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(ClORPT)

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/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 (from pressure release or heating)
   *Results from release of confining pressures (Exfoliation)
   *Has been observes 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:

$$H_2 O + CO_2 = H_2 CO_3$$

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 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:

Fe^{2+} and Fe^{3+}

Oxygen prefers Fe^{3+}

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)

Roles of Weathering

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

<u>Weathering Characteristics of Common Rocks</u>

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

<u>Geologic Features of Weathering</u>

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

<u>Soils</u>

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= Saporlite 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 slop 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 Siemon 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 claw, now tilts a bout 5°

Other Soil Problems

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

Case Studies

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