Surface Processes that affect the Geosphere:

Weathering and Erosion
(How large rocks turn into smaller ones)

Foot prints on the moon are still there.

Weathering

- Weathering describes the **breaking down** or **chemically altering** of rocks and minerals on the surface to become sediment.
- *Water, ice, acids, salts, plants, animals, and changes in temperature are all agents of weathering.*
- *Can be Mechanical, Chemical or Biological*

Physical Weathering

- ***Physical weathering*** *is the weakening and subsequent disintegration of rock by physical forces. These physical forces include temperature fluctuation, abrasion, frost action (freezing and thawing), and salt crystal growth.*
- *Temperature fluctuation can cause expansion or contraction of rock.*
- *When the temperature of rock increases, the rock expands. When the temperature of rock decreases, the rock contracts.*
- *This process of expansion and contraction is a physical stress and can crack or break rock.*
- *Abrasion of rock is caused by the friction of water, wind, or ice upon the rock. The continuous exposure to these elements slowly breaks down the exposed surface of the rock*.

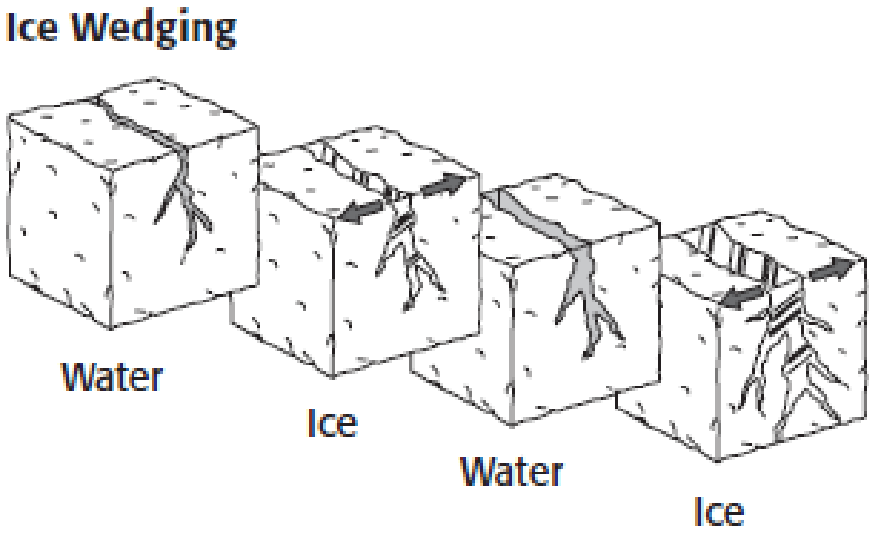
Mechanical (Physical) Weathering

- Minerals remain **unchanged.**
- Types of mechanical weathering:
  - **Freeze-thaw**
  - **Exfoliation – due to expansion and contraction**
  - **Abrasion**
  - **Plants and Animals**

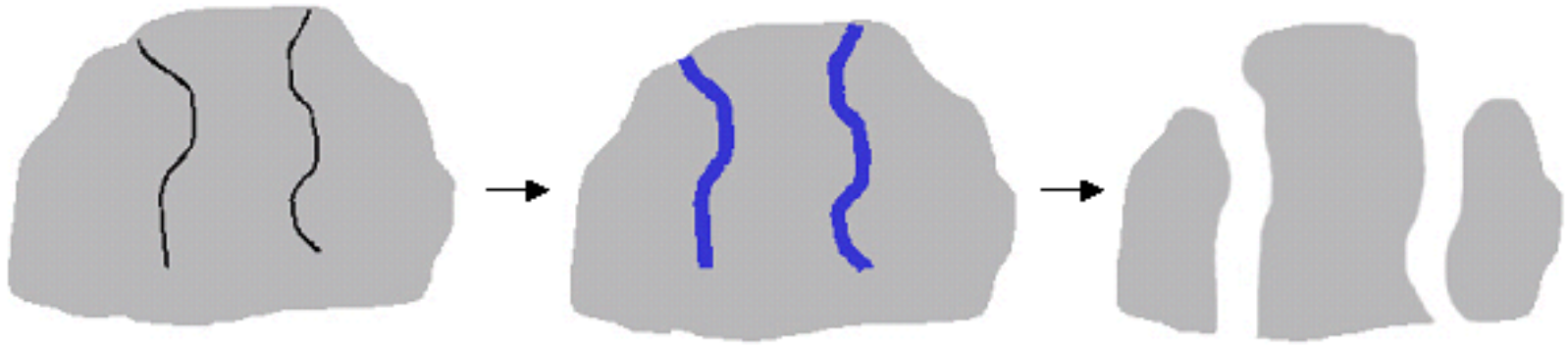
Freeze-thaw (Ice-wedging)

- Occurs when water continually seeps into cracks, freezes and expands, eventually breaking the rock apart.
- https://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle/page4268.html

Ice Wedging



- *Cycles of freezing and thawing can cause ice wedging, which can break rock into pieces:*
- *Water seeps into cracks in a rock.*
- *When the water freezes, it expands.*
- *The ice pushes against the cracks causing cracks to widen.*
- *When the ice melts, the water seeps further into the cracks.*
- *As the cycle repeats, the cracks get bigger.*
- *Finally, the rock breaks apart.*



The black lines in the rock represent fractures that are occurring in the rock.

The blue lines in the rock represent water soaking into the fractures.

The water freezes and expands. If this cycle of freezing, expansion, and thawing continues, the rock will gradually disintegrate.

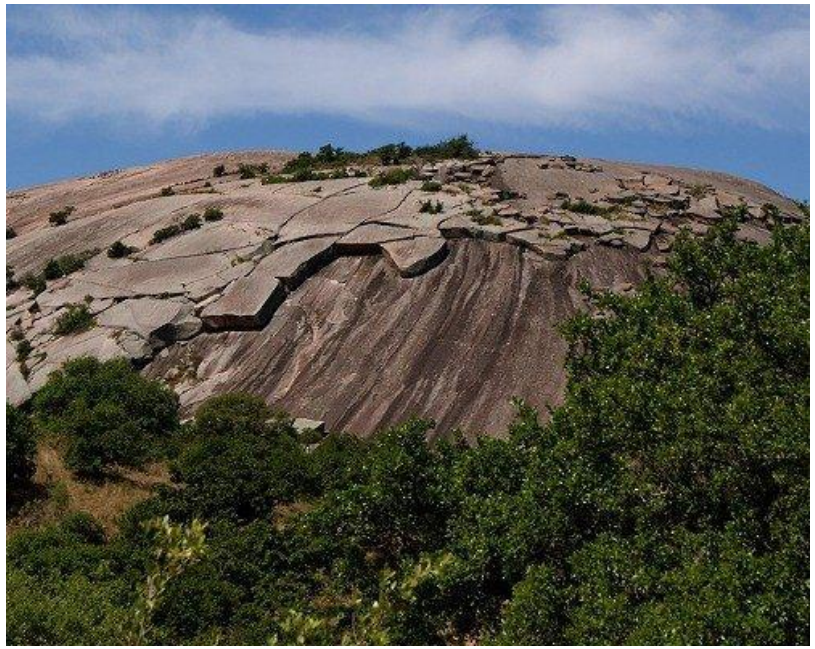
Figure 4. Frost action progressively disintegrates a rock. *Image courtesy of*

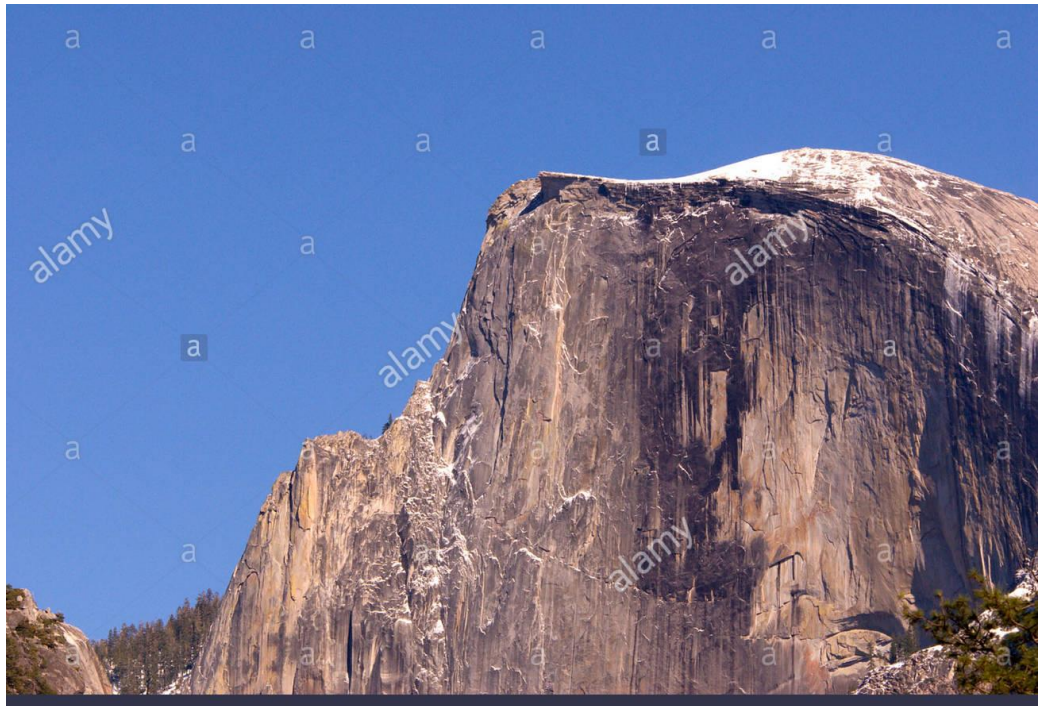
Salt wedging

- *Salt crystal growth can cause the break-up of rock materials.*
- *Crystal growth often occurs when groundwater moves into empty pores or spaces of rock by capillary action.*
- *As the water evaporates, salt crystals grow and accumulate, putting pressure on the rock and causing it to break apart.*
- *Salt crystallization is common in **drier** climates.*

Exfoliation (onion skin weathering)

- Hot and cold temperatures -->Expansion and contraction of rock -->Sheets of rock loosened--> exfoliation domes
- https://www.youtube.com/watch?v=WkEh0MLCNRE





Abrasion

- Abrasion - When rocks rub against each other and become rounded.

Abrasion by Wind

“desert varnish.”

Eg. Arches National Park, Utah

Ventifacts – stones shaped by wind

Plants and Animals

- Animals can walk on rock or disturb it, causing landslides that scrape or smooth rock surfaces.
- Burrowing animals such as badgers and moles can break up rock underground or bring it to the surface, where it is exposed to other weathering forces.

Plant Growth (Biological)

- Lichen and mosses wedge tiny roots into pores and crevices of rocks
- Tree roots

Name 5 Agents of Mechanical Weathering

Agents of Mechanical Weathering

- Wind, water, ice, plants, animals

Chemical Weathering

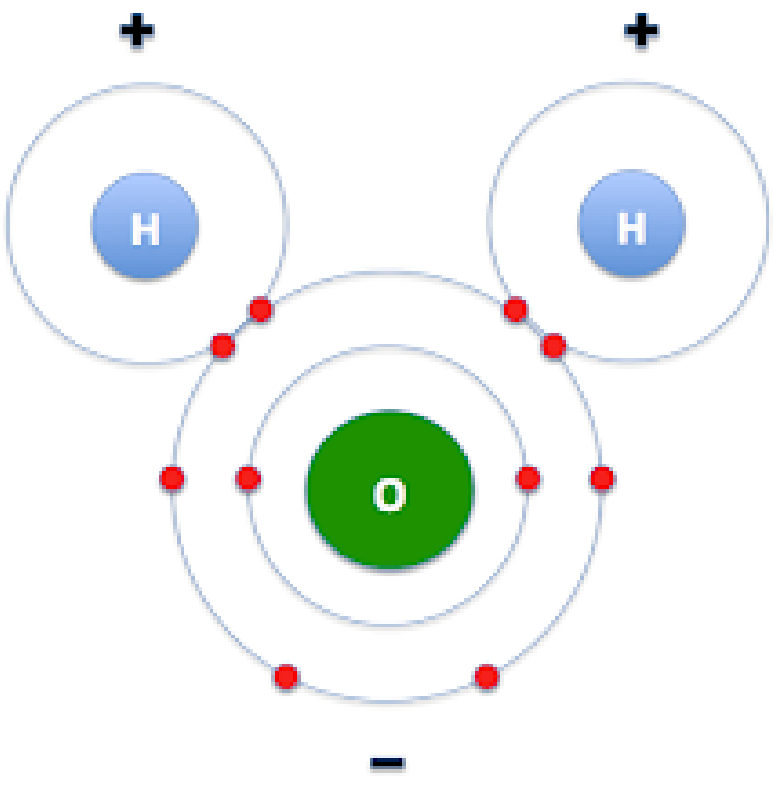
- Chemical weathering refers to the processes by which rocks **react** with the atmosphere to form **new** substances.
- These reactions can alter a rock and transform the rock into sand, clays, and other minerals.
- *Agents of Chemical Weathering:* ***Water, oxygen, carbon dioxide, acids*** *of plant decay*

Rock formed deep under ground become more susceptible as they reach the surface.

- *Most minerals form at high pressure or high temperatures deep in the crust, or sometimes in the mantle.*
- *When these rocks reach the Earth's surface, they are now at very low temperatures and pressures.*
- *This is a very different environment from the one in which they formed and the minerals are no longer stable.*
- *In chemical weathering, minerals that were stable inside the crust must change to minerals that are stable at Earth's surface.*
- *The minerals that form at the highest **temperatures** and **pressures** are the least **stable** at the surface. Clay is stable at the surface and chemical weathering converts many minerals to clay.*

Reaction with Water

- *The positive side of the molecule attracts negative ions and the negative side attracts positive ions.*
- *So water molecules **separate** the ions from their compounds and surround them.*
- *Water can completely **dissolve** some minerals, such as salt.*



Reaction with Water

- **Hydration:** New substance created when water is **absorbed** (water molecule used to form a bond), expanding and deforming the rock.

Eg. As the mineral anhydrite reacts with groundwater, it transforms into gypsum, one of the most common minerals on Earth.

$$CaSO_4\ 2H_2O == Ca^{2+} + SO_4^{2-} + 2H_2$$

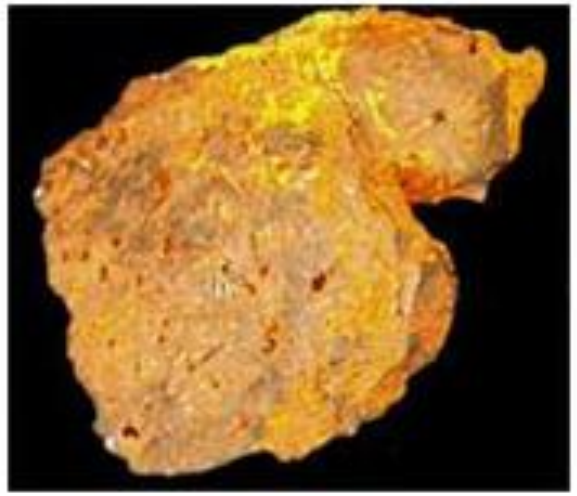
A 35% increase in volume which results in less stability.

Figure 6. The images above show anhydrite ($CaSO_4$), which can convert to gypsum ($CaSO_4.2H_2O$) through hydration. *(Image on the left is anhydrite, courtesy of*

Reaction with Water: Hydrolysis

- **Hydrolysis**: New substance created when water molecule **cleaves** (breaks) chemical bonds.
- *Dehydration is the removal of water from rock or mineral structures.*
- *A good example of dehydration is the removal of water from limonite, resulting in the formation of hematite.*
- Eg. Mineral potassium feldspar (in granite rock) is leached of potassium and changed into a clay mineral.

Dehydration



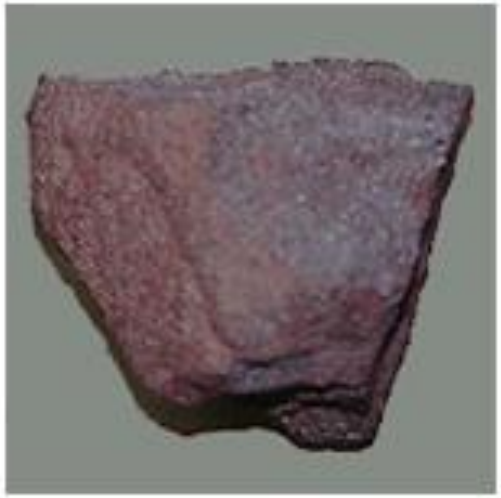


Figure 7. The images above show the dehydration reaction of limonite ($Fe_2O_3.H_2O$) on the left to hematite (Fe_2O_3) on the right. The water, which was a structural component of limonite, has been removed in the process of dehydration.

Hydrolysis

- When potassium feldspar reacts with slightly acidic water, it can be transformed into kaolinite, a clay mineral:

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

(potassium feldspar) + (hydrogen ion) + (water) → (potassium ion) + (kaolinite) + (silica)

- Granitic pebbles within the rock have weathered, partly through hydrolysis, into kaolin (seen as white spots in the picture above).

Dissolution

- Dissolution is when a mineral **<u>completely dissolves in water.</u>**
- especially in rocks that contain either magnesium carbonate or calcium carbonate, which easily dissolve in water or other acidic solutions (often carbonic acid - the result of a reaction between carbon dioxide and water).
- $CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$
- (calcite) + (carbonic acid) → (calcium ion) + (bicarbonate ion)

Dissolution

- *Rainwater falling on this rock, and flowing along fractures in the rock, has slowly dissolved some of the limestone to create pits and channels.*

Dissolution -> Karst

- Soluble rocks such as **limestone, dolomite**, and **gypsum** (contain calcium carbonate) can be dissolved and carried away leaving behind huge land forms called **Karst.**

Dissolution → Karst

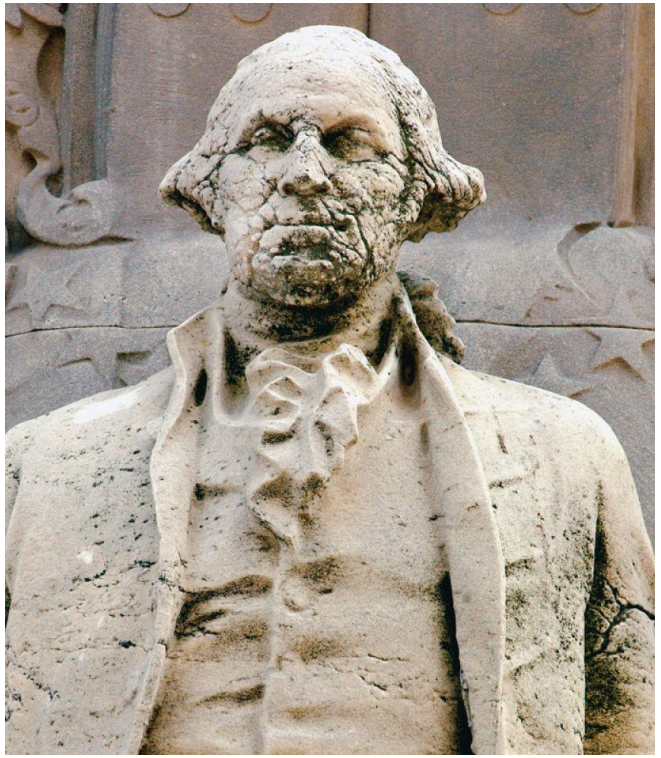
- *One of the world's most spectacular examples of karst is Shilin, or the Stone Forest, near Kunming, China.*
- *Hundreds of slender, sharp towers of weathered limestone rise from the landscape.*

Carbonation: Reaction with Carbon Dioxide

- Carbon dioxide from the **air** or **soil** can combine with water to form **carbonic acid,** a weak acid that can dissolve rock, especially **limestone** (calcium carbonate)

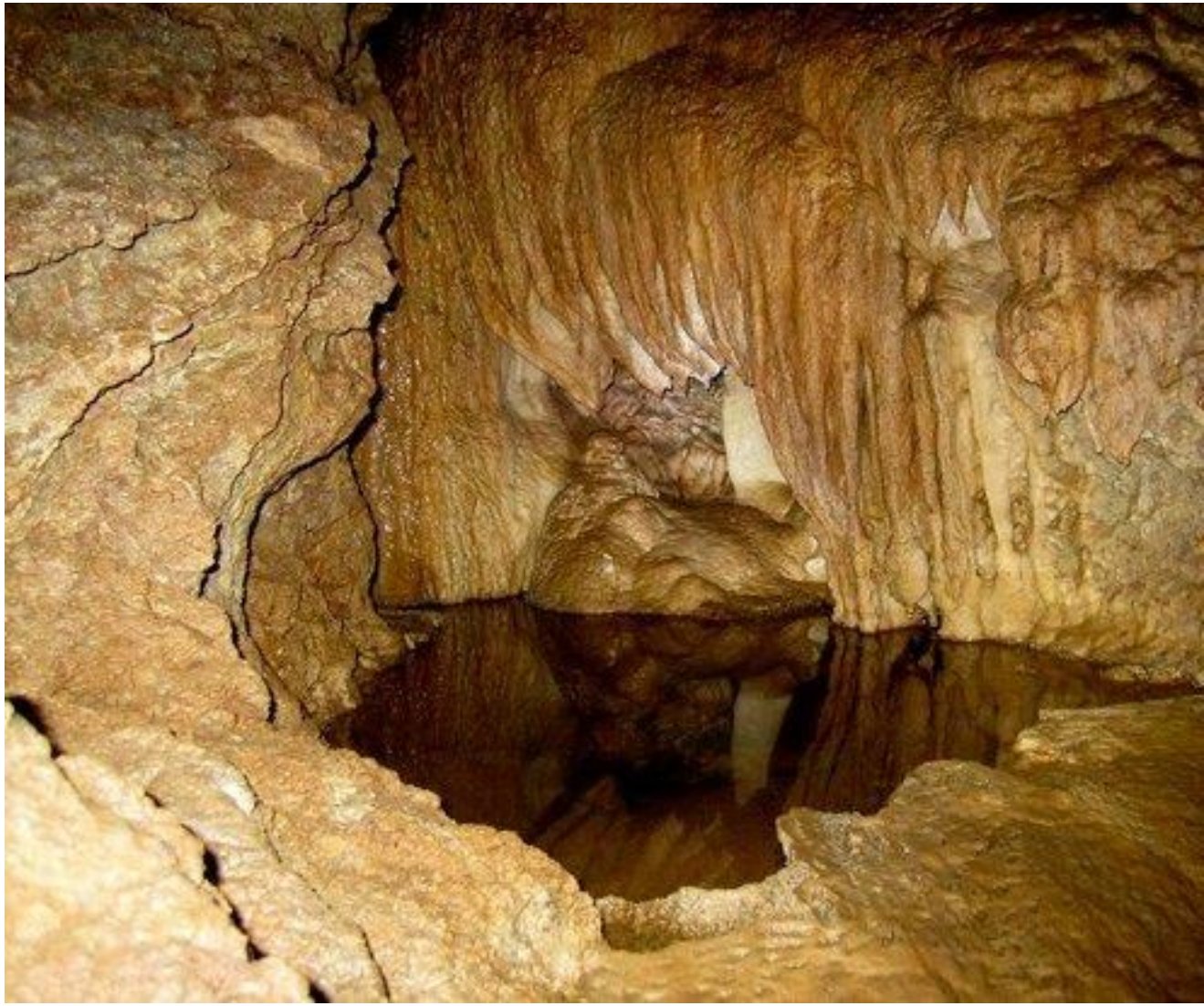
$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

carbon dioxide + water *carbonic acid*



Carbonation

- *When carbonic acid seeps through limestone underground, it can open up huge cracks or hollow out vast networks of caves.*



Carbonation

- *Carlsbad Caverns National Park, New Mexico, includes more than 119 limestone caves created by weathering and erosion.*
- *The largest is called the Big Room. It is the size of six football fields.*

Oxidation: Reaction with Oxygen

- *Oxygen is very strongly reactive.*
- Minerals rich in **iron** break down as the iron oxidizes and forms new compounds.
- *As rust expands, it weakens rock and helps break it apart.*
- *Iron oxide produces the red color in soils.*

Oxidation

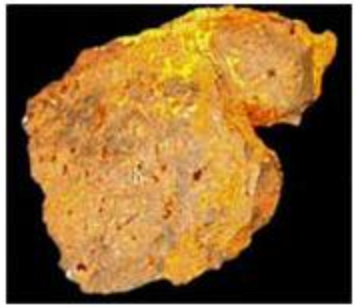
- the oxidation of pyroxene into limonite and dissolved silica:
- $4FeSiO_3 + O_2 + H_2O \rightarrow 4FeO(OH) + 4SiO_2$
- (pyroxene) + (oxygen) + (water) → (limonite) + (silica)

Uluru, also known as Ayers Rock, is a sandstone which gets its coloring from the oxidation of iron-bearing minerals.

Oxidation

- **Oxidatio** th
  oxygen, t on of the
  rock.
- When mi less
  resistant
- Iron, a co ed or rust
  colored when oxidized.

Olivine



Limonite

Figure 5. The iron in olivine (Fe_2SiO_4) is reduced and the iron in limonite ($Fe_2O_3.H_2O$) is oxidized. In addition, the release of silicon and hydration makes the mineral more susceptible to physical weathering. *(Image on the left*

Factors Affecting Rates of Weathering:

<u>1. Rocks</u> themselves – how resistant they are

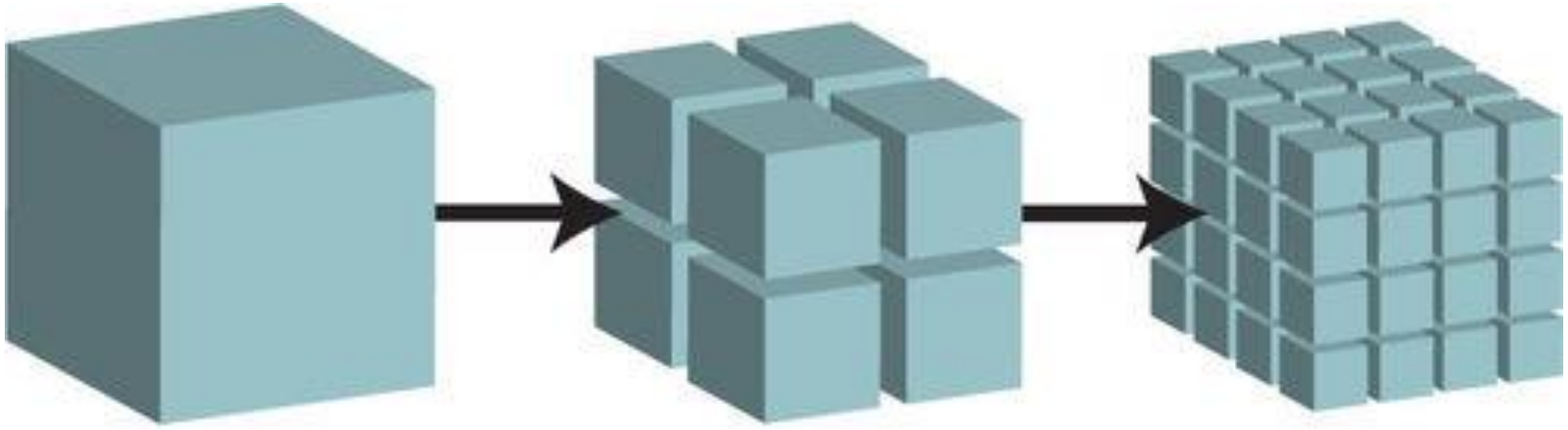
Rock (texture) and Mineral Type (composition)

- **Composition:** Mineral such as **Quartz** is hard, no cleavage makes it resistant to weathering.
- **Texture:** Igneous rocks, especially intrusive igneous rocks such as **granite**, weather slowly because it is hard for water to penetrate them.
- **Composition**: Other types of rock, such as **limestone**, are easily weathered because they dissolve in weak acids.

- *Rocks that resist weathering remain at the surface and form ridges or hills. Devil's Tower in Wyoming is an igneous rock from beneath a volcano*
- *As the surrounding less resistant rocks were worn away, the resistant center of the volcano remained behind.*

2. Amount of **surface area** exposed

- Mechanical weathering increases the rate of chemical weathering.
- As rock breaks into smaller pieces, the surface area of the pieces increases.



As rock breaks into smaller pieces, overall surface area increases.

3. Climate:

<u>Warm, wet</u> *climates favor* ***chemical*** *weathering – more and increased rate of chemical reactions. Increased water also increases physical weathering.*

<u>Cold, dry</u> *climates favor* ***mechanical*** *weathering – increase freeze-thaw cycles, exfoliation (cooling/shrinking, warming/expanding). Ice.*

Warm, wet *climates favor* ***chemical*** *weathering*

- **Increased temperature** increases **rate** of chemical reactions. For each 10°C increase in average temperature, the rate of chemical reactions doubles.
- Increased p**recipitation** increases **amount** of chemical reactions. Water causes **both** mechanical and chemical weathering.

Climate

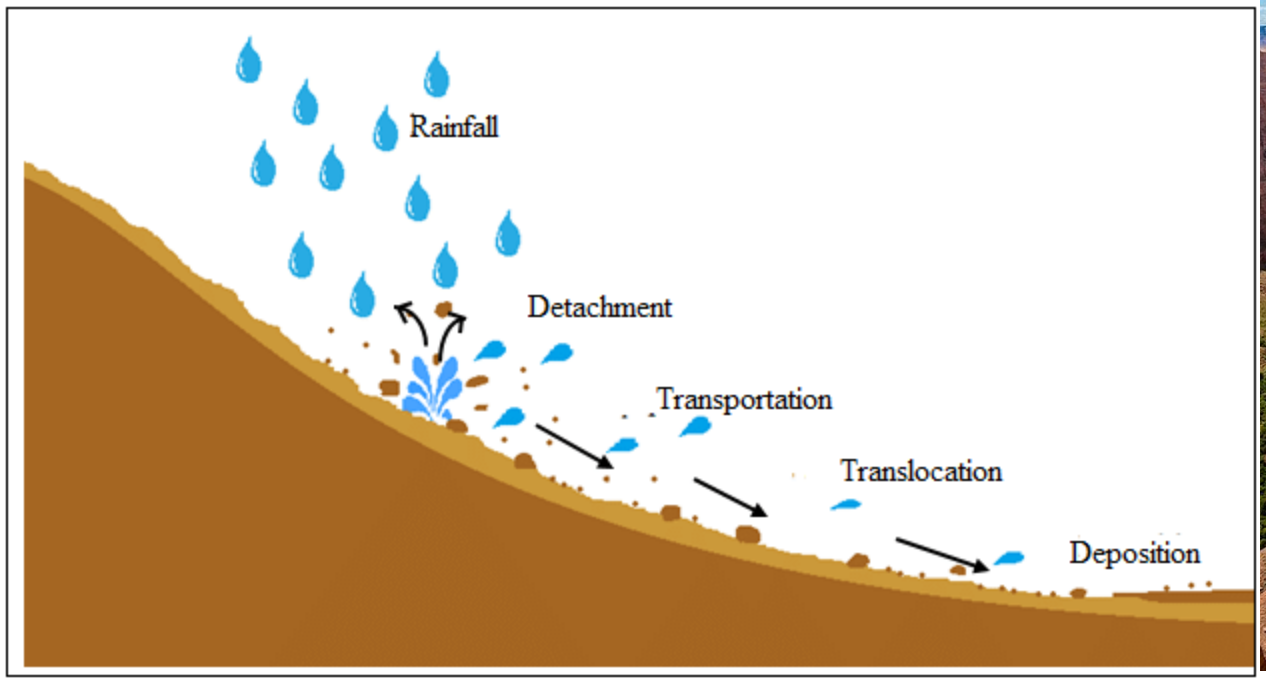
- *Highest Rate of Weathering: warm, wet climate. Also allows for more types of vegetation, increasing rate of biological weathering.*
- *Lowest Rate of Weathering: cold, dry climate.*

Which Rocks and Minerals Resist Most?

- Sedimentary rocks are only as strong as their **cement** holding them together.
- S**hale** (fine grain) is weakest of all sedimentary rocks, easily split.
- Rocks with **silica** or **quartzite** as a cement are more **durable**.
- **Marbles and limestones** are **fairly resistant** to mechanical weathering (except **calcite** often found in marble reacts to **acid**).
- **Limestones** deteriorate **faster in wet climates** where water can carry dissolved acid. Therefore last longer in dry climates because where there is very little dissolved acid.

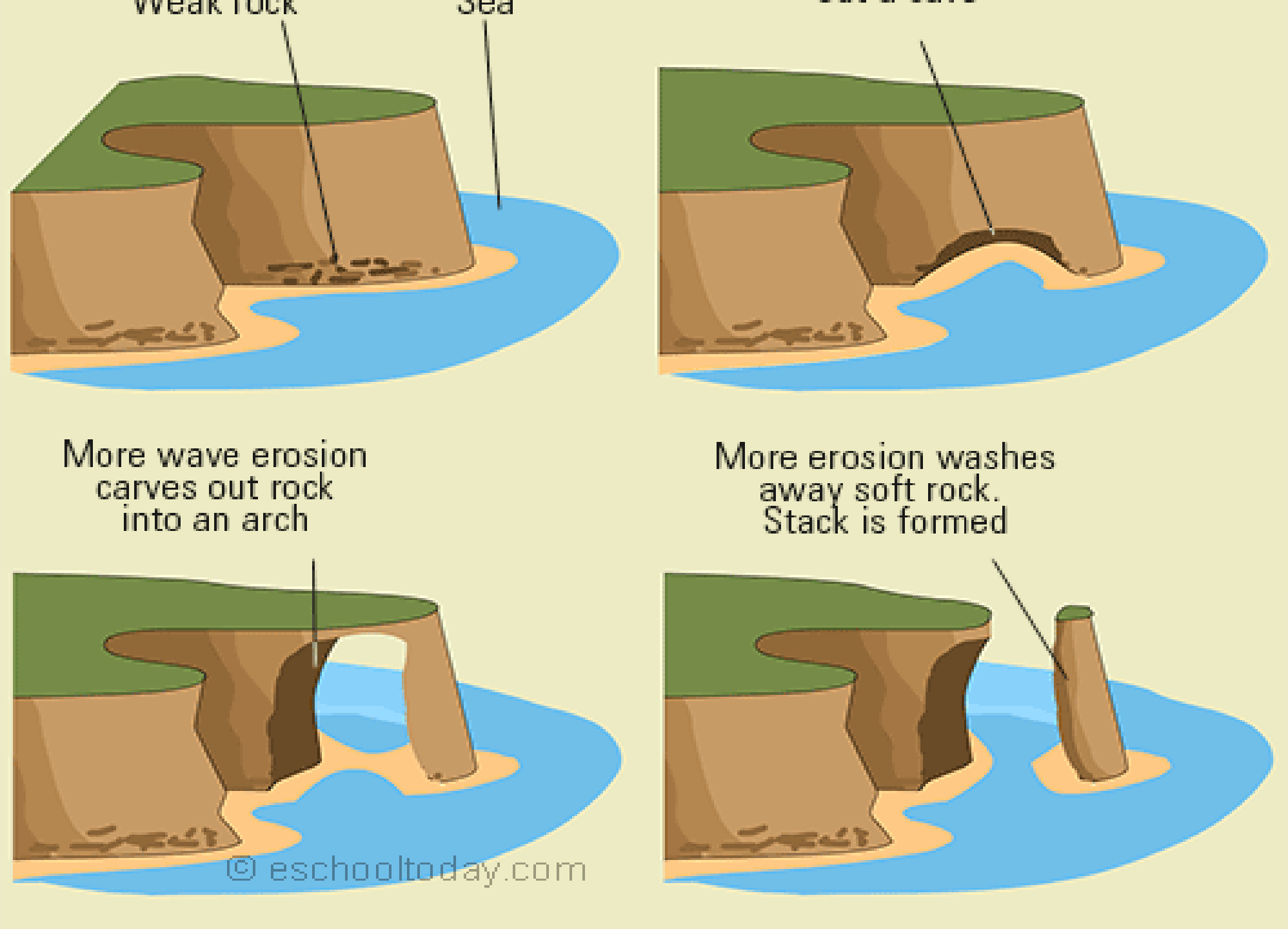
What is Erosion?

- Erosion is the **removal** and **transport** of earth materials by natural agents.
- Agents of Erosion: Wind, Water, Ice, Gravity



Erosion by Water

- *Rain, rivers, floods, lakes, and the ocean carry away bits of soil and sand, and slowly wash away the sediment.*


Weak rock
Sea
More wave erosion carves out rock into an arch
More erosion washes away soft rock. Stack is formed
© eschooltoday.com

Erosion by Ice: Glaciers

Glaciers are large slabs of ice. As glaciers move, they transport everything in their path, from tiny grains of sand to huge boulders.

- **Abrasion** is the process in which a glacier scrapes underlying rock
- **Glacial striations** are scratches and grooves that show the direction the glacier moved.

Erosion by Ice: Glaciers

- **<u>Plucking</u>** is the process by which rocks and other sediments are picked up by a glacier.
- *They freeze to the bottom of the glacier and are carried away by the flowing ice.*
- Glacier sediment deposits are called **<u>moraine.</u>**

Erosion by Ice

Moving glaciers gouge out basins and form steep-sided mountain valleys.

Erosion by Wind

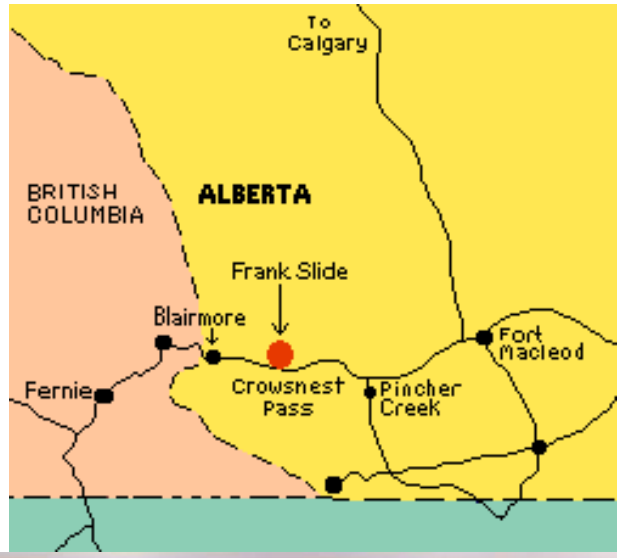
- Aeolian (wind-driven) processes constantly transport dust, sand, and ash from one place to another.
- *Wind can sometimes blow sand into towering dunes.*
- *Eg. Sand dunes of Badain Jaran section of the Gobi Desert in China, reach more than* ***400 m high****.*

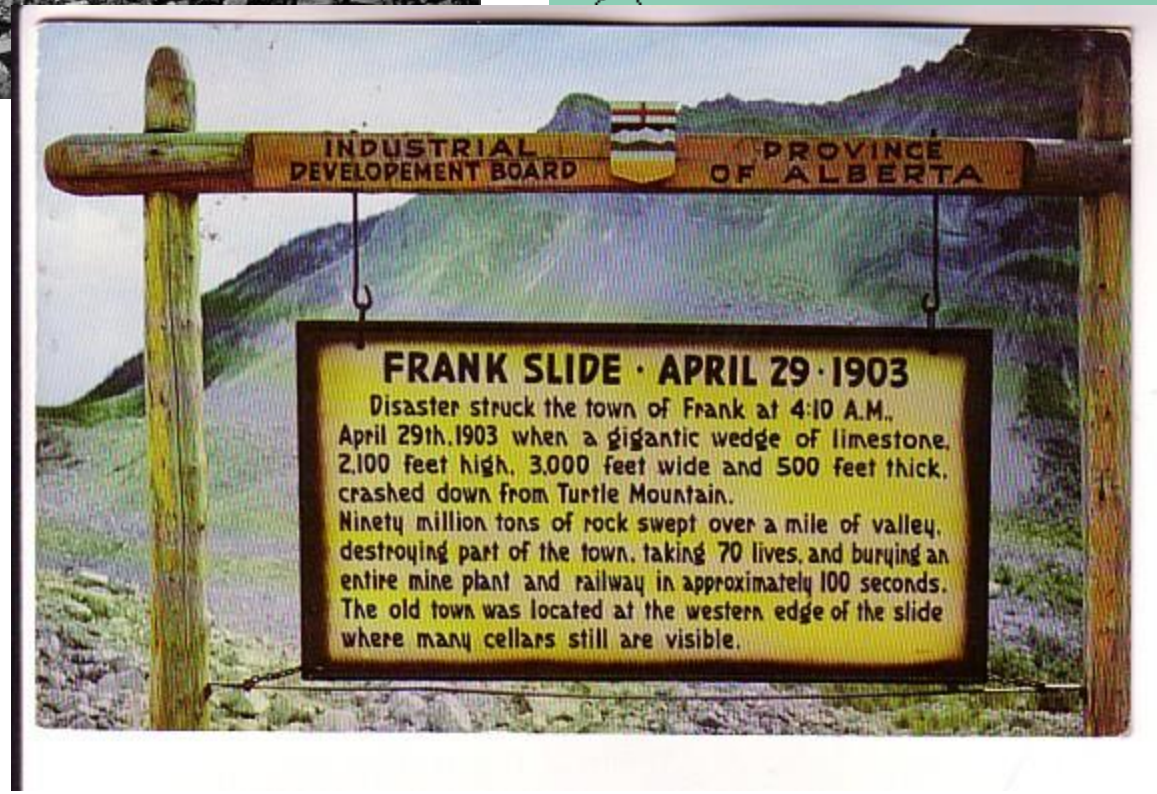
Erosion by Gravity

- **Landslides** and other forms of **mass wasting**
- These processes cause rocks to dislodge from hillsides and crumble as they tumble down a slope.

Frank Slide 1903

*It is the deadliest landslide in Canadian history and was the largest until the Hope **Slide** in 1965.*





What is the difference between Weathering and Erosion?

What is the difference between Weathering and Erosion

- Weathering is the **breakdown** or **dissolving** of rock but does not involve movement.
- Erosion is the **movement** of material

Check in

1. Which rocks are most resistant to chemical and physical weathering?

2. Why?

3. Which are most susceptible?

4. What kind of climate promotes weathering?

5. What types of rocks are susceptible to chemical weathering?

Check in

1. Which rocks/minerals are most resistant to chemical and physical weathering?

Granite/Quartz

2. Why? Hard, no cleavage

3. Which are most susceptible? Shale is weakest – splits easily, limestone (calcite/calcium carbonate) dissolves easily in water especially in acidic conditions.

4. What kind of climate promotes weathering? Warm, damp

5. What types of rocks are susceptible to chemical weathering? Those containing calcite are susceptible to acid.

Summary

- Mechanical weathering breaks rocks into smaller pieces *without* changing their composition.
- Ice wedging and abrasion are two important processes of mechanical weathering.
- Chemical weathering breaks down rocks by forming new minerals that are stable at the Earth's surface.
- Water, carbon dioxide, and oxygen are important agents of chemical weathering.
- Different types of rocks weather at different rates. More resistant types of rocks will remain longer.

Can you answer these?

1. What are the four forces of erosion and which is responsible for the most erosion?
2. Name two types of mechanical weathering. Explain how each works to break apart rock.
3. What are three agents of chemical weathering? Give an example of each.
4. What type of climate would likely produce the greatest degree of weathering? Explain.
5. What causes differential weathering in a rock?
6. Would a smooth even surface weather faster than an uneven, broken surface?
7. What type of rocks would be best suited to making monuments?

Consider the following

- What other types of surfaces are affected by weathering other than rock?
- What might the surface of the Earth look like if there was no weathering? Think about the Moon or other planets.
- Do you think that you would be alive today if water did not dissolve elements?
- Would the same composition of rock weather the same way in three very different climates?

Homework

- Read pages 131-136
- Answer #4ab, 5, 6 p 137

- Next Class: Weathering Simulation Lab

Biological Weathering

- **Biological weathering** is the weakening and subsequent disintegration of rock by plants, animals and microbes.
- Growing **plant roots** can exert stress or pressure on rock. Although the process is physical, the pressure is exerted by a biological process (*i.e.*, growing roots). Biological processes can also produce chemical weathering, for example where plant roots or microorganisms produce organic acids which help to dissolve minerals.
- **Microbial activity** breaks down rock minerals by altering the rock's chemical composition, thus making it more susceptible to weathering. One example of microbial activity is lichen; lichen is fungi and algae, living together in a symbiotic relationship. Fungi release chemicals that break down rock minerals; the minerals thus released from rock are consumed by the algae. As this process continues, holes and gaps continue to develop on the rock, exposing the rock further to physical and chemical weathering.

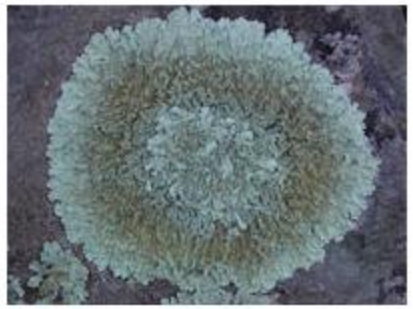


Figure 8. Two examples of lichen: Left, circular lichen in Great Falls, MD, and right, a lichen covered rock at Lake Superior. *(Images by C. Geiss.)*

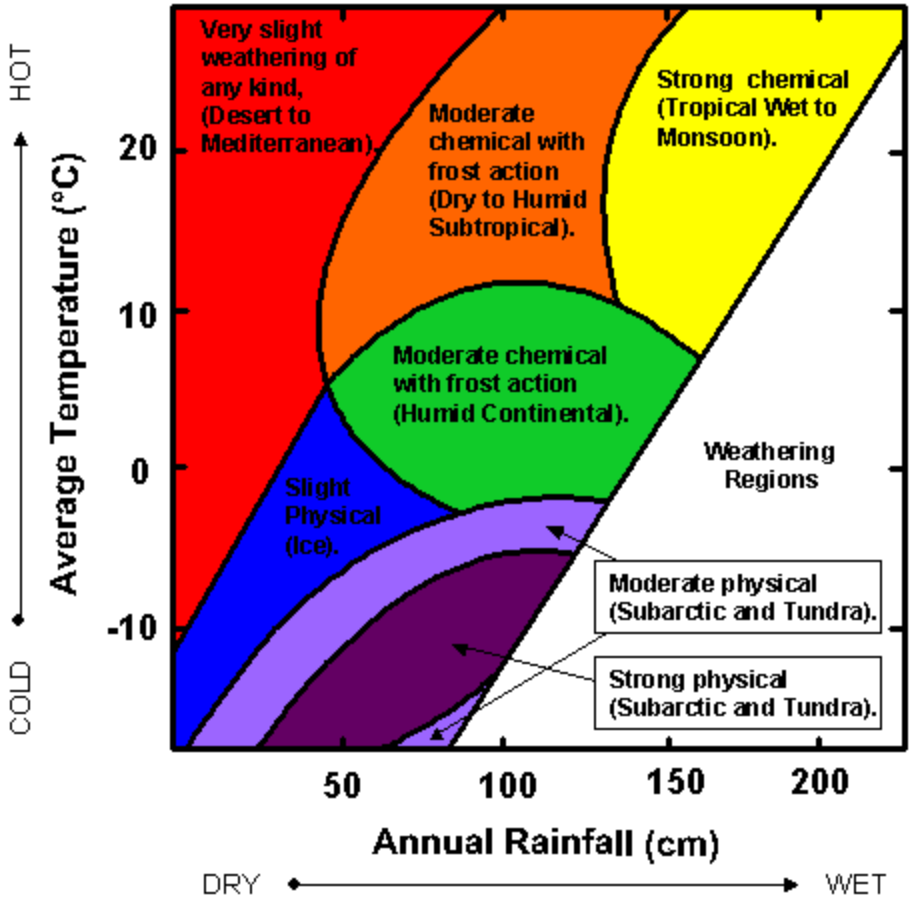
- Burrowing **animals** can move rock fragments to the surface, exposing the rock to more intense chemical, physical, and biological processes and so indirectly enhancing the process of rock weathering.

Although physical, chemical, and biological weathering are separate processes, some or all of the processes can act together in nature.

- **Question 1:** Which type of weathering creates a rusting effect on minerals?

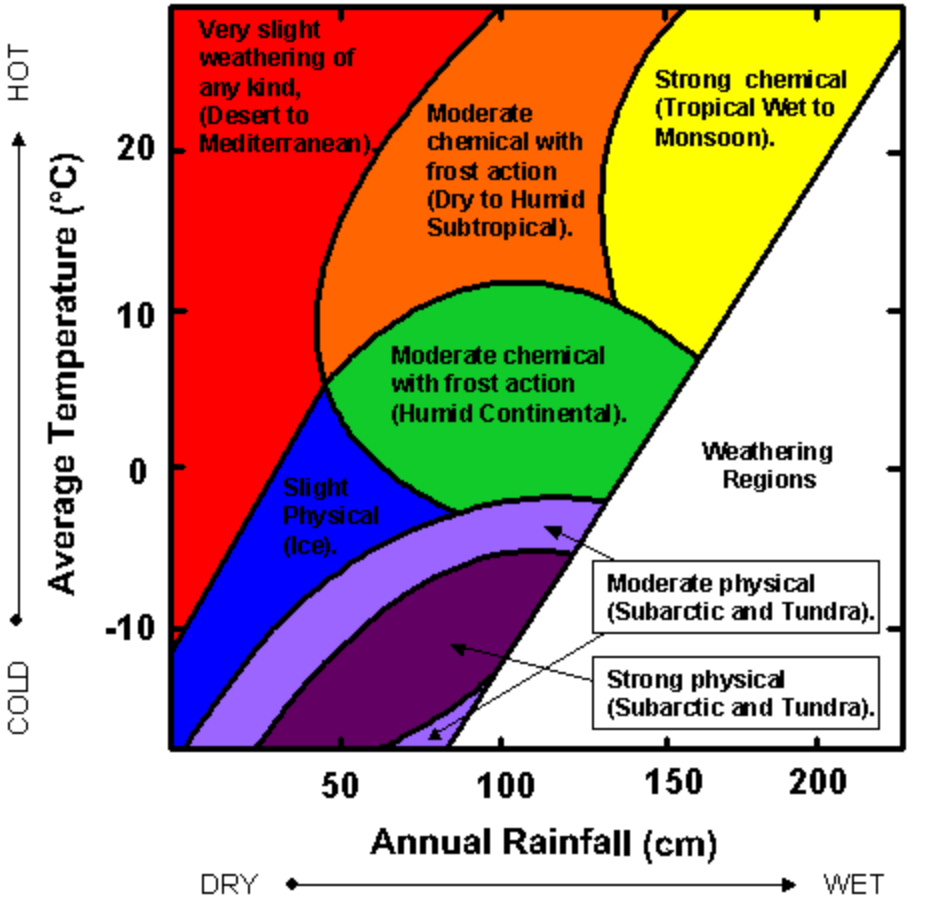
  A. Hydration
  B. Hydrolysis
  C. Oxidation
  D. Carbonation

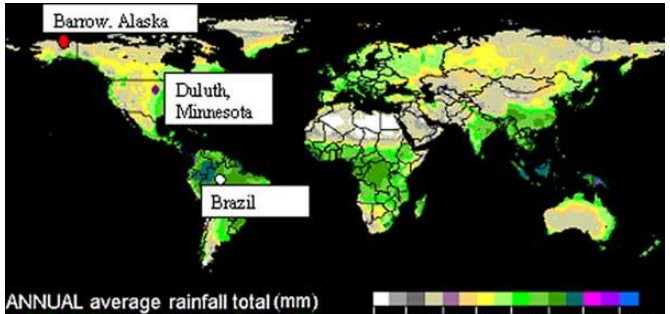
- **Question 2:** Use Figure 2 to decide which type of weathering process will dominate in Antarctica?
  A. Physical
  B. Chemical
  C. Biological

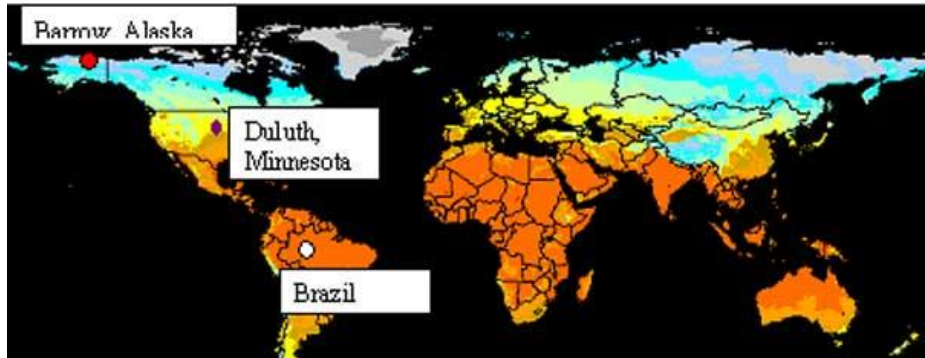


- **Question 3:** Use Figure 1 and the following links to decide which type of weathering process will dominate in central Africa?View Annual Average Rainfall Map
- View Annual Average Temperature Map
-

  A. Physical
  B. Chemical
  C. Biological







- **Question 4:** One of the experiments shown previously in this lesson demonstrated the hydrolysis of feldspar. How does physical weathering increase the rate of chemical weathering?

- **Question 4:** One of the experiments shown previously in this lesson demonstrated the hydrolysis of feldspar. How does physical weathering increase the rate of chemical weathering?
- Physical weathering gradually shatters the rock into small pieces. This gives more surface area exposure to chemical weathering. The key here is surface area

- **Question 5:** If calcite, a primary component of limestone rock, is only slightly soluble in water, under what environment would you expect this limestone to be dissolved?

- **Question 5:** If calcite, a primary component of limestone rock, is only slightly soluble in water, under what environment would you expect this limestone to be dissolved?
- In areas where carbonation occurs (humid and warm environments), the acid formed from carbon dioxide and water, slowly dissolves the limestone

- **Question 6:** Is pressure exerted by roots on a rock structure physical or chemical weathering? Why?

- **Question 6:** Is pressure exerted by roots on a rock structure physical or chemical weathering? Why?
- Tricky question. The answer is both physical and chemical weathering. Although the pressure of growing roots is physical, chemicals released by roots enhance microbiological activity. The chemical by-products of the microbial activity can gradually consume/disintegrate the rock as well.

activities

- https://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1124303183&topicorder=7&maxto=7&minto=1