

Weathering is the process that converts rock into soils and sediment, providing the raw materials for creation of sedimentary rocks and redistributing chemical compounds and elements throughout the biosphere. The effects of weathering vary depending upon the types of rocks, the environmental conditions in which they are exposed on or near the Earth's surface, and global climate.

Weathering = the chemical and physical breakdown of rock and the release of chemical and particulate material into the Earth's surface environment.

Types of Weathering:

Chemical: chemical transformation of rocks and their constituent minerals at or near the Earth's surface at surface temperatures and pressures. (as distinct from metamorphic processes).

Physical: physical breakup of rock without substantial chemical alteration of the constituent minerals

Physical Weathering:

Begins with fracturing rocks in the subsurface:

Layers can be depositional or metamorphic features (seds, volcanics or Metamorphics)

Or they can be **Joints**--subparallel fractures without appreciable movement along them

Caused by:

1. **removal of overburden** and expansion of the rock--joints are often parallel with the ground surface
2. **cooling joints** caused by the rapid cooling of lava flows that split into long columns of rock (columnar jointing) due to contraction while cooling.
3. **regional tectonic stress** that opens vertical cracks at right angles to each other.

All types of joints can be very important in allowing ground water to move easily through rock and providing access to water to speed up weathering reactions.

Rocks can be broken down further by:

1. **crystal growth** = salts and ice take up more space as crystals than as liquids so they can wedge apart crystals through freeze-thaw cycles or by evaporation-precipitation; water, for example, expands about 9% when it freezes; need water, temperature changes above and below the freezing point and pre-existing cracks. = **Frost wedging**
2. **rapid heating** (as in fires)
3. **Wedging by plant roots**—trees falling over can pull up tons of rock

Chemical Weathering:

Four main processes using ground water or hydrothermal water:

1. **Leaching**—passing water through rocks and soil dissolves some water-soluble components and removes them, by ground water flow, to other places;
2. **Dissolution**—an extreme form of leaching in which all rock is dissolved; most often affects carbonates and evaporates—formation of *sinkholes*
3. **Acid Hydrolysis**—water and acid reactions that lead to decomposition of a mineral by addition of hydrogen ions to the chemical structure of a mineral; hydrolysis of potassium feldspar adds H⁺ and water and produces kaolinite clay, silica and potassium ions.
 - a. For example: $\text{H}_2\text{O} + \text{CO}_2 = \text{H}_2\text{CO}_3$ (Carbonic acid)
 - b. Calcite (CaCO_3) + H_2CO_3 (Carbonic acid) = $\text{Ca} + 2\text{HCO}_3$ (Bicarbonate)
 - c. MgSiO_3 (pyroxene) + $\text{H}_2\text{O} + 2\text{H}_2\text{CO}_3$ (Carbonic acid) = $\text{Mg}^{+2} + 2\text{HCO}_3^- + \text{H}_4\text{SiO}_4$ (Silicic acid)
 - d. In another case: $2\text{NaAlSi}_3\text{O}_8$ (Na-Plagioclase) + $2\text{H}_2\text{CO}_3$ (Carbonic acid) + $9\text{H}_2\text{O}$ (water) = $2\text{Na}^+ + 2\text{HCO}_3^-$ (Bicarbonate) + $4\text{H}_4\text{SiO}_4 + \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ (Clay) (This reaction is a major source of Na for salt in saltwater).
4. **Oxidation**—combination of oxygen with a mineral to form a completely different mineral in which at least one element has a higher ionic charge (one ion loses an electron)
 - a. E.g. the oxidation of iron: Fe is oxidized to form Fe^{+2} or Fe^{+3}
 - b. Iron minerals are oxidized, the iron is transformed from Ferrous iron) Fe^{+2} to (ferric iron) Fe^{+3}
 - c. For example, $2\text{Fe}_2\text{SiO}_4$ (Olivine) + $4\text{H}_2\text{O}$ (water) + $\text{O}_2 = 2\text{Fe}_2\text{O}_3$ (Hematite) + $2\text{H}_4\text{SiO}_4$ (Silicic acid)

Weathering of major rock types

Controlled by composition and texture (rock effects) and temperature, rainfall (climate effects)

Rapid Weathering
(carbonates and salts),

Pyrite

Olivine

Ca-Plagioclase

Pyroxene

Amphibole

Biotite

Na-plagioclase

K-spar

Muscovite

Slow weathering

Quartz

Clay

Al-oxide

Notice anything?

Looks like Bowen's reaction series in reverse; most stable minerals are highly polymerized and at the low temp end of Bowen's reaction series.

Weathering Rinds

Exfoliation occurs by concentric shells as water penetrates to un-weathered rock

Spheroidal weathering = weathering underground along joint sets that preferentially attack the areas with highest surface area. Produces spheres of rock which have less surface area than the original roughly cubic blocks of un-weathered rock.

Rock weathering also affected by *grain-size and texture*

Dense, well cemented rocks weather more slowly than loosely cemented or carbonate cemented rocks,

Soil:

Types vary with 1) length of time, (2) climate, and (3) rock type:

1. Simplest soil is **Regolith**—loose rock debris but includes more complex forms of soil too
2. Soil = mixture of organic matter with loose mineral grains and minerals formed by chemical alteration of original rock minerals (like clay)
3. Soils formed by
 - a. mineral formation through hydrolysis and oxidation of original minerals to form clays and oxides,
 - b. production of humus mostly from plant cover,
 - c. remobilization of minerals and ions by leaching enriching deeper parts of the soil horizon in clay and oxides
4. **Soil differentiated into discrete layers:**
 - a. *A horizon*: topsoil (sometimes an O Horizon is designated as leaf litter); otherwise consists minerals and organic matter; an E Horizon is sometimes designated as a bleached interval due to acid washing beneath the humus-rich layer in coniferous forests
 - b. *B horizon*: subsoil: enriched in clay and Fe and Al hydroxides—often reddish with Fe oxides
 - c. *C horizon*: partly decomposed rock which grades downward into un-weathered rock (A K Horizon may be present between the B and C horizon consisting of precipitated carbonates (Caliche))

Soil types vary with climate (Rainfall and temperature)

Climate:

Physical weathering dominates at low temperatures and arid climate

Chemical Weathering dominates at high temp and abundant water (Rainfall)

Polar environments: mostly thin soils since chemical weathering is weak (hence little clay formation and development of B horizons)

Temperate Soils: Acidic soils (associated with evergreen forest) develop E Horizon and strong B horizon

Desert Soil: Often have well developed K horizon caused by ppt of carbonates as ground water rises and evaporates. May also have significant wind blown material: Loess

Tropical Soils: may have very well developed B horizon formed by leaching most minerals aside from clay and Al/Fe oxides; Can be rich in Aluminum: called *Laterites* and be very deep (~100 m); Al-rich laterite = Bauxite

Fossil soils: Paleosols

Transportation of weathering products:

Sediment mobilized in land slides, soil creep, wind transport and rock falls; Collectively known as “mass wasting”.

Rock falls can have long runouts and transport very large boulders

Once materials enter drainages they can be

Bedload (moves along the bottom of a stream), suspended load (supported by stream flow) and dissolved load (present as ions in the water)

Global weathering patterns:

Three largest Rivers (in terms of dissolved load) are the Yangtze, Amazon, and Ganges-Brahmaputra which deliver ~20% of the dissolved load and fresh water to the oceans; the Himalaya and Andes provide the large majority of all the dissolved load to the oceans suggesting that mountain formation is critical to controlling input of dissolved ions to the ocean

Rapid uplift contributes to:

Abundant supply of fresh rock

Abundant rain

Strong chemical weathering

Easily eroded rocks (sedimentary rocks) in convergent margins.

Large mountain masses can set up monsoon systems due to the large mass of mountain plateaus at high elevation.

