

Introduction to Weathering

- Chemical Weathering
- Physical Weathering
- Rates of Weathering

National Park Service Photo

Earth is a very dynamic environment.

Volcanic & other mountain building processes elevate portions of the Earth's surface, while opposing forces move material from high elevation to lower elevation.

- ***Weathering*** is the physical breakdown and/or chemical alteration of rocks at or near the Earth's surface.
- ***Erosion*** is the physical removal of material by mobile agents such as water, wind or ice.
- ***Mass Wasting*** involves the transfer of rock and soil downslope under the influence of gravity.



Two Types of Weathering

Chemical Weathering involves a chemical transformation of rock into one or more new compounds.

Physical (Mechanical) Weathering involves physical forces that break rock into smaller and smaller pieces without changing the rock's mineral composition (same minerals).

Weathering is the response of rocks to a changing environment. For example, plutonic rocks form under conditions at high pressures and temperatures. At the Earth's surface they are not as stable as the conditions under which they formed. In response to the environmental change, they gradually weather (transform to more stable minerals).

Although we will look at them separately, physical and chemical weathering work simultaneously and aid one another.

Chemical Weathering

Chemical weathering is a chemical process that breaks down minerals.

Chemical weathering involves the transformation of the original minerals into new minerals that are stable at surface conditions.

Chemical weathering also involves putting mineral components into solution - dissolution in water.

Water is the most important agent in the three different processes of chemical weathering:

1. Dissolution
2. Oxidation
3. Hydrolysis



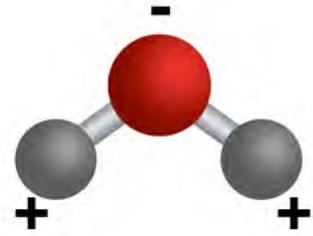
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Chemical Weathering (cont.)

1. **Dissolution** is a process where a solid dissolves into a solvent such as water forming a solution.

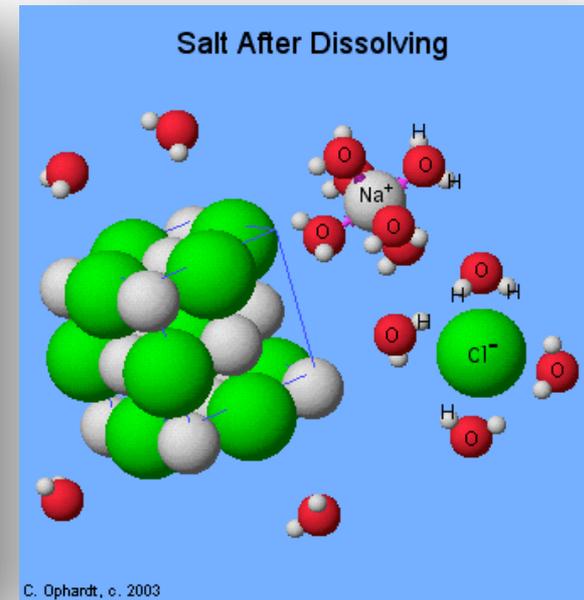
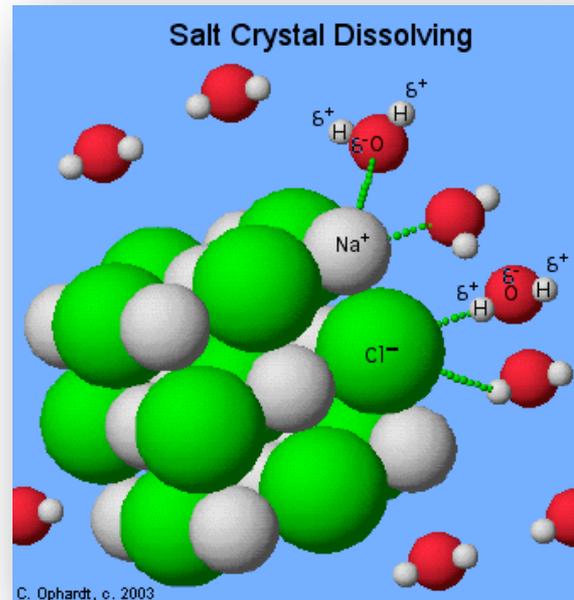
Water molecules are polar (bent shape) - oxygen end has slight negative charge and hydrogen atoms have slight positive charge.



The uneven charge distribution on the water molecule disrupts the attractive forces holding a crystal together.

The charged ends act as little wedges to take a crystal apart - *dissolve* it.

The figure shows the *dissolution* of the mineral halite by water.



Pure water acts as a solvent, however the presence of even a small amount of acid in water dramatically increases the corrosive force of water.

Carbonic acid is produced when atmospheric CO₂ dissolves in rainwater and surface waters



Other sources of acid:

- organic acid from the decay of organic matter
- sulfuric acid from the weathering of sulfide minerals like pyrite.

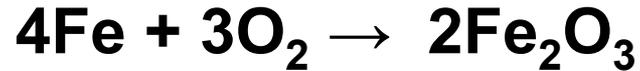
The mineral calcite is particularly susceptible to dissolution by acid (*remember acid test*).



In this process, calcite is dissolved. This process is important for the formation of caves in limestone.

Chemical Weathering (cont.)

2. *Oxidation* is a chemical process that is responsible for rust forming from iron.



The *oxidation* of iron is greatly accelerated in water.



[PublicDomainPictures.net](https://www.PublicDomainPictures.net) (Charles Rondeau)

Some minerals such as olivine, pyroxene and amphibole can iron and *oxidize* in the presence of water at surface conditions.

Another important *oxidation* reaction occurs when sulfide minerals such as pyrite (FeS_2) oxidize to form iron oxide minerals.

2. Oxidation (cont.)

The *oxidation* of iron is responsible for many rocks having a rusty red color.



Chemical Weathering (cont.)

3. *Hydrolysis* is a chemical reaction involving the breaking of a bond in a molecule using water. As an example, feldspars chemically alter (hydrolysis) to form clay minerals such as kaolinite.

Typically, natural waters contained some dissolved ions that accelerate the *hydrolysis* of minerals.

Clay minerals are the end products of weathering of many silicate minerals (such as feldspar) and are very stable under surface conditions.

Clays make up a major portion of soils and sedimentary rocks such as shale.





Wikimedia Commons User: Siim Sepp

Quartz, unlike many other minerals, is particularly resistant to weathering - that is why it tends to accumulate on beaches and sand dunes since everything else has weathered away.



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Physical Weathering

Four physical processes lead to physical weathering:

1. Frost Wedging
2. Unloading (release of pressure)
3. Thermal Expansion
4. Biologic Activity

Erosional agents (water, wind & ice) may also result in physical weathering by "breaking rocks" during the transport of sediment.



National Park Service Photo

Physical Weathering (cont.)

1. *Frost Wedging* is caused by repeated cycles of freezing and thawing.

- H_2O has the unique property of expanding (~9%) when it freezes.
- H_2O works its way into cracks in rock, and upon freezing, expands and enlarges these openings. After many freeze-thaw cycles, the rock is broken into angular fragments.



[flickr: Andy Cross](#)



[flickr: Tim Shields](#)

Frost wedging is most prevalent in mountainous regions where there is a daily freeze-thaw cycle.

It is *frost wedging* that causes potholes in roads during the winter.



<http://hays.outcrop.org/images/weathering/press4e/figure-07-12.jpg>

Physical Weathering (cont.)

2. *Unloading* is a geologic process where overlying rocks at the surface are removed.

Rock that form deep in the Earth (like granite) will begin to *expand* as they reach the Earth's surface (decompression).

This can result in the generation of onion-like layers or sheets of rock that begin to separate.

Half-Dome (right) in Yosemite N. P. showing sheet-like structures due to unloading at the Earth's surface.



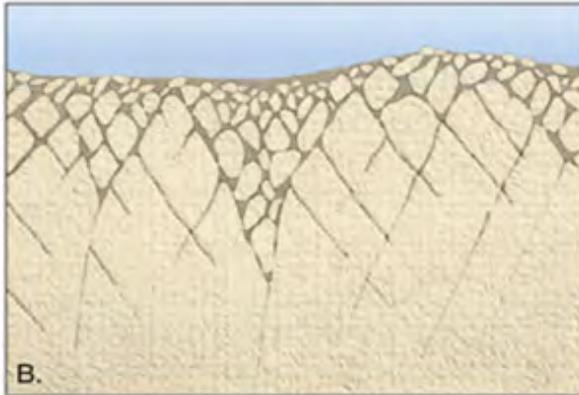
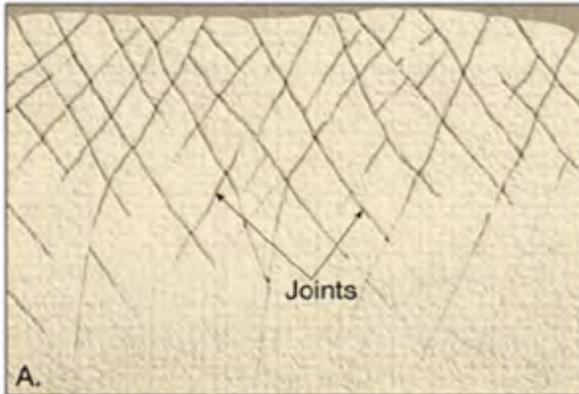
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The sheets of rocks, such as these on Half Dome (Yosemite NP), that result from *unloading* are sometime referred to as “exfoliation sheets.”

Scott T. Marshall, Appalachian State University

Some fractures may form by tectonic forces during mountain-building processes.



Wikimedia User: Brocken Inaglory

Fractures produced by these processes are known as *joints*.

Physical Weathering (cont.)

3. *Thermal Expansion* as a weathering process occurs where daily thermal expansion and contraction of individual minerals can exert destructive forces on the cohesion of a rock.

This is especially true in desert environments where the change in temperature during the day may be as great as 30°C.

This mechanism is probably the least effective of all the weathering processes.



Physical Weathering (cont.)

4. **Biological Activity** can cause rocks to be broken into smaller pieces.

This type of physical weathering can be accomplished by organisms such as trees and burrowing animals.

For example, plant roots can grow into fractures, and as they grow larger, they wedge the rock apart.



pasadenanow.com



The primary agents of erosion (water, wind and ice) may also contribute to the physical weathering of rocks.

1. Water may transport rocks, knocking them together and breaking them into small pieces. Commonly, rocks found in streams are rounded by physical weathering while being transported by water.

National Geographic



2. Ice (glaciers) grinds rock as glaciers move across the surface of the Earth. Rock flour is produced by the grinding action of glaciers where the rock is pulverized into a fine dust.



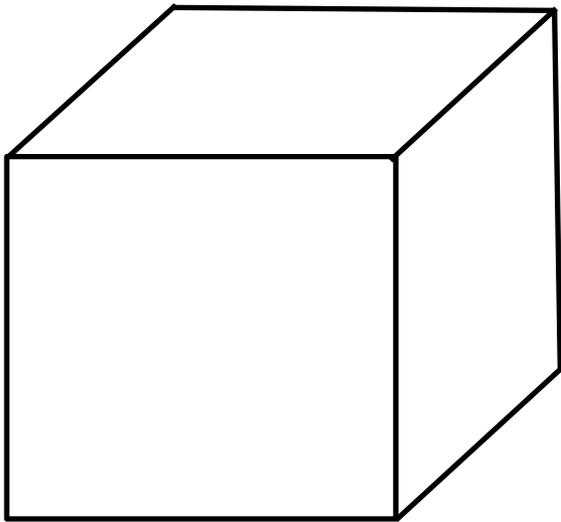
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3. Wind may blow particles such as sand that can abrade rocks (similar to sand blasting).

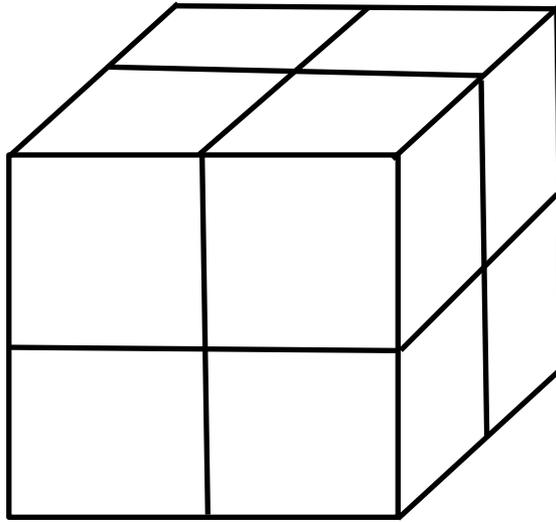


Thomas Wilken

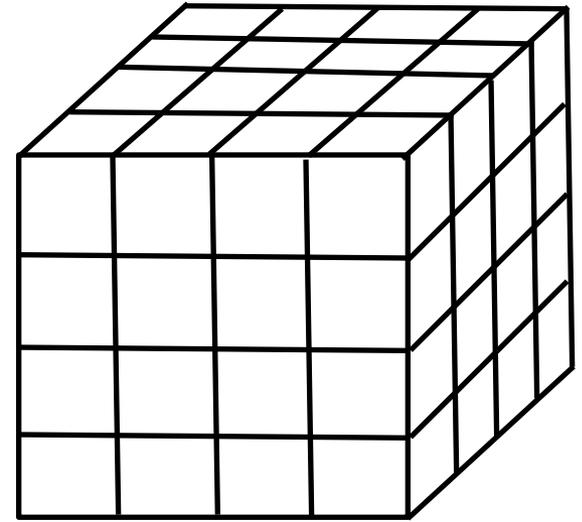
Physical (mechanical) weathering increases the surface area available for chemical weathering. Increased surface area usually results in more rapid chemical reactions (chemical weathering).



1 cube x 6 sides x 1 m
= 6 m²



8 cubes x 6 sides x .5 m
= 24 m²



64 cubes x 6 sides x .25 m
= 96 m²

Rates of Weathering

— several factors influence the type and rate of weathering.

- 1. Climate** - chemical weathering is enhanced in warm, moist climate.
- 2. Rock characteristics** - such as chemical/mineralogic composition and the presence of joints. Note that a mineral's susceptibility to chemical weathering is related to the Bowen's reaction series.

