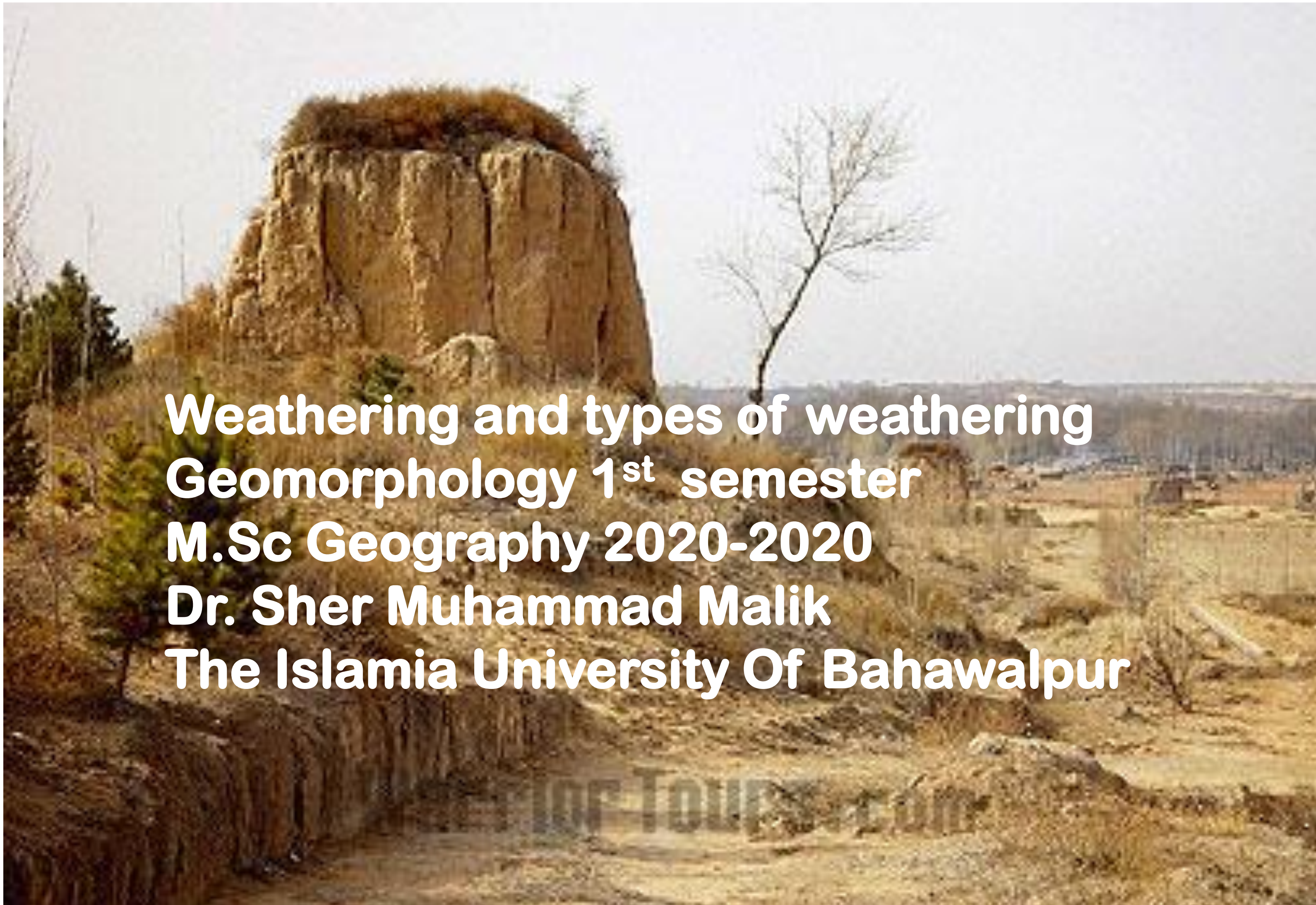
Weathering



Weathering and types of weathering
Geomorphology 1st semester
M.Sc Geography 2020-2020
Dr. Sher Muhammad Malik
The Islamia University Of Bahawalpur

Introduction

Large chunk of bedrock many hundreds of feet long is broken down into smaller and smaller pieces, until finally there are many tens of thousands of small rocks. Often rocks are broken down so much that they become dirt.

Weathering

- Weathering takes place as rocks are broken down into progressively smaller pieces by the effects of weather. These pieces do not move to a new location, they simply break down, but remain next to one another.

Weathering

- **Weathering** is caused by water, as it freezes and thaws, as well as by chemical reactions that loosen the bonds holding rocks together.

- Weathering is most common at the surface where exposed bedrock meets the atmosphere. However, weathering can extend many thousands of feet downward into the Earth’s crust, following cracks, fissures, and microscopic holes that allow water to penetrate

- Weathering is a complex interaction of physical, chemical and biological processes that alters the stone in some general or specific way.

  The physical properties of stone differs widely between stone groups and even within the same stone type. The mineral composition, textural differences, varying degrees of hardness and pore/capillary structure are the main reasons why stone nor all the surface of the same stone shows signs of alteration the same and evenly.

  These minerals can be broken down, dissolved or converted to new minerals by a variety of processes which are grouped as **Mechanical** and **Chemical.**

- There are three broad categories of mechanisms for **weathering**:
- **chemical**,
- **physical** and
- **biological**

Physical or Mechanical Weather

- is the breakdown of mineral or rock material by entirely mechanical methods brought about by a variety of causes. Some of the forces originate within the rock or mineral, while others are applied externally. Both of these stresses lead to strain and the rupture of the rock.

MECHANICAL PROCESSES

This includes the processes of**.**

- Frost action
- Thermal expansion
- Wetting and drying
- Salt decay.

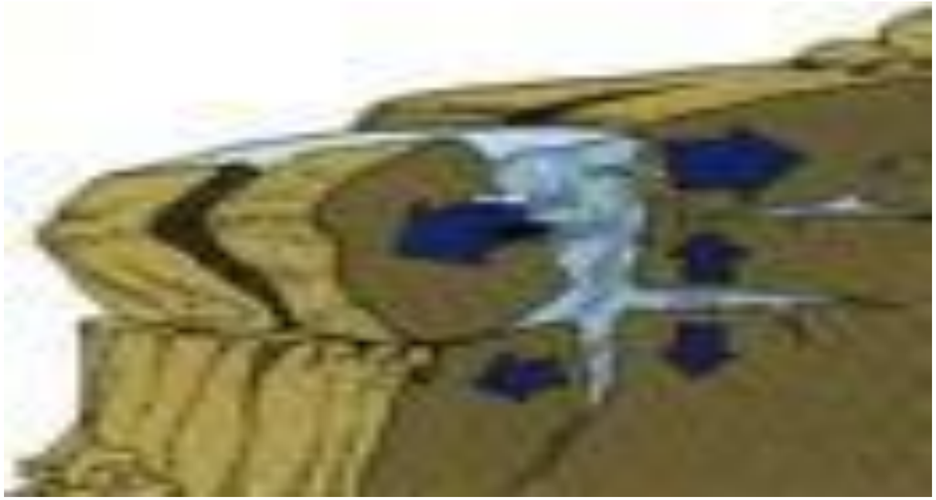
Frost Action

Frost action or commonly called freeze/thaw cycles occur when water in the pore within the pore structure or cracks freezes to ice. It has been estimate when water freezes it expands between 8 to 11 percent, with a force of 2,000 pounds per square inch to 150 tons per square foot. This increases of internal pressure combined with repeated freeze/thaw cycles produces micro-fissures, cracks, flaking and spalling.

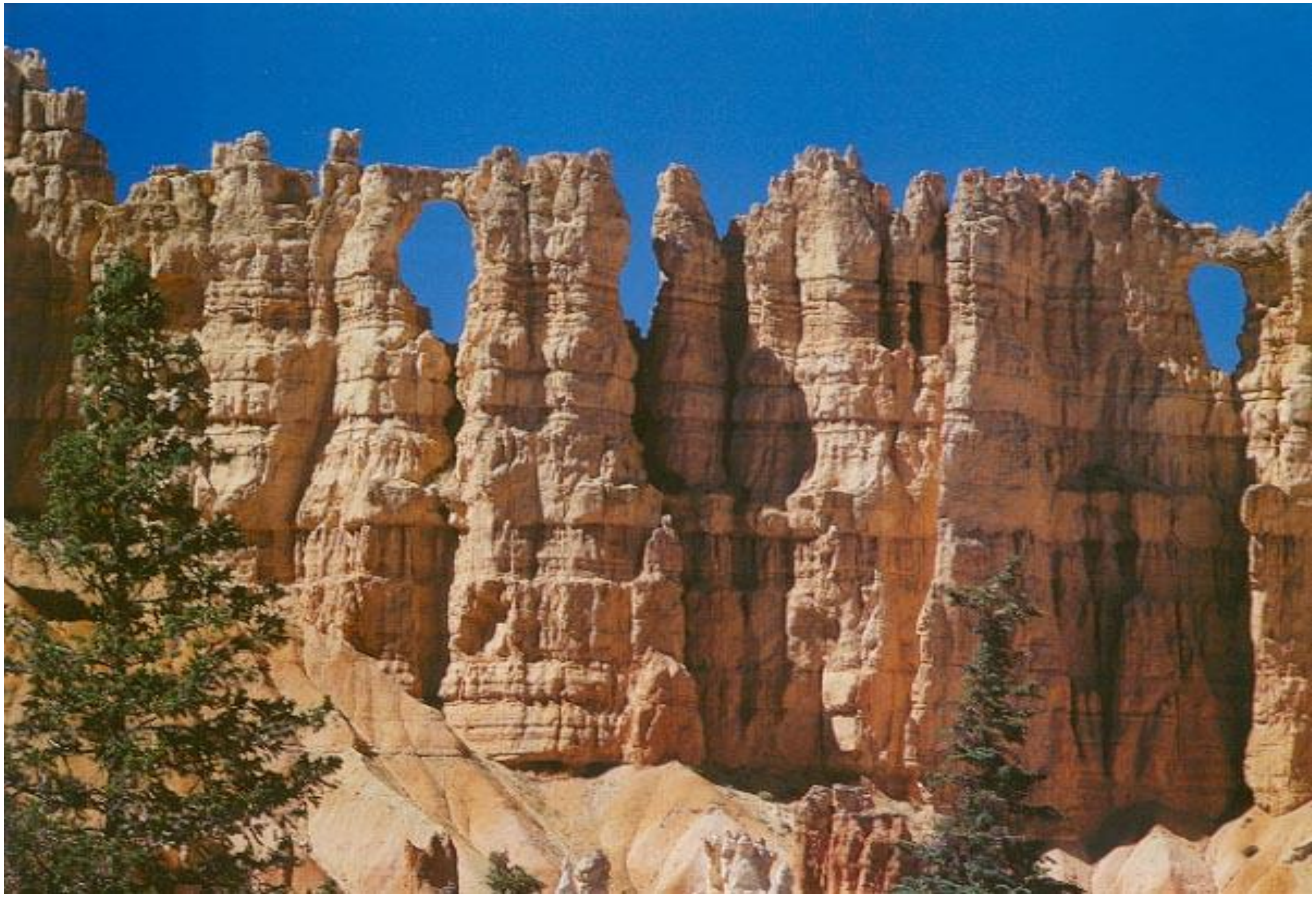
Frost Action

Frost action or Ice Wedging

- Occurs mostly in porous rocks and rocks with cracks in them
  - Bare mountaintops are especially subject to ice wedging.



Frost Action

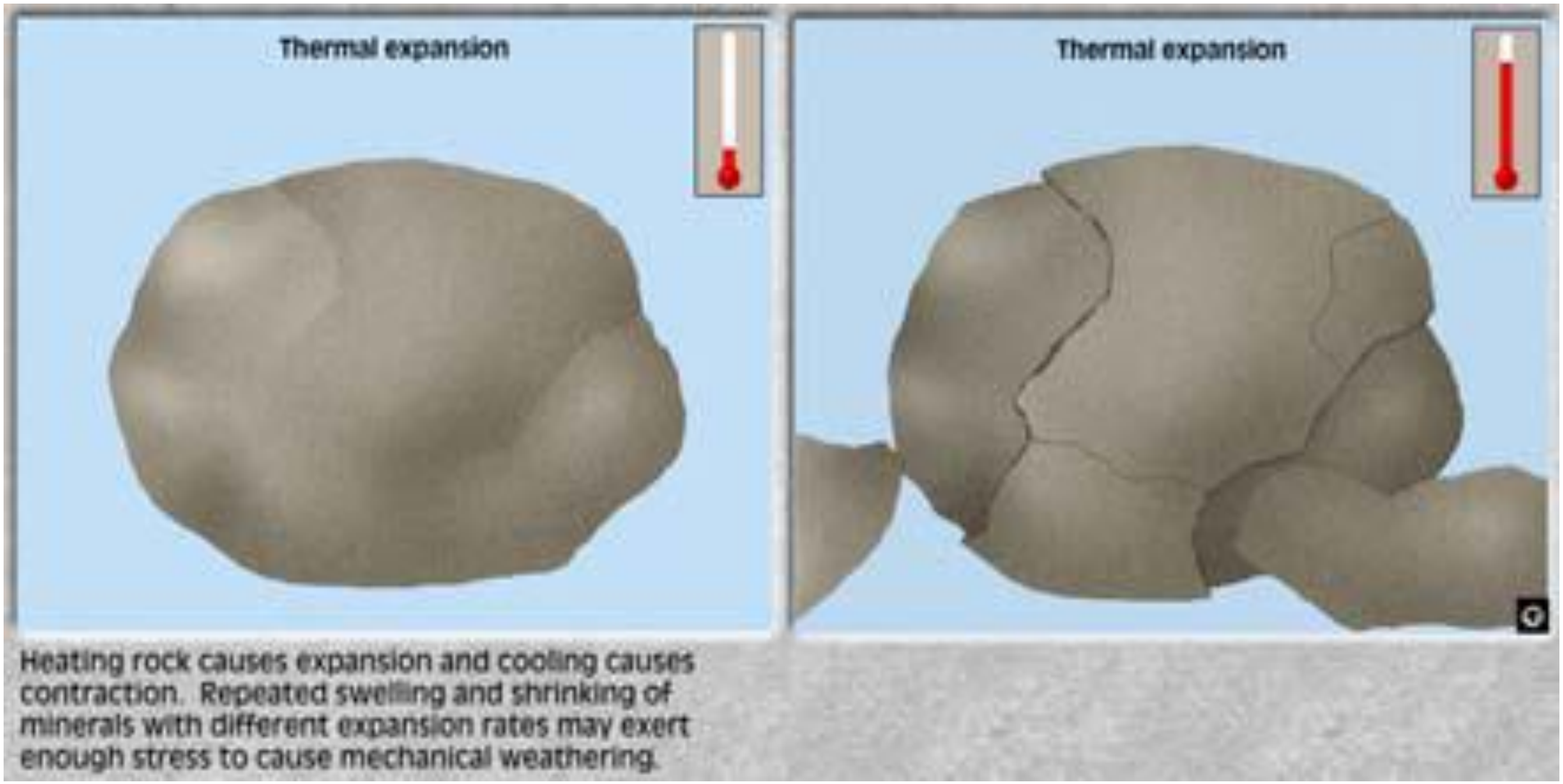


Thermal Expansion

Different minerals expand and contract at different rates, this is known as the coefficient of heat expansion and contraction.

It is known that the temperature of stone can vary between 30 and 50 percent higher than the average air temperature. Some of the darker minerals, absorb heat more readily, and also give it up more quickly than some of the lighter ones. The daily and seasonal heating and cooling of stone can cause stresses and micro-fractures in and along mineral grains. Water in the pores makes thermal stressing more effective. This can eventually produce surface flaking. Marble is particularly affected by this.

Thermal Expansion



Thermal expansion

Thermal expansion due to the extreme range of temperatures can shatter rocks in desert environments.

Repeated swelling and shrinking of minerals with different expansion rates will also shatter rocks.

- **Wetting & Drying :** Coefficients of expansion and contraction are also involved in volume change. Stone expands when it absorbs water and shrinks as it dries. This expanding and contracting produces internal stresses at the grain boundaries. When the stone heats up a "baking effect" occurs, which will eventually lead to surface flaking. Marble is affected by this "baking effect."

- ***S*alt Decay :** Salts are some of the most damaging agents to stone. Salt manifest themselves in a process commonly referred to as **Efflorescence**. There are several different types. The most common form of efflorescence is the appearance of salts at the surface in the form of whitish to grey powdery fluffy blooms. This occurs when the stone, substrate or other sources of soluble salts are in contact with moisture and move to the surface be capillary action. As the moisture moves to the surface these soluble salts are deposited at the surface to recrystallize into these blooms. This form is generally harmless

Subflorescence is similar to efflorescence, however instead of the salts being transported to the surface they crystallize and buildup within the pore/capillary structure beneath the surface. As the salts accumulate internal pressures develop generating spalling and flaking and may eventually lead to deep deterioration of the stone. Numerous varieties of salts have been identified in the efflorescence process. Some of these varieties by themselves or when combined with others will form a "hard and glassy skin" adhering rather strongly to the surface.

Crystalline efflorescence

These mechanical processes generally lead to a weakening of the stone, increasing its permeability providing greater penetration of water and increasing the areas for the chemical weathering processes to take place.

- **Exfoliation** - Concentrated shells of weathering may form on the outside of a rock and may become separated from the rock. These thin shells of weathered rock are separated by stresses that result from changes in volume of the minerals that occur as a result of the formation of new minerals

Exfoliation

Exfoliation

Chemical weathering:

The decomposition of rock by chemical reactions occurs in water especially soil water and groundwater are rich in dissolved carbon dioxide produced during the decomposition of plants carbonation dissolving of calcium carbonate (limestone) in acidic groundwater

similar to hydrolysis but the all the products are ionic, there is no residue bicarbonate (HCO3-) is a product of carbonation and a major part of the dissolved load of most rivers the carbonation of limestone results in karst topography: caves, sinkholes, etc.

Chemical Weathering

- The process that breaks down rock through chemical changes.
- The agents of chemical weathering
  - Water
  - Oxygen
  - Carbon dioxide
  - Living organisms
  - Acid rain

- **Chelation**
- bonding of mineral cations and organic molecules produced by plants
- these chelates are stable at a pH at which the cation would normally precipitate and thus they are leached in seeping soil water
- H+ released during chelation from organic molecules is available for hydrolysis
- thus plants, such as the lichens on bare rocks, contribute to the decomposition of soil and rock

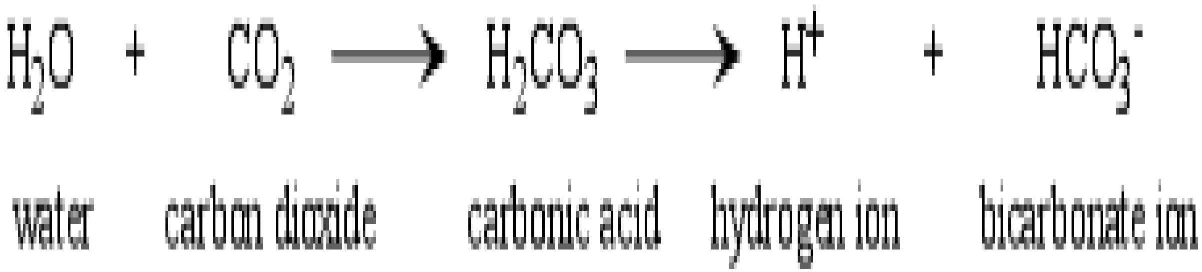
Hydrolysis

- mineral cations (*e.g.*, Ca+, Fe+, Na+, K+, Al+) are replaced by hydrogen ions (H+) from acidic water
- the most common weathering process
- pure water is a poor H+ donor, however biogenic CO2 dissolves in water to produce carbonic acid:
- the weathering products are in solution or a residue is clay, that is, the first stage of soil development
- the soil water solution becomes more basic as H+ is consumed

Water

- Water weathers rock by dissolving it

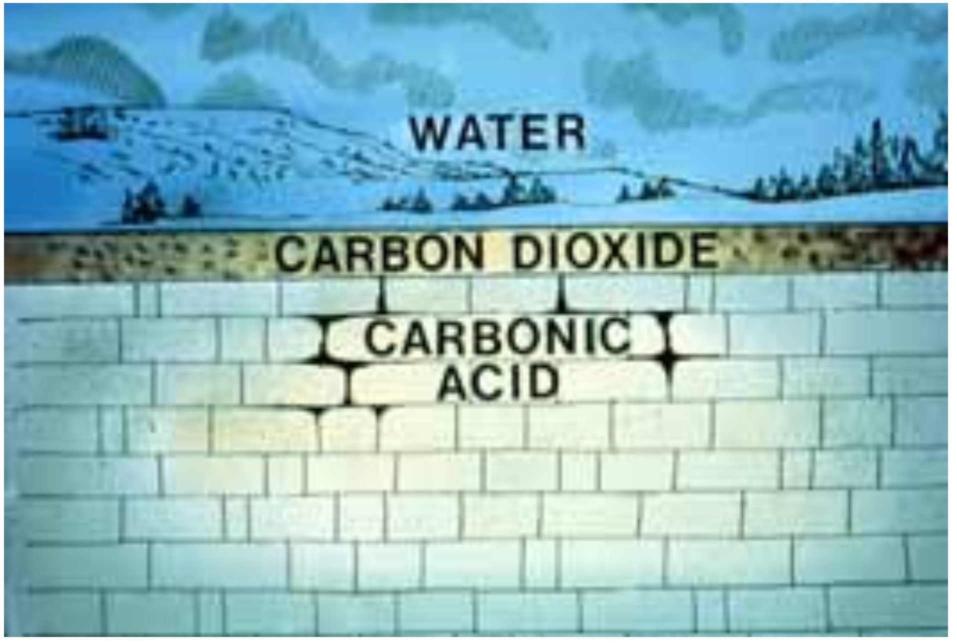
- Carbonic acid is produced in rainwater by reaction of the water with carbon dioxide (CO2) gas in the atmosphere.



- H+ is a small ion and can easily enter crystal structures, releasing other ions into the water.

Carbon Dioxide

- CO_2 dissolves in rain water and creates carbonic acid
- Carbonic acid easily weathers limestone and marble



Hydrolysis

- \- H+ or OH- replaces an ion in the mineral. Example:

•***Hydrolysis*** - H^+ or OH^- replaces an ion in the mineral. Example:

$$4KAlSi_3O_8 + 4H^+ + 2H_2O \longrightarrow 4K^+ + Al_4Si_4O_{10}(OH)_8 + 8\,SiO_2$$

Orthoclase	Hydrogen ion	water	Potassium ion	Kaolinite (clay mineral)	quartz

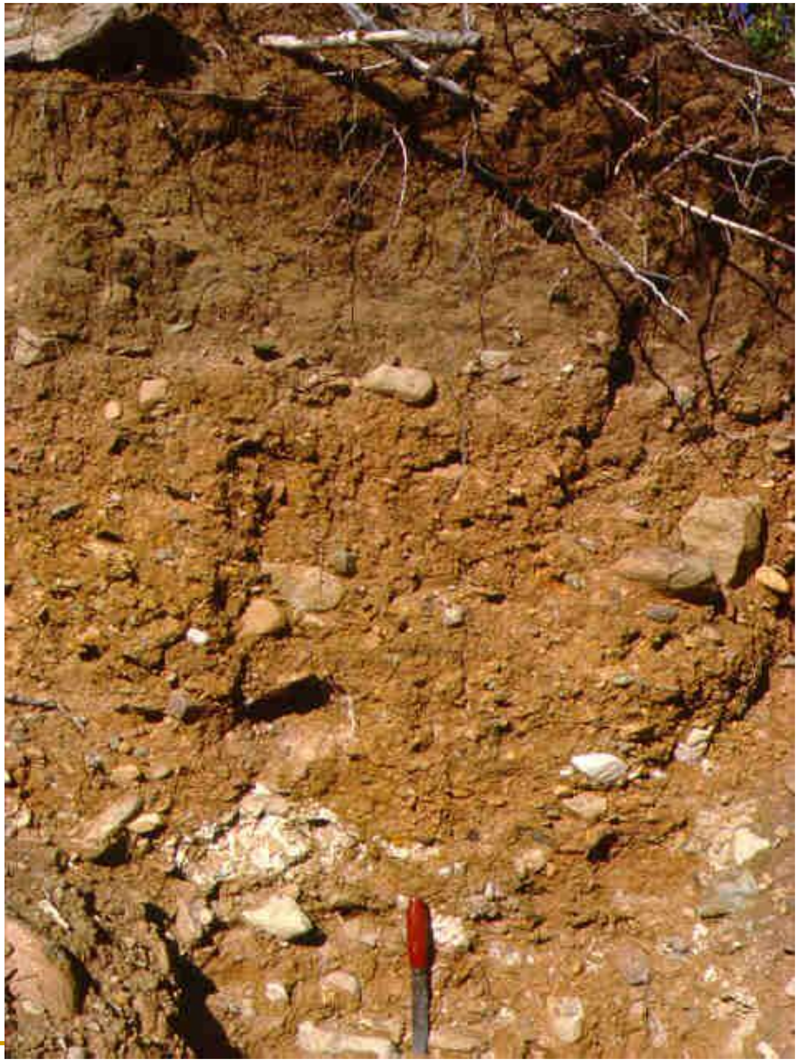
- Oxidation
- loss of an electron to dissolved oxygen
- iron is the most commonly oxidized mineral element Fe^{+2} (ferrous iron) ——> Fe^{+3} (ferric iron) or $2FeO + O_2$ ——> Fe_2O_3
- other readily oxidized mineral elements include magnesium, sulfur, aluminum and chromium

- ***Oxidation*** - Since free oxygen (O2) is more common near the Earth's surface, it may react with minerals to change the oxidation state of an ion. This is more common in Fe (iron) bearing minerals, since Fe can have several oxidation states, Fe, Fe+2, Fe+3. Deep in the Earth the most common oxidation state of Fe is Fe+2.
-

$$\underset{\text{Pyroxene}}{3Fe^{+2}SiO_3} + \underset{\text{Oxygen}}{1/2O_2} \longrightarrow \underset{\text{Magnetite}}{Fe_3O_4} + \underset{\text{Quartz}}{3SiO_2}$$

Oxygen

- Iron combines with oxygen in the presence of water in a processes called oxidation
- The product of oxidation is rust



- ***Dehydration -*** removal of H2O or OH- ion from a mineral.

$$2FeO \cdot OH \longrightarrow Fe_2O_3 + H_2O$$

Goethite → Hematite + water

- ***Complete Dissolution*** - all of the mineral is completely dissolved by the water.

- $$CaCO_3 + H_2CO_3 \longrightarrow Ca^{2+} + 2(HCO_3)^-$$

Calcite + Carbonic Acid → Calcium ion + Bicarbonate ion

Factors that Influence Weathering

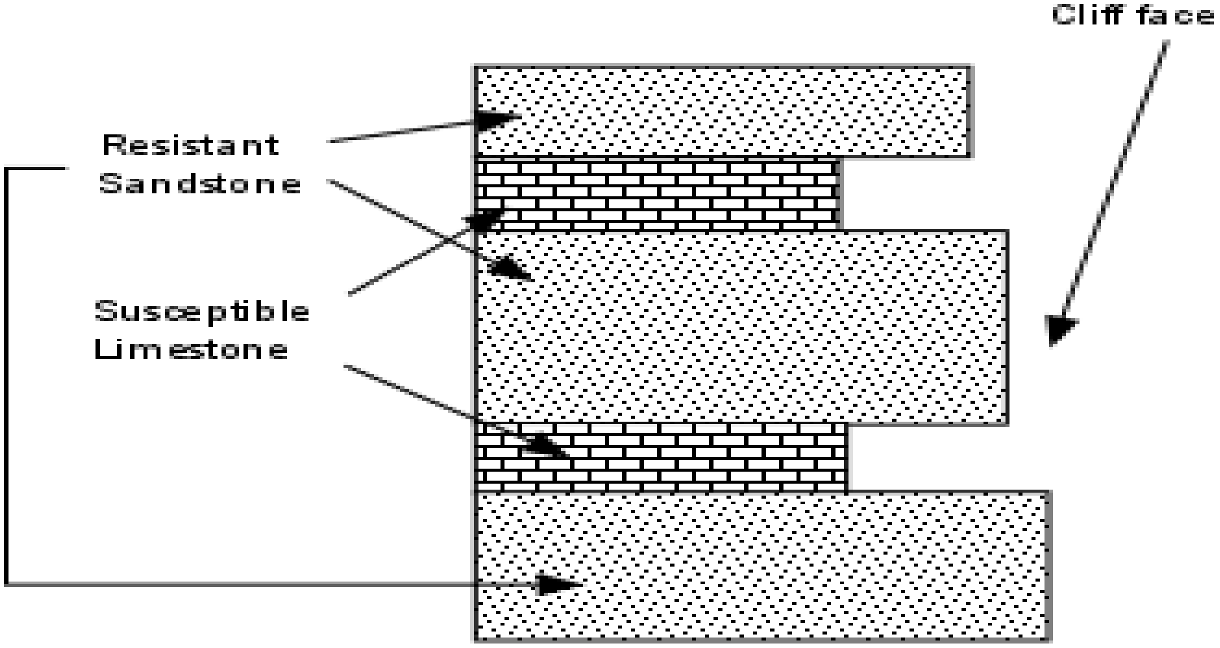
- Rock Type and Structure-
  - Different rocks are composed of different minerals, and each mineral has a different susceptibility to weathering. For example a sandstone consisting only of quartz is already composed of a mineral that is very stable on the Earth's surface, and will not weather at all in comparison to limestone, composed entirely of calcite, which will eventually dissolve completely in a wet climate.

- Bedding planes, joints, and fractures, all provide pathways for the entry of water. A rock with lots of these features will weather more rapidly than a massive rock containing no bedding planes, joints, or fractures

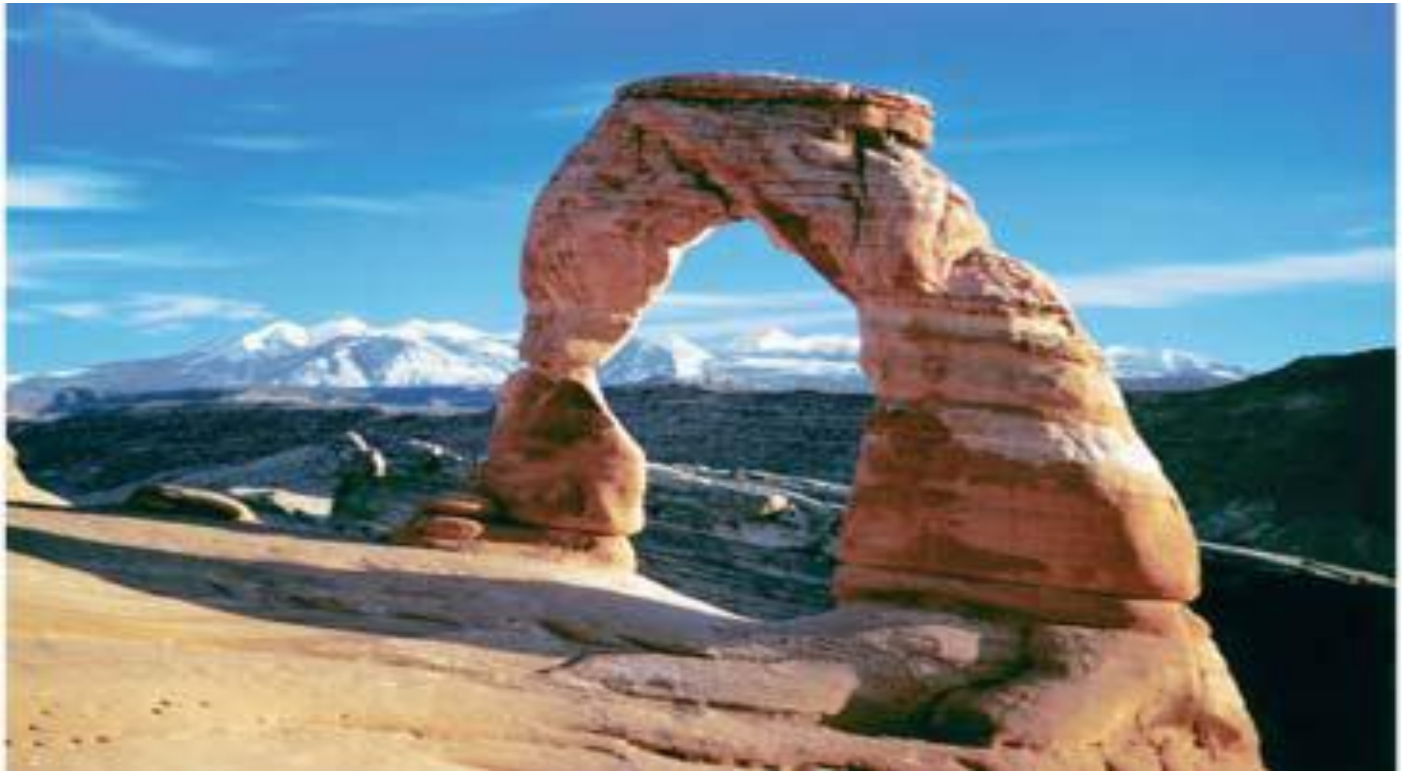
Differential Weathering.

- If there are large contrasts in the susceptibility to weathering within a large body of rock, the more susceptible parts of the rock will weather faster than the more resistant portions of the rock. This will result in ***differential weathering.***

Differential Weathering



Differential Weathering



Differential Weathering

Photo by David McGeary

Slope

- On steep slopes weathering products may be quickly washed away by rains. On gentle slopes the weathering products accumulate. On gentle slopes water may stay in contact with rock for longer periods of time, and thus result in higher weathering rates

Where steep, rocky slopes occur, **frost wedging** may generate large quantities of angular rock fragments that accumulate to produce **talus slopes**.

Climate

- High amounts of water and higher temperatures generally cause chemical reactions to run faster. Thus warm humid climates generally have more highly weathered rock, and rates of weathering are higher than in cold dry climates. Example: limestones in a dry desert climate are very resistant to weathering, but limestones in a tropical climate weather very rapidly

Temperature Changes

Courtesy Canadian Fire Research

Animals

- Burrowing organisms like rodents, earthworms, & ants, bring material to the surface were it can be exposed to the agents of weathering

Animal

Burrowing of Animals

Time

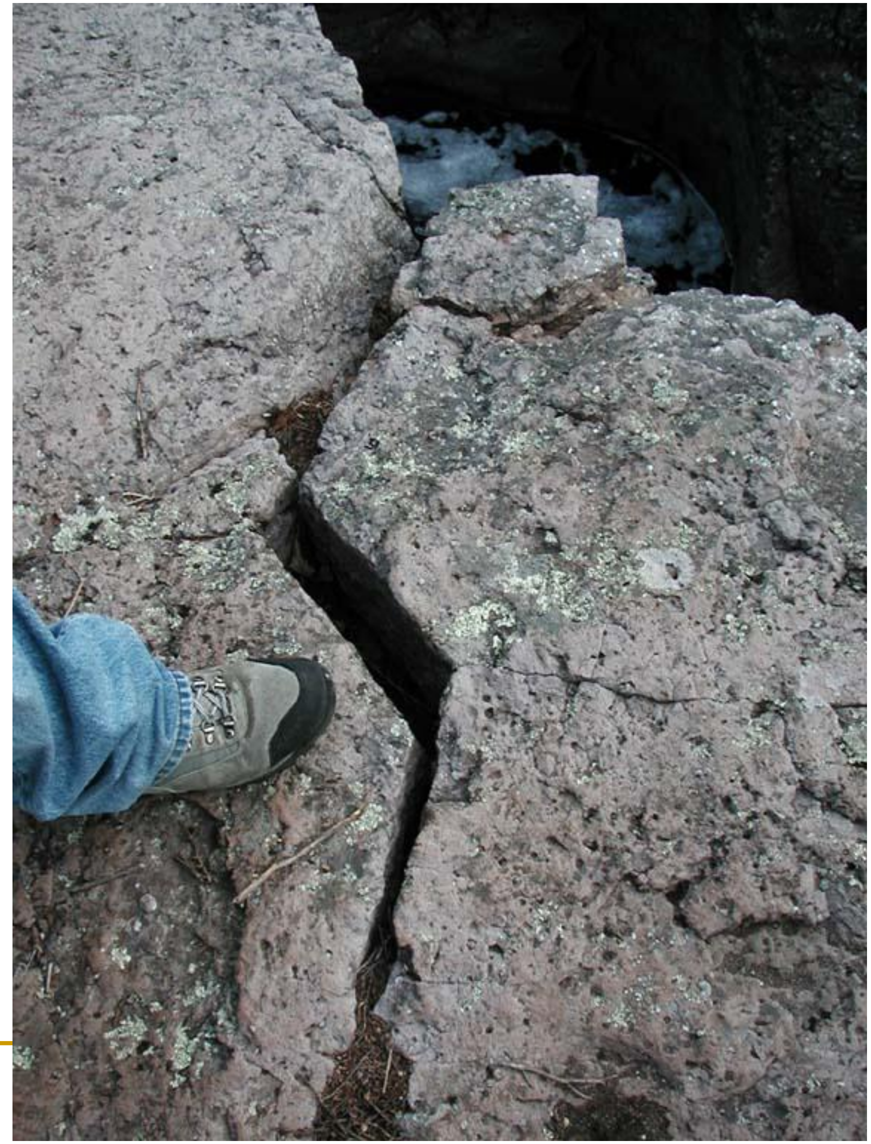
- since a rate is how fast something occurs in a given amount of time, time is a crucial factor in weathering. Depending on the factors above, rates of weathering can vary between rapid and extremely slow, thus the time it takes for weathering to occur and the volume of rock affected in a given time will depend on slope, climate, and animals.

Significance of weathering

1. General lowering of Landscape
2. Production of landscape hollows and pockets
3. Preparing of material for transportation by wind water, and ice
4. Weathered material recombine the sedimentary rocks.
5. Formation of soil

- Due to weathering the thickness of soil layers are effected
- Weathering produce raw materials

Frost Wedging



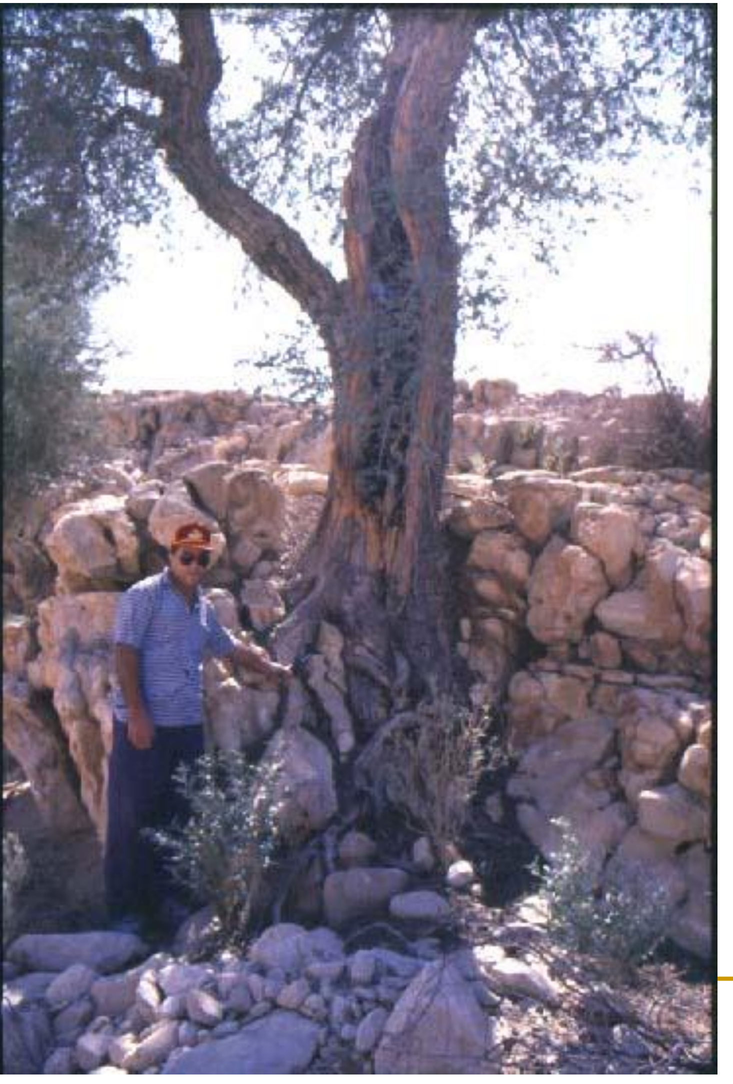
Frost wedging

Frost Action

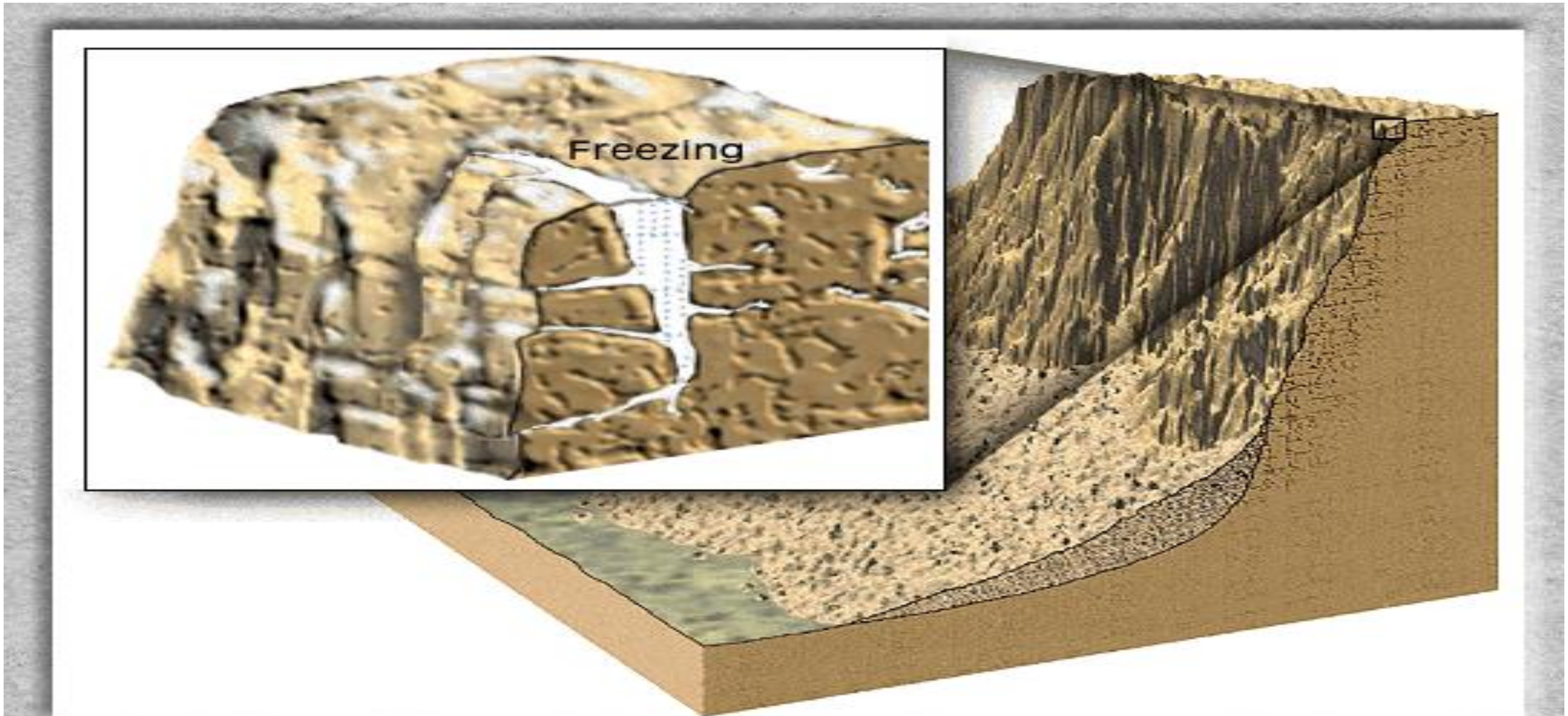
Frost Action

Frost Heaving

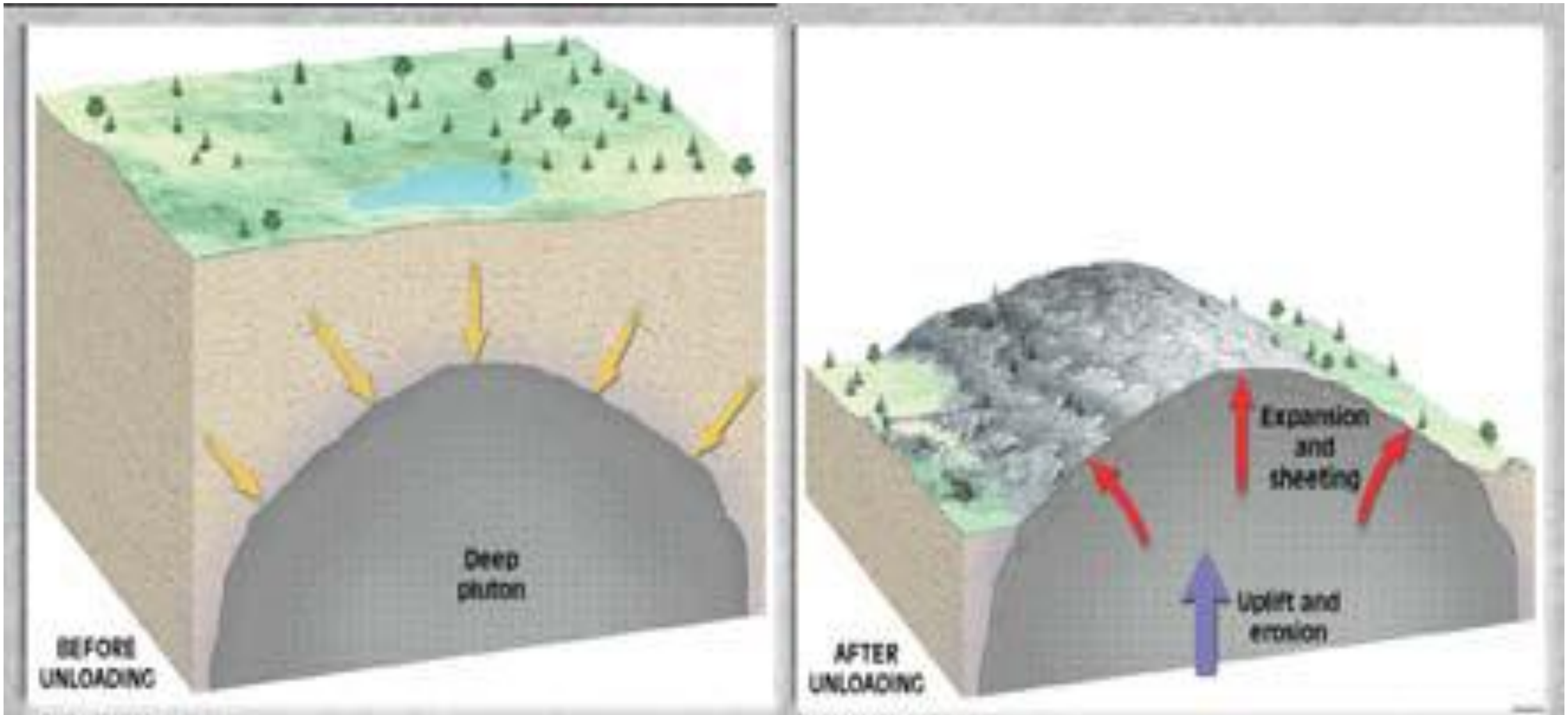
Plant Roots



When liquid water freezes, its volume expands about 9 percent. As a result, water freezing in a confined space exerts a tremendous outward force.



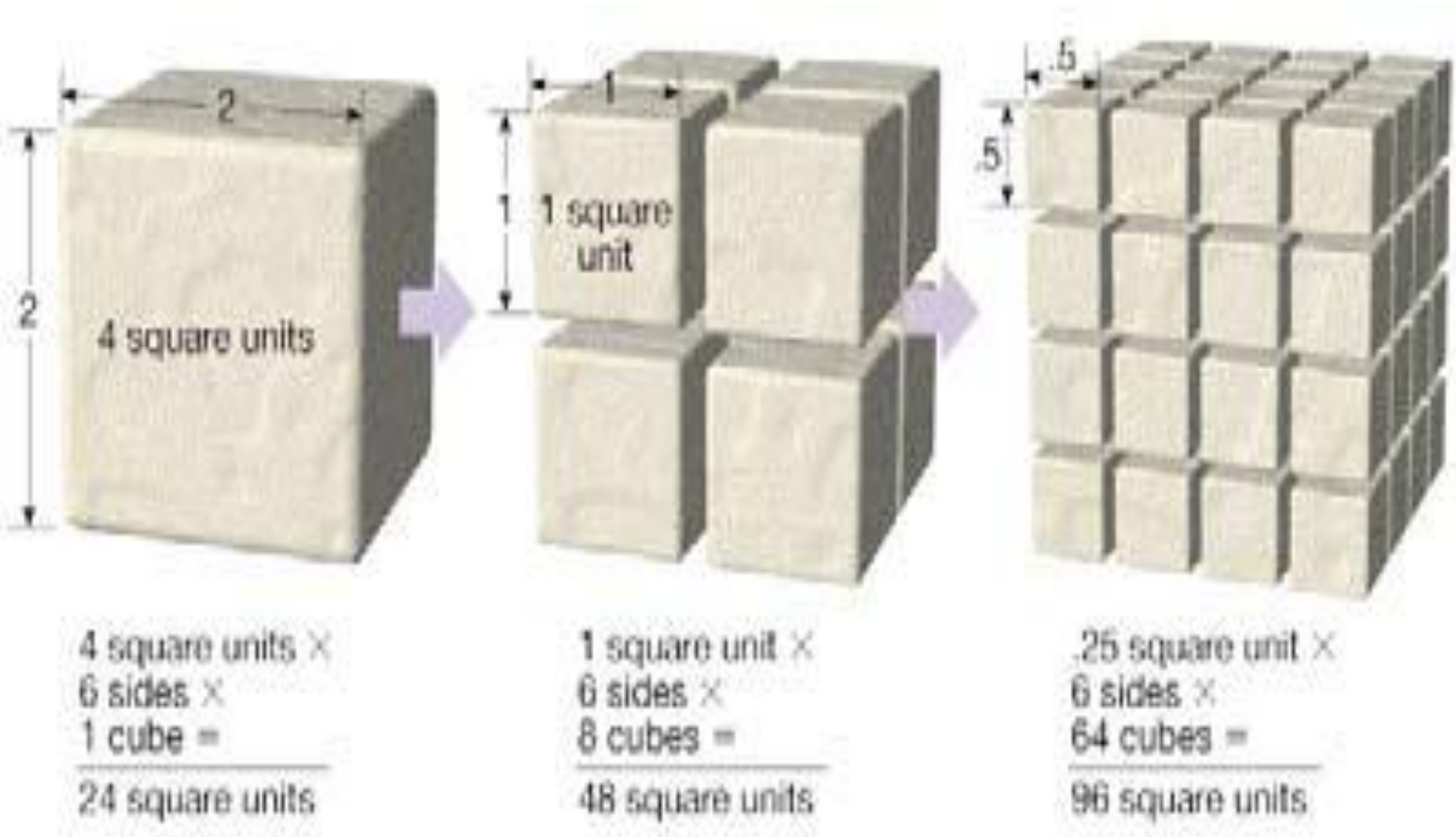
In nature, water works its way into cracks in rock. After many freeze-thaw cycles, rock is broken into angular fragments.



The process generating these onionlike layers is called **sheeting**. It happens in response to the great reduction in pressure that occurs when the overlying rock is removed by erosion, a process known as **unloading**.

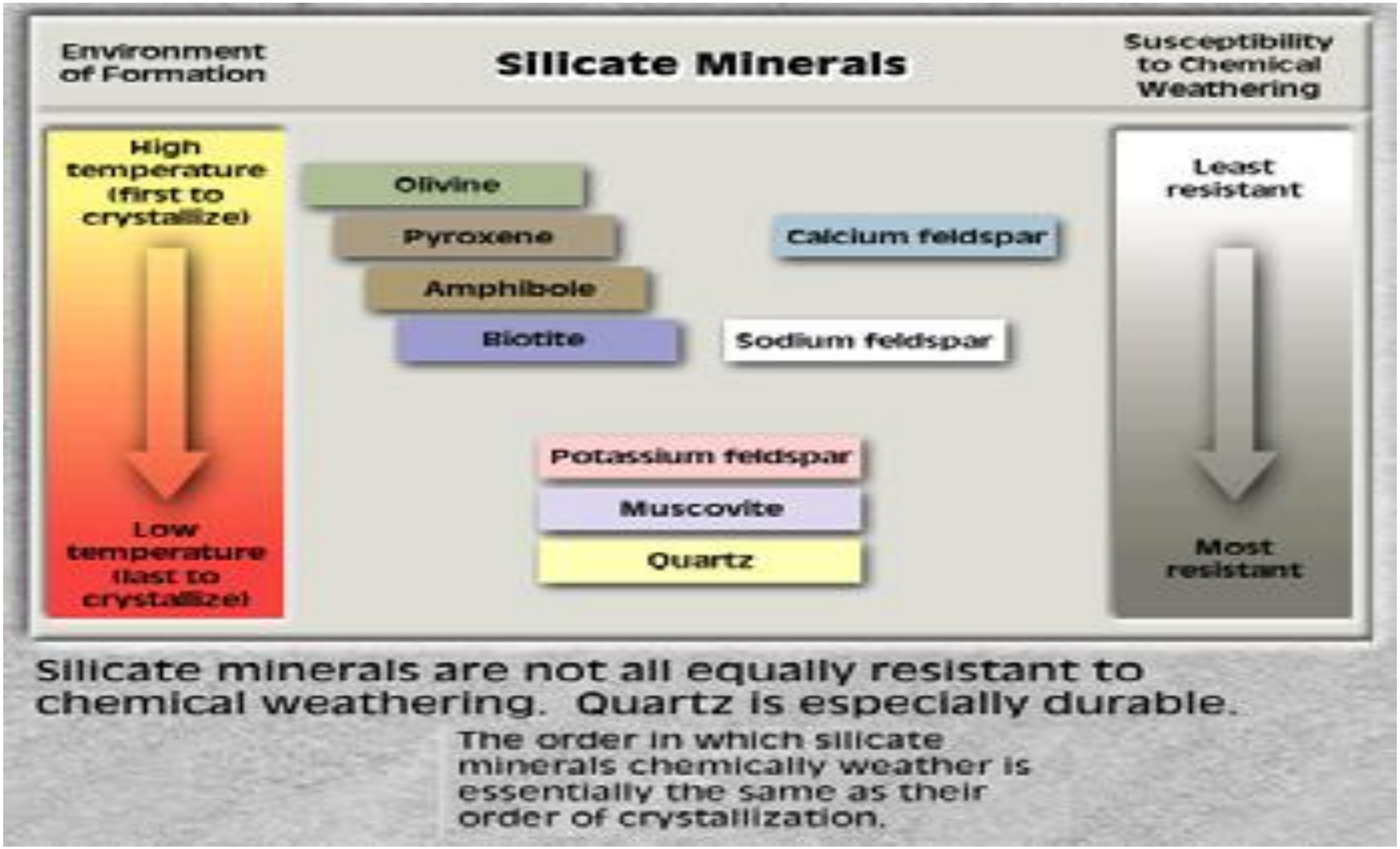
Exfoliation in Granite

Chemical weathering



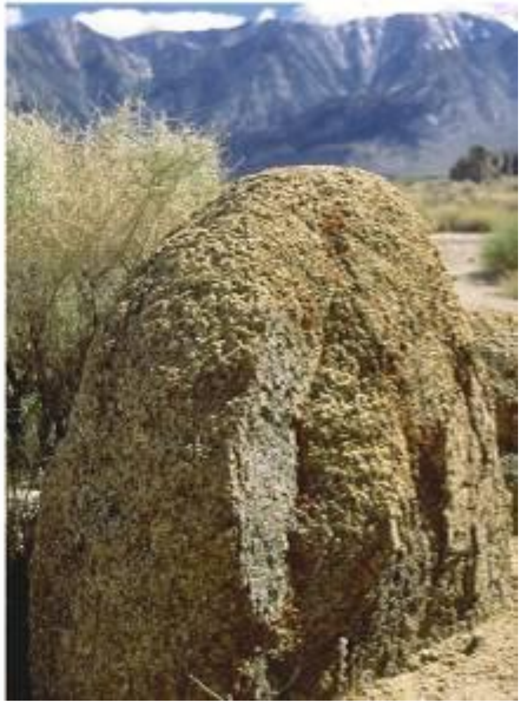

SWEAT
Granite
Marble
One of the important rock characteristics that influences weathering is the mineral composition of the rock.
These headstones were erected at about the same time in the same cemetery.
Here you can see that the granite headstone is relatively resistant to chemical weathering as compared to the marble headstone. The marble headstone is composed of calcite, which readily dissolves in a weakly acidic solution. The silicate minerals composing granite are much more resistant.

chemical



Environment of Formation
Silicate Minerals
Susceptibility to Chemical Weathering
High temperature (first to crystallize)
Low temperature (last to crystallize)
Olivine
Pyroxene
Amphibole
Biotite
Calcium feldspar
Sodium feldspar
Potassium feldspar
Muscovite
Quartz
Least resistant
Most resistant
Silicate minerals are not all equally resistant to chemical weathering. Quartz is especially durable.
The order in which silicate minerals chemically weather is essentially the same as their order of crystallization.

Chemical decomposition on surface rocks weather Spheroidally



Living Organisms Biological

- Lichens that grow on rocks produce weak acids that chemically weather rock

thanks!