

Soils: Weathering and Erosion

Soils can be defined many ways, depending upon who uses them.

Geologist: Weathered rock and mineral grains capable of supporting life

Engineer: Loose material at the surface

Farmer: Interested w/r/t crop growth

Regolith: Fragmented rock material at the surface that forms soils.

Carrying Capacity of Earth is dependent upon soils.

SOIL = f(CIORPT)

Where: Cl= Climate

P= Parent Material

O= Organic Activity

L= Length of Time

R= Relief of Land

Weathering

Definition: Physical disintegration and chemical decomposition of Earth materials at or near the Earth's surface.

Erosion: Removal and transportation of materials (weathered and un-weathered) by wind, running water, waves, glaciers, underground water and gravity.

Mechanical or Physical Weathering: Breaks rocks into smaller particles

Chemical Weathering: Alters rock by chemical reactions

Mechanical or Physical Weathering

1) Ice Wedging

- *Results from 9% expansion when water turns to ice.

- *High stress (110kg/cm², 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) Sheetting (from pressure release or heating)

- *Results from release of confining pressures (Exfoliation)

- *Has been observed directly in quarries and mines, even in roadways

- *Spalling: surface of rock expands due to extreme heating but core of rock remains cool

3) Disintegration

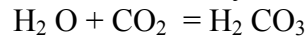
- *Breakdown of rock into smaller pieces by critters, plants, etc. a grain at a time

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

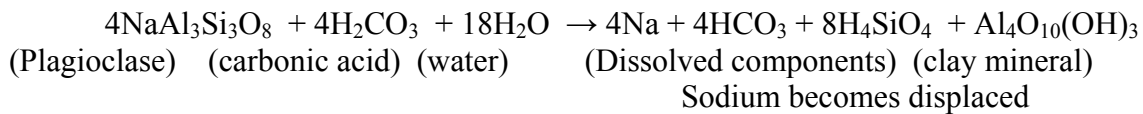
1) Hydrolysis: Chemical union of water and a mineral

*Ex. Feldspar → clay mineral

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



Then the mineral is broken down:



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

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

>Wet areas, limestone forms caves and valleys

>Dry areas, cliffs

*Water's polarity helps dissolve stuff

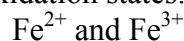
*Also responsible for leaching of minerals through soils

*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)

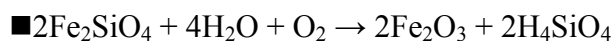
Iron (Fe) has two common oxidation states:



Oxygen prefers Fe^{3+}

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

Olivine oxidation



(olivine) (water) (oxygen) (hematite) (dissolved silicic acid)

Roles of Weathering

- ⇒ Controlled by the surface environment, grain size (surface area) and climate.
- ⇒ Stability
 - Most Stable Least Stable
 - Quartz → orthoclase feldspar → Amphibole → Pyroxene → Olivine

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.

Figure- Surface Area

- ⇒ Monolithic rocks weather more slowly
- ⇒ Climate: wet vs. dry

⇒ Human Influence: Pollution

Geologic Features of Weathering

Spheriodal Weathering: Rounded forms produced by jointing (physical/mechanical weathering)

Method: Exfoliation, a form of shearing

Cavernous Weathering: Holes produced by chemical and physical/mechanical weathering of rock.

Chemical Method: Typically hydrolysis

Physical Method: Disintegration

Soils

Climate is the most important factor in soil development

Soil Profile: Representation of soil layering and is made up of horizons.

Soil Profile Basics

O= Organics

A= Top soils and Leaching Zone

B= Subsoil and Accumulation Zone

C= Saprolite or Weathered Bedrock

R= Rock

Accumulation gone bad = Caliche

Residual Soils: Developed in place on bedrock

Transported Soils: Designated by a specific geologic event

Eolian ~ wind Glacial Etc.

Volcanic Soils of Hawaii – Pahala Ash

⇒ Sometimes too rocky, thus grasses for cows

Loess – Windblown silt (from glaciers, rivers and deserts)

⇒ Largest in the world – China

⇒ Yellow River, Yellow Sea – yellow is from loess

⇒ Earthquake dangerous

Soil Color and Texture

- ⇒ Colors are important for determining organics (black), irons (red)
- ⇒ Munzell color chart
- ⇒ Texture Chart: Triaxial with sand, silt and clay
 - Well mixed: loam
 - Too pure with anything usually poses problems
 - Clays
 - Sands

Soil Classification: Once again this depends on who's looking

Zonal Classification: Based on climate, four major types

- 1) Pedalfers- high in aluminum and iron, humid regions
- 2) Pedocals- high in calcium, dry areas
- 3) Laterites- brick red soils of the tropics, enriched in iron oxides
- 4) Tundra Soils- soils of severe polar climates

US Comprehensive Soil Classification System

- ⇒ Seventh Approximation
- ⇒ Soils are classified by physical characteristics (non genetic)
- ⇒ Soils modified by humans are classified in with everything else
- ⇒ Soil names convey info.
- ⇒ For the pno

Soil Problems:

Soil Erosion

- ⇒ Soil is essentially a non reversible resource
- ⇒ 3-5 times as much soil is being lost as to being formed
- ⇒ Soil Degradation – Irreparable, fixing beyond third world nation forming

Erosion Processes

- ⇒ Agents are wind and running water
 - 1) Sheet Erosion – removal of soil particles in thin layers from an area of gently sloping land.
 - 2) Rill Erosion – removal of soil in discrete streamlets carved into the soil
 - If rills grow deep (over a foot, 10-14inches), they form gullies
- ⇒ Winds & Drought = Dust Bowl of 1930's
 - some of it brought on by us – conversion of semi-arid land into croplands (10-12inches of rain/year)
- ⇒ Table 6.2: Total Soil Losses
- ⇒ Table 6.3: Causes of World Soil Erosion
- ⇒ ORV – Off Road Recreation Vehicles – studies in 1970's

The Impact of Cropland Loss on Humans

⇒ Between 1950 and 1998: grain growing land declined from 0.23 to 0.012 hectare per person

- Productivity until the 1990's kept this decrease manageable
- Future population growth

Mitigation of Soil Erosion

⇒ Thomas Jefferson was among the first in the US to comment on methods publicly

- 1) Terracing- creating flat areas
- 2) Strip Cropping- close growers are alternated with wide ones
- 3) Crop Rotation- soil depleting followed by soil enriching and repeat
- 4) Conservation- Tillage- practice minimize plowing in the fall and encourage the contour plowing of furrows perpendicular to the field's slope to catch runoff
- 5) No-till and Minimum-till
 - No-till: seeds are planted into the soil through previous crop's residue and weeds are controlled by chemicals (soy)

Expansive Soils

- ⇒ Some clay minerals can absorb between the layers
- ⇒ More than 6% expansion – highly expansive, 10% - critically expansive

Methods of Dealing with Expansive Soils

- 1) Removal
- 2) Mixing them with non-expansive material or with chemicals
- 3) Keep soil moisture constant
- 4) Using reinforced foundations

Permafrost

- ⇒ Contraction of permanent and frozen, coined by Simon Muller of USGS in 1943
- ⇒ More than 20% of the Earth's land surface
- ⇒ Thickest 5000ft (Siberia) and 2000ft (Alaska) formed during last great ice age 18K years ago
- ⇒ Permafrost Table, Active Layer
- ⇒ Talik – Unfrozen
- ⇒ Pingo – Dome shaped mound from pressure release
- ⇒ Thawing of permafrost results in various types of gravity induced mass movements (creep, debris flows).

Mitigation

- 1) Houses can be built with open space beneath the floor
- 2) Utilize foundation piers to regulate temperature
- 3) Roads are constructed on top of coarse gravel

Alaska Pipeline

Settlement

- ⇒ Is an engineering problem, not a geological
- ⇒ Famous: Leaning Tower of Pisa
 - on a clay layer
 - originally tilted forward north , now south
 - 1990 they removed some clay, now tilts about 5°

Other Soil Problems

- ⇒ Laterites can turn hard, prone to extensive leaching
 - Angkor Wat – 13th century
- ⇒ Hard pans

Case Studies

- 6.1 Salinization and Waterlogging
 - Aswan Dam of the Nile
- 6.2 Soils, Health and Loess
 - Like vitamins, depends on solubility
 - Iodine-Goiter
 - Selenium – low okay, high is toxic
 - Enzyme catalysts: Zn, Cu, Fe, Co, Mn, Mo
- 6.3 Rx for Contaminated Soils
 - Bioremediation
 - Vapor Extraction
 - Phytoremediation