through wind, water, and ice as it occurs in the case of physical weathering.
- Nor does it break rocks apart through the action of plants or animals (that's biological weathering).
- Instead, it changes the chemical composition of the rock, usually through different chemical reactions like carbonation, hydration, hydrolysis or oxidation.
- Chemical weathering causes decomposition of the rocks, i.e it alters the composition of the minerals present in the rock.

2.1. Principal Agents of Chemical Weathering

a) Water
b) Organisms

2.2.Main Processes of Chemical Weathering

a). Hydration- Hydration occurs when water reacts with an anhydrous mineral, creating a new mineral. The water is added to the crystalline structure of a mineral, which forms a hydrate. This added water results in swelling of the minerals that exerts pressure on the rock due to which the rock may crumble upon continued hydration. Two main types of minerals that undergoes hydration are- anhydrite and hematite.

$CaSO_4$ (Anhydrite) + 2 H2O (Water) -> CaSO4 . 2H2O (Gypsum)

Fe2O3 (Hematite) + n H2O -> F eO(OH)·nH 2O (Limonite)

b). Hydrolysis- Hydrolysis is the opposite of hydration. It is an exchange reaction. It is a chemical reaction during which water dissociates into hydrogen-ion (H+) and hydroxyl-ion(OH−). The H+ -ion is a very active cation and replaces the positive-ions in silicate minerals thus creating a new mineral. Most common example of hydrolysis is that of Orthoclase mineral-

KAlSi3O8 (Orthoclase) + HOH(Water) -> HAlSi3O8(Alumino-silicic acid) + KOH(Potassium hydroxide)

Carbon dioxide present in the atmosphere when reacts with rain water it forms the carbonic acid. The acidic water may further react with the Potassium hydroxide formed by hydrolysis of orthoclase to form potassium carbonate. The reaction is as follows-

H2O + CO2 -> H2CO3

2KOH + H2CO3 -> K2CO3 + 2H2O

The alumina-silicic acid formed in the above reaction finally forms clay minerals as it is unstable hence breaks down.

Another example of hydrolysis is the formation of magnesium-hydroxide from olivine-

(Mg, Fe)2 SiO4 (Olivine) + 2HOH (Water) ->

Mg(OH)2 (Magnesium-hydroxide) + H2SiO3 (Silicic acid) + FeO(Ferrous oxide)

c). Oxidation- Oxidation refers to the reaction of oxygen with metal elements in a rock, forming oxides. An easily recognizable example of the formation of rust as the Fe (Iron) present in minerals reacts easily with oxygen, turning into reddish-brown iron oxides.

The free oxygen present in the atmosphere and those in water in dissolved state are very active chemical agents. It reacts readily with the forreomagnesium minerals like olivine, pyroxenes and hornblende to form oxides (that dominantly consists of oxides of iron). The effect of oxidation is most evident in warm and moist climate.

An example of oxidation is of pyrite-

FeS2 (Pyrite) + nO2 +mH2O -> FeSO4 (Ferrous sulphate)-> Fe2(SO4)3 (Ferric sulphate)

-> **FeO(OH)·nH2O(Limonite).**

d). Carbonation - The carbon- dioxide gas is a common constituent in the earth's atmosphere. During rainfall as the rain water passes through the atmosphere some of the carbon- dioxide get dissolved with it in presence of air, thus forming a weak acid called the carbonic acid, i.e.-

H2O + CO2 -> H2CO3 (Carbonic acid)

This acid may further react with other carbonate or feldspar minerals-

(i) It combines with a calcium carbonate ($CaCO_3$), such as limestone and chalk. The interaction forms calcium bicarbonate, or $Ca(HCO_3)_2$.

CaCO3 + H2CO3 -> Ca(HCO3)2

(ii) It combines with orthoclase feldspar to form Kaolinite which is a clay mineral.

2KAlSi3O8 (Orthoclase)+ 2H2CO3 + H2O -> K(HCO3) (Potassium bicarbonate) +

Al2Si2O5(OH)4 + 4SiO2 (Silica)

These calcium bicarbonate deposits being soluble in nature are easily removed in solution under the influence of groundwater. This effect is observed in limestone and chalk areas and in humid climate.

The process of carbonation is very evident in minerals containing alkali-metals like sodium, potassium, calcium or magnesium(as seen in case of orthoclase).

e). Solution- Solution process mostly affects the chloride minerals deposits like Halite(NaCl) and Sylvite(KCl) and also calcium carbonate deposits like calcite and dolomites).

The solution process is sometimes referred to as dissolution and it is the driving force behind the formation of different erosional features like-sinkholes, caverns and underground rivers flows in areas of Karst topography (It is the formation of landforms due to solution and deposition on any limestone or dolomitic region by the action of groundwater or surface water).

Leaching- The process of removing soluble minerals from rocks by solution effect aides by groundwater or surface water is called as leaching.

Factors On Which Rate of Weathering Depends-

1. **Particle size**- Weathering action is more on smaller grain size than in larger grain size as the surface area is more in the former case than compared to the later.

2. **Mineral composition**- Minerals that are formed at higher temperatues are very unstable hence are more prone to weathering than monirals formed at lower temperature(that have high stability). As is evident in the Bowen's reaction series the ferromagnsium minerals like olivine, pyroxene and amphiboles are easily wathered but on the contrary quartz being a very stable mineral (as formed as low temperature) is very resistant to waethering.

3. **Climatic condition**- Rates of chemical weathering are high in warm and humid climate than in cold or arid climate.

Product of Granite Weathering

Mineral	Residual Products	Material in Solution
Quartz	Quartz grains	Silica
Feldspars	Clay minerals	Silica K^+, Na^+, Ca^{2+}
Amphibole (hornblende)	Clay minerals Limonite Hematite	Silica Ca^{2+}, Mg^{2+}