Weathering: The Breakdown of Rocks

Mechanical Weathering: Breaks rocks into smaller particles
Chemical Weathering: Alters rock by chemical reactions

<u>Mechanical Weathering (aka Physical Weathering)</u>

1) Ice Wedging
   - *Results from 9% expansion when water turns to ice.
   - *High stress (110 kg/cm^2, about the wedge of a sledge)
   - *It occurs when:
     - >Adequate supply of moisture
     - >Have preexisting fractures, cracks, and voids
     - >Temperature rises above and below freezing
   - *Was even used in some quarry operations to break up rock
2) Sheeting
   - *Results from release of confining pressures
   - *Has been observes directly in quarries and mines, even in roadways
   - *Sheeting from heat results in a rock spalling
   - *Spalling: surface of rock expands due to extreme heating but core of rock remains cool
3) Disintegration
   - *Breakdown of rock into smaller pieces by critters, plants, etc.

Results of Mechanical Weathering

- o Talus Cones (From ice wedging mostly)
- o Boulder fields (From ice wedging mostly)
- o Jointing: Cracks in the rock from ice wedging and sheeting

<u>Chemical Weathering</u>: Rocks are decomposed and the internal structure of the minerals is destroyed, and new minerals are created.

1) Hydrolysis: Chemical union of water and a mineral

   *Ex. Feldspar $\rightarrow$ clay mineral

   Water first form carbonic acid by combining with carbon dioxide in the reaction:

   $$H_2O + CO_2 = H_2CO_3$$

   Then the mineral is broken down:

   $4NaAl_3Si_3O_8 + 4H_2CO_3 + 18H_2O \rightarrow 4Na + 4HCO_3 + 8H_4SiO_4 + Al_4O_{10}(OH)_3$

(Plagioclase) (carbonic acid) (water) (Dissolved components) (clay mineral)

Sodium becomes displaced

2) Dissolution: Process whereby rock material passes directly into solution, like salt in water

   *Most important minerals to do this: CARBONATES (Calcite, dolomite)

   - o Water is a universal solvent due to its polar nature
   - o Behaves like a magnet
   - o A good example is limestone which is made of calcite or dolomite
   - o In wet areas, it forms valleys…In arid areas, it forms cliffs
   - o Some rock types can be completely dissolved and *leached* (flushed away by water)
   - o Best examples are natural salt (halite) and gypsum.
   - o As a result, guess where you find the best examples of this stuff?

Quartz Dissolution

- Although Quartz is stable in contact with water, it will also dissolve in common surface water according to the following reaction:

$$SiO_2 + 2H_2O \rightarrow H_4SiO_4$$
(Quartz) (water) (Silicic Acid)

- Each Year, rivers carry 3.9 million metric tons of dissolved minerals to the oceans.
- Not a surprise that seawater contains 3.5% dissolved salts, all of which came from the continents!

3) Oxidation: Combination of oxygen in the atmosphere or dissolved in water, with a mineral to form a new mineral

*One or more of the components of the new mineral will have a higher oxidation state (or ionic charge)

Iron (Fe) has two common oxidation states: Fe^{2+} and Fe^{3+}

Oxygen prefers Fe^{3+} …results in our red rocks!

Oxidation is especially important in the weathering of iron-rich minerals like olivine, pyroxenes, and amphiboles: Olivine oxidation

$$2Fe_2SiO_4 + 4H_2O + O_2 \rightarrow 2Fe_2O_3 + 2H_4SiO_4$$
(olivine) (water) (oxygen) (hematite) (dissolved silicic acid)

What changes the rates of these reactions?

Temperature, plants, critters

Importance of Joints and Fractures

Almost all rocks are broken in a system of fractures that greatly influence the weathering of rock bodies in two ways:

1) They effectively cut large blocks of rocks into smaller ones, thereby increasing the surface area where chemical reactions take place
2) Joints and fractures act as channel ways through which water can penetrate to break down rock by ice wedging

Geometric Patterns of Rock Disintegration

1) Joint Block Separation
2) Bedding Plane Separation
3) Jointing
4) Shattering

Special Case, Spheroidal Weathering: The process by which corners and edges of a rock body become rounded as a result of exposure to weathering on all sides, so that the rock acquires a spheroidal or ellipsoidal shape. (Exfoliation)

Result: Produces rounded shapes, like those seen in Joshua Tree or the Alabama Hills

Special Case, Differential Weathering: Different rock bodies or different sections of the same rock that weather at different rates

Result: Pinnacles, Badlands, Monument Valley

Special Case, Cavernous Weathering: The development of holes in the rock (tafoni), typically created by the combination of both chemical and mechanical weathering.

Weathering Characteristics of Common Rocks

1) Granite
    - Composed of feldspar, quartz and mica
    - Forms at considerable depth, pressure and temperature, therefore out of equilibrium with the surface
    - Coarse grained
    - Mechanical Weathering: Exfoliation, a form of sheeting from pressure release
    - Chemical Weathering: Feldspar to clays, micas to chlorite

2) Basalt
    - Composed of feldspar, olivine and pyroxene
    - Forms at the surface, extrusively out of a volcano
    - Chemical weathering: feldspars to clays, olivine and pyroxene to iron oxides
    - Weathering product results in a brown to red soil

3) Sandstone
    - Composed mostly of quartz grains with rock fragments, feldspar and clay minerals
    - Forms at the surface from a river, beach, as a dune, etc
    - Chemical weathering: Largely on the cement of the rock which is usually calcite, iron oxides, or quartz.
    - Mechanical weathering: Granular disintegration, one grain at a time

4) Limestone
    - Composed of the mineral calcite although it may contain clays and other materials
    - Forms in water from mostly dead critter parts
    - Chemical weathering: dissolution (soluble in water)
    - Weathering products: Cliffs in arid regions, slopes in humid regions.
    - Caves, sinkholes, karst topography

5) Shale
    - Composed of clays, weathers fast
    - Forms in a gentle environment such as a lake, offshore marine
    - Mechanical weathering: Due to water content, ice wedging, disintegration
    - Chemical weathering: Due to clay mineral structure
    - Clays are phyllosilicates which form sheets of atoms, water molecules can break sheets apart easily.

The Major Products of Weathering

Regolith, meaning blanket, composed of bedrock

*Can range from a few centimeters to hundreds of meters, depending on climate, type of rock, and length of time that weathering processes have been operating.

*The uppermost layer of regolith is the soil.

*Soil is composed chiefly of small particles of rocks and minerals, plus varying amounts of decomposed organic matter.

*Soil Profiles show a constant sequence of layers, or horizons, which are distinguished by composition, color and texture.

- Blanket of loose, layered rock debris>>Rock bodies modified into spheroidal shapes

  *Through exfoliation, a form of sheeting

Soil Formation

Soil Formation

- Climate is the single most important factor influencing weathering
- Other factors:
  1) Parent rock material
  2) Topography, such as slope steepness
  3) Time
  4) Vegetative Cover

Soil Facts

- Thickest soils in the tropics
- Quartz generally forms thin infertile soils
- Deserts often form thick eluviation horizons
- Well-drained areas form rich, thick soils.

Soil Profiles

Lateritic Soil	Temperate Soil	Young Soil
(wet climate: Ultisol, Oxisol)	(Mid-latitude: Mollisol, Alfisol)	(Inceptisol)

Terminology
Horizon: a soil layer
Zone of Accumulation: the region where new materials collect. Typically in B horizon. Also called illuviation.
Zone of Leaching: the region of the profile where fine material and some nutrients move downward. Also called eluviation.
Saprolite: Weathered bedrock. The C horizon.
R Horizon: Original rock.

Lateritic...wet soil, like an Oxisol, Ultisol or Histosol

Pedocal…dry soil, like an Aridosol

Pedalfer…temperate climate, like an Alfisol

Climate and Weathering
- Climate is the single most important factor influencing weathering
- It determines not only the type and rate of weathering, but also the characteristics of regolith and weathered rock surfaces.
- Intense chemical weathering occurs in hot, humid regions and develops thick regoliths
- Chemical weathering is minimal in deserts and polar regions.

Rates of Weathering
- The rate at which weathering processes decompose and breakdown a solid rock body depends on three main factors:
- Susceptibility of the constituent minerals to weathering
- Climate
- The amount of surface exposed to the atmosphere

Examples that help determine weathering rates
- Pyramids in Egypt (made of different compositions)

Mass Wasting

Mass Movement: the downslope transfer of material through the direct action of **gravity**. Mass Movement can be fast, as in landslides, or slow, as in creep.
Angle of Repose: The steepest slope on which loose material such as talus, will remain at rest without rolling farther downslope (Average = 30°).

Factors influencing Mass Movement

*Saturation of material with water

Lubricates and adds weight

*Vibrations from earthquakes

1970 Peru Quake – 400m^3 moved downslope 300km/hr, killing 40,000 at the base of Mount Huascaran.

1976 Guatemala – Quake resulted in 10,000 mass movements

*Oversteepening of slopes by undercutting.

By nature (rivers) or humans (Highways, Malibu)

*Alternating Freezing and Thawing

Cases: Madagascar, Vaiont Reservoir (1963) in Italy

<u>Types of Mass Movement</u>

<u>Creep</u> – Extremely slow, almost imperceptible downslope movement of soil and rock debris that results from the constant minor readjustments of the constituent particles.

Creep Evidence:

1) Hard to see it move, but evidence can be seen
2) Bulges or low, wave-like swells in the soil
3) Bending of steeply dipping strata
4) Tilted trees and posts
5) Deformed roads, fence lines
6) Tilted retaining walls

Includes Block Slides: caused by heaving process that results from the alternating expansion and contraction of loose rock fragments in the regolith.

Freeze/Thaw

Wetting/Drying

Other Factors that lead to Creep:

Growing plants (or lack of)

Undercutting by streams

Increased loads by rainwater or snow

Earthquakes

Construction by humans

Rates of Creep

1-2 mm/yr in humid temperature regions

5-10 mm/yr in semi arid with cold winters

Special Type: ***Solifluction*** (soil flowage)

Common in polar regions (permafrost)

Can occur in water drenched soils

<u>Slump</u>

Slump: A slow to rapid movement of a coherent body of rock along a curved rupture surface.

- Debris flows often occur at the end of slumps

Mudflows, Debris Flows, Lahars

Debris Flow: No definite plane of slippage, medium to fast movement

- Consist of mixtures of rock fragments, mud and water that flows downslope as a viscous fluid.

    Rate: Flowing concrete to running water, depending on the amount of water present.

Mudflow: Variety of debris flow that consists of a large percentage of silt and clay sized particles.

- Results from heavy rain or quick thaw, water content can be as high as 30%
- Common in arid or seim-arid regions (like here)
- Can float houses, barns or boulders
- Many are over 100m thick, and can be 80km long
- Glacial muds can create “quick-clays” like quicksand, only smaller particles with lots of water.

Example: Slumgullion Mudflow Colorado

Lahars: Volcanic Mudflows**,** loose pyroclastics and water from rain or melted snow due to heating up of the volcano

Examples: Mt. St. Helens
Vesuvius (79AD) 20m thick
Armero, Columbia (1985) Andean Volcano, buried 23,000 people (Nevado Del Ruiz)

Slides

Landslides: Involves movement of a mass rock or regolith along a definite plane

Usually fast moving

A landslide differs from creep and debris flows in its mechanics of movement. Landslides move as a unit, or series of units, along a fracture or system fractures, with much of the material moving as a large slump block

Rockslide: Rapid downslope movement of rock material along a bedding plane, joint, or other plane of structural weakness.

Debris Slide: Rapid movement of soil and loose rock fragments.

Falls

Rock Fall: From Steep Cliffs, free fall of large chunks of rock

Debris Fall: Free fall of smaller chunks of materials

Special Varieties of Mass Wasting

Rock Glaciers:

Looks and moves like a glacier

Has some ice in its pores which helps it to move (5cm/day, 1 m/yr)

Subaqueous Sand Flow: Flow of water saturated sand or slit beneath the surface of a lake or ocean

Subsidence: Downward movement of earth material essentially vertical.

- Controlled by gravity
- Karst Topography – collapse due to excavation of caves
- Mining of ores, coals, gems
- Pumping of groundwater for use in houses
- Lava tunnels
- Pumping oil

Famous Historical Events

Mine Dumps Disaster

Loose, unconsolidated materials
1966, Wales, Town of Aberfan
Heavy rain caused mine refuse to overtake a school, killing 140.

St. Francis Dam-Near Santa Clarita

Vaiont Reservoir (Italy)

Slope Systems

Open systems in which the effects of weathering, mass movement, and erosion of minor gully tributaries combine to transport rock material downslope to the main stream.

Be careful building your house on a slope, or have good insurance!