Weathering, Soils and Mass Wasting

I. Basic Definitions/Introduction

A. Continental Dynamics / Landscape Evolution
  1. Mass Transfer Functions
    a. Dynamic interaction between uplift of earth's crust, or emergence on crust, and erosion of materials from higher elevations and moving them to lower elevations
    b. mass transfer = energy driven

B. **Weathering** - disintegration and decomposition of rock at or near the surface of the earth, fragmenting rock into particles via physical and chemical processes
  1. *In-situ* ("in place, without transport") disintegration of rock or unconsolidated materials
  2. Earth Surface Conditions
    a. Water-rich Atmosphere and Hydrosphere
    b. Low Temperature
  3. Water - universal solvent, very effective at chemically altering rocks

C. **Sediment** - fragments of rocks and/or minerals that are produced from the weathering of pre-existing rock

  1. Grain Size Classification According to Clast Diameter (from large fragments to small)
    a. Gravel: pebble to boulder size range (>2 mm)
      (1) boulders: > 256 mm (25.6 cm)
      (2) cobbles: 16 mm - 256 mm
      (3) pebbles: 4 mm - 16 mm
      (4) granules: 2 mm - 4 mm
    b. Sand: 0.0625 mm to 2 mm in diameter
    c. Silt: 4 micrometers (0.004 mm) to 0.0625 mm)
    d. Clay: < 4 micrometers in diameter

D. **Erosion** - incorporation and transportation of sediment by a mobile agent, driven by mechanical energy

  1. Surface Agents of Transportation and Erosion
    a. Wind (eolian)
    b. Water (river-fluvial)
    c. Ice (glacial)
    d. Gravity (mass wasting = transfer of surficial material downslope under the influence of gravity)
      (1) also drives flow of water and ice

E. **Denudation of earth's surface**: physical systems driving towards equilibrium: in this case the system includes elevating the earth's surface to provide potential energy, with subsequent driving towards peneplanation via gravity, water, and weathering.

F. Surficial Materials at Earth's Surface
   1. Bedrock - in situ, consolidated, indurated, rock (igneous, sedimentary, metamorphic)
   2. Regolith - all weathered and unconsolidated surficial materials at the Earth's surface
      a. residuum - in-situ regolith, weathered rock material that has not been significantly transported
      b. colluvium - regolith deposits that have been transported primarily by gravity and mass wasting processes
      c. alluvium - regolith deposits that have been transported primarily by fluvial processes
      d. Other Surficial Materials
         (1) Eolian deposits - wind-blown sediment
            (a) loess - windblown silt
            (b) sand dunes
         (2) Glacial deposits - ice-transported sediment
            (a) "drift" - all glacially transported sediment
            (b) "till" - ice-transported sediment, deposited as ice melts
            (c) "outwash" - ice-transported sediment, reworked by fluvial processes from streams of glacial meltwater
         (3) Lacustrine Deposits - lake sediment
            (a) lacustrine delta sediments (sediments deposited at the mouths of rivers emptying into lakes)
            (b) beach sediments - wave reworked deposits
            (c) offshore sediments - quiet water deposition of fine sediments and/or chemical deposits (e.g. playas)
         (4) Coastal Deposits
            (a) tidal marsh deposits - fine mud and sand, influenced by tidal and estuary processes
            (b) beach sand / gravel - wave reworked sediment at the beach
            (c) marine delta deposits - sediments deposited at the mouths of rivers emptying into the ocean

G. Soil Characteristics
   1. Pedogenesis - chemical and physical processes that alterate regolith into soil
   2. unconsolidated surficial material with well-defined mineral and chemical horizons
      a. O-horizon: organic layer, forms the interface between plants and regolith
      b. A-horizon: zone of leaching, downward percolating soil water
      c. B-horizon: zone of accumulation, deposition of clays and mineral deposits
      d. C-horizon: unaltered regoltih
      e. R-horizon: fresh, unweathered bedrock
   3. Comprised of a mixture of air, water, mineral, and organic matter
      a. porosity- open space between mineral grains
         (1) storage points for water and air in soil
      b. interface for plant growth
         (1) root systems
         (2) organic matter
         (3) micro-organisms

H. Clay - a special note

1. "Clay" is used in two ways:
   a. all sediment < 4 microns in diameter (as discussed above)
   b. a chemically distinctive mineral species

2. Basic Rock Composition
   a. Rocks made up of minerals, minerals composed of elemental compounds
   b. Average Rock Forming Minerals
      (1) typically form in igneous environment at high temperatures
      (2) silicate-based compounds (with no water in their structure)
         (a) Quartz SiO_2
         (b) Orthoclase Feldspar $KAlSi_3O_8$
         (c) Plagioclase Feldspar $(Ca\text{-}Na)AlSi_3O_8$
         (d) Pyroxene $Ca(Mg,Fe)AlSi_2O_6$
         (e) Hornblende $(Ca,Na)(Mg,Fe)Al_3Si_6O_{22}$

3. Clay Minerals
   a. Form near Earth surface in low temperature, low pressure environment
   b. incorporate water (H2O) into the crystal structure
   c. represent the stable end-product of rock weathering at the Earth's surface
   d. examples
      (1) Kaolinite $Al_2Si_2O_5(OH)_4$
      (2) Illite $KAl_3Si_3O_{10}(OH)_2$

II. **Weathering** - physical and chemical processes that breakdown rock to form regolith.

A. Physical Avenues of Rock Weathering - enhanced pathways for water percolation.

1. **Rock Fractures** serve as the avenues from which the weathering process can take place.
   a. **Microfractures**- down to the mineral grain level
      (1) Atomic bond weaknesses serve as avenues for chemical alteration by water
   b. **Joints**- open rock fractures/cracks- form as a result of stress release on bedrock as overburden is removed or due to subtle tectonic stress.
   c. **Faults**- zones of weakness which may shatter wide zones of rock
   d. **Pore spaces**- e.g. vesicules, intergranular, secondary
      (1) Pore openings provide the permeability conduit for water to flow through rocks and surficial material
   e. **Solution Cavities**-dissolution of rock by water, e.g. limestone caves

2. Climate and Weathering

   a. The dominant style of weathering process will be controlled by climate in form of available moisture, temperature and vegetative growth

B. **Physical or Mechanical Weathering**

1. Defined - Physical fragmentation of bedrock as it is exposed at or near the earth's surface

    a. Physical weathering accomplished by differential stress induced within rock = results in cracking

2. **Frost Wedging** - process of alternate freezing and thawing of water/moisture contained in cracks and fractures of rock.
    a. Water expands 9% in volume as it freezes, exerting outward stress on rock surfaces, "wedging" apart pieces of rock to form sediment.
    b. Ice expansion in confined space can create pressures of up to 30,000 lb/sq. in.
    c. water infiltrates rock through meteoric precipitation and infiltration through joints, cracks and microfractures
    d. Necessary Climatic Factors/Temp. Fluctuation
        (1) supply of water
        (2) alternating freeze/thaw cycles
        (3) temps. below 0 C to ensure freezing at depth
            (a) common in high latitude/high altitude areas
    e. Landscape Evidence
        (1) Talus Slopes - rubble accumulations at the base of rocky slopes / cliffs
            (a) Talus = landform of rubbly slope
            (b) Scree = rubble material that forms talus

3. **Unloading or release of overburden pressure during denudation**

    a. Erosion / denudation of Earth crust
        (1) isostatic response to unloading = crustal uplift
        (2) crustal unroofing = pressure release and rock expansion
            (a) Original depths of eroded mountain cores range from 8-30 km
            (b) equivalent to 8 kbar pressure, capable of producing 0.8% expansion upon release
        (3) rock expansion = brittle cracking

    b. particularly common in weathering of granite bodies, e.g. Yosemite National Park.
    c. **Sheeting** - rock breaking into concentric, onion-like slabs. The slabs peel off to produce domelike structures known as Exfoliation Domes.
        (1) exfoliation fractures or sheet joints
            (a) joints found predominantly within first few meters of exposure

4. **Thermal Heating and Rock Expansion**

   a. basic premise:
      (1) physical heating of materials = volume expansion
      (2) physical cooling of materials = volume contractions
   b. rocks poor conductors of heat:
      (1) outer layers of rock heat and expand, while inner layers remain cooler: differential expansion results in cracking.
   c. Heat Sources / Geographic Areas
      (1) Forest Fire / Fire-Prone Areas
      (2) Hot desert regions (e.g. Death Valley) - solar heating

5. **Organic/Biologic Activity** - activities of plants, animals, and humans can act as a weathering agent.
   a. The physical growth processes result in placing stress on the rocks causing them to fracture.
   b. Plants/trees readily root and grow in cracks and fractures of rock (e.g. weeds growing up through concrete).
   c. Burrowing organisms constantly stir/mix sediment and enhance weathering processes.
   d. Examples
      (1) root wedging
      (2) lichen / moss growth
      (3) boring clams on Oregon Coast

6. Mineralogic Crystal Growth - mineral growth causes expansion and rock cracking
   a. Salt Wedging-
      (1) Precipitation of Calcium sulfate, chloride salts, and carbonates
      (2) salt precipitation from intra-fracture/inter-granular waters can have
      (3) prevalent in sandstones and porous rocks
      (4) Arid areas / coastal areas
      (5) Evidence in nature
         (a) Tafoni - weather-pitted surfaces (honey-comb) common on sea cliffs in coastal areas

   b. **Salt Hydration**: hydration or addition of water to molecular structure of salt precipitates can cause expansion

      e.g. Anhydrite to Gypsum: $CaSO_4 + 2H_2O = CaSO_4 2H_2O$

   c. **Thermal Expansion of Salt**:
      (1) salts have a relatively high coefficient of thermal expansion compared to common rock forming silicate minerals.
         (a) i.e. salt expands more easily when heated compared to rock material
      (2) Differential rate of thermal expansion creates stress and avenue for physical weathering.

7. **Clay Expansion: Wetting and Drying of Clay Minerals**

a. Clay Minerals = layered sheet structures of hydrated alumino-silicates

silica sheet
alumina sheet + OH (hydroxyl)
silica sheet
alumina sheet

(1) Fine clay particles have net negative charge in layered lattice
(a) electrostatically charged ("static cling")
(b) readily exchange cations and water
(c) clay minerals used in water softening devices

b. Wetting and drying of clay minerals results in expansion of mineral lattice, differential stress and disintegration of material
(1) layered sheets in clay allow absorption and release of water
(2) water absorption = expansion; expansion = weathering process

c. Shale - layered sedimentary rock comprised of clay minerals
(1) clay expansion -important mechanism in breakdown of shale in rock outcrop
(2) Shale = low resistance to erosion = "soft" = easily weathered
(a) owing to hydration processes.

B. Chemical Weathering: Effective process in that common igneous (high temperature) silicate-bearing rocks and minerals are seldom in equilibrium with near-surface conditions of high water content, low temperatures and low pressures.

1. Net Driving Effects of Weathering Process: oxidation (loss of electrons in select ionic species, e.g. Fe^{+2} to Fe^{+3}), clay formation, and hydrating of mineral species.

THE SIGNIFICANCE OF WATER IN THE WEATHERING ENVIRONMENT

0. H_2O = a dipolar molecule with a 105 degree bond angle formed between the oxygen in the center, and the two hydrogen atoms, forming a dipolar tetrahedron

a. "dipolar" refers to the idea that the O end of the molecule tends towards a negative charge, and the H end of the molecule tends towards a positive charge.

O (-2)
H(+) H(+)

This arrangement gives water its unique properties that makes it the most ubiquitous and essential substance on the surface of the earth!!!

1. Can exist in all three physical states: liquid, solid (ice), and gas (water vapor)

2. Transformation Processes related to energy input and entropy of water: heating of water, > atomic activity of the water molecules, i.e. > vibrational energy of water atoms.

ICE ----------HEAT----- WATER-------HEAT -------WATER VAPOR
(<32 degrees) (32-212) (>212 degrees F)

a. Evaporation- process of transforming water from liquid to gaseous state (Heat Gain)

b. Freezing- process of transforming water from liquid to solid state (Heat Loss)

c. Condensation- transformation of water vapor to liquid form (Heat Loss)

d. Sublimation- process of transforming ice to water vapor directly through superheating, bypassing liquid form. (Heat Gain)

3. Water is one of few earth substances that remains in a liquid state at the operating surface temperatures of the earth.

A. The liquidity of water makes it a dominant and pervasive component of all earth processes

4. Water has High Heat Capacity- it has a capacity to absorb and hold energy with only a small amount of temperature rise.

A. Result- large bodies of water are very slow to warm during the day, and slow to cool during night and similarly so for seasonal changes.... acts as a heat sink and "energy lag" compared to heating and cooling of continental material. Thus have a moderating effect on surrounding temperature changes on land.

5. Water expands in volume when it freezes/ becomes colder, in contrast to majority of substances (which contract when colder)

A. Result Density of ice < Density of water: thus ice floats on water
B. Also of importance for water playing the role of hydraulic press during process of frost wedging

6. Water strongly influenced by the force of gravity, constantly driven downward, and can possess great erosive/ landscape carving force

7. Water has property of high surface tension, ability to have strong molecular attractive forces (sticks to itself and electrostatically attracts ionic forms of elements)

a. Capillarity- phenomena of water moving upward against the force of gravity, due to strong electrostatic adhesive forces, most notable in narrow, restricted pore spaces where surface to surface contact in high.

1) capillarity/high surface tension allows water to move upward through plant vascular system.

8. Water acts as a "universal solvent" and can dissolve most any substance over time. Water + carbon dioxide forms a mild carbonic acid solution naturally in hydrosphere, as an acid can result in cationic exchange with positive ionic species, and result in chemical breakdown of substances.

a) Water dissolves substances by forming "sheaths" or "envelopes" of molecules surrounding ions, insulating ions from one another and inhibiting inter-ionic crystal growth.

Processes of Chemical Weathering

1. **Hydrolysis**: cation exchange reaction between water (H+ ion) and silicate rock-forming minerals (results in freeing OH- from water molecule). Hydrolysis refers to the dissociation of water molecules into H+ and OH-.

a. Model: driving force lies in unsatisfied atomic bonds of silicate mineral cations, oxygens, and hydroxides at crystal surface.

Dissociation: H_2O ----- $H^+ + OH^-$ pH = $-\log[H^+]$

(3) Di-polar (+ H side and - O side, with bond angle of 105 degrees) water molecule is attracted to cation exchange site of crystal lattice, force of attraction dissociates water: H+ ions (of dissociated water molecule) combine with O^{-2} ions of crystal surface and OH- ions (of water molecule) combine with Si^{+4} or Al^{+3} of silicate mineral. H+ ions may also replace metals cations (e.g. K+) in mineral crystal lattice, further disrupting mineral stability.

Net effect: chemical alteration and breakdown of mineral

e.g. Generic Formula:

Aluminosilicate + H_2O + H_2CO_3 ----- Clay Mineral + Cations + OH^- + HCO_2^- + H_4SiO_4

Orthoclase alters to Kaolinite:

$2KAlSi_3O_8 + 2H^+ + 9H_2O$ ---- $H_4Al_2Si_2O_9 + 4H_4SiO_4 + 2K+$

orthclase kaolinite silicic acid free ions

(4) Reaction is irreversible at earth's surface temperatures and pressures.

(5) Hydrolysis: most common type of chemical reaction at earth's surface, resulting in the derivation of clay minerals, very important weathering process.

2. **Oxidation**: process by which elements tend to lose an electron, resulting in net increase in positive ionic valence. Fe^{2+} ---- $Fe^{3+} + e^-$ Eh and pH dependent.

a. Iron is a common component, in some degree, of many silicate bearing minerals (and rocks).

1. Weathering of Iron bearing minerals commonly releases free iron (Fe^{+2}) to the weathering system, which is in turn oxidized to Fe^{+3}) to form iron oxides (hematite Fe_2O_3) or iron oxy-hydroxides (Limonite Fe(O)(OH)).

2. Iron minerals may breakdown due to oxidation of iron, e.g. fayalite to hematite.

$Fe_2SiO_4 + 2H_2CO_3 + 2H_2O$ -----$2Fe^{+2} + 2HCO_3^- + H_4SiO_4 + 2OH-$

$2Fe^{2+} + 4HCO_3^- + 1/2O_2$ --- $Fe_2O_3 + 4H_2CO_3$

3. **Chelation**: biological reaction between plant and mineral medium, very significant in soil-forming processes and also common in lichen-rock interaction.

a. Model: an organo-chemical process whereby more than one bond is formed between a metal (from rocks/minerals) and an organic-complexing molecule. Net result: a ring organic structure incorporating the metal ion with concomittant release of hydrogen ion from reaction (possibly aiding in hydrolysis described above).

1. Once in solution, the organic-metal chelate complex may be mobile in the system, migrating through weathering solutions.

4. **Hydration (and dehydration)**: process by which water is added or removed from a mineral species.

e.g. gypsum alteration to anydrite: $CaSO_4 \cdot H_2O$ ---- $CaSO_4 + 2H_2O$

e.g. hematite to goethite: $Fe_2O_3 + H_2O$ --- $2FeO(OH)$

5. **Ion Exchange**: generally an exchange of cations between solid mineral species and weathering solutions.

a. Common in Na-bearing clay minerals (e.g. zeolites), where the Na ion from the clay structure is readily exchanged with cations of similar ionic radii and ionic strengths (e.g. Ca)

E.g. water softening systems:

$Na_2Al_2Si_3O_{10} \cdot H_2O + Ca^{2+}$ --- $CaAl_2Si_3O_{10} \cdot H_2O + Na^+$

6. **Solution/Dissolution of Mineral Species**: process of dissolution of readily soluble mineral species, commonly carbonates or evaporites (salts), in weak solutions of carbonic acid.

a. Biologic/bacterial decay of organic matter in soil (under oxidizing conditions) results in release of CO_2 to subsurface soil-gas environment, results in formation of weak carbonic acid. CO_2 also may be dissolved in percolating surfaces waters directly from atmosphere.

7. **Carbonation:** process of dissolution of atmospheric CO_2 (at ~0.03% of atmosphere) into water to create weak carbonic acid Reaction/Equation:

$H_2O + CO_2$ --- H_2CO_3 H_2CO_3 --- $HCO_3^- + H^+$

Reaction dependent upon partial pressure of carbon dioxide gas and temperature of solution.

Cold water + high pressures = increased solubility = > acidity, <pH
Warm water + low pressures = decreased solubility = < acidity, >pH.

Net Dissolution of Limestone: $H_2O + CO_2 + CaCO_3$ ------ $Ca^{2+} + 2HCO_3^-$

In Class Exercise: Focus on Chemical Weathering

(1) Place a large fragment of limestone in a beaker of hydrochloric acid. Describe your observations.

(2) Place crushed fragments of limestone in a beaker of hydrochloric acid. Describe your observations.

(3) Write a generic chemical formula that describes the chemical weathering process illustrated in (1) and (2) above.

(4) Compare the rates of reaction in (1) and (2) above, what is your hypothesis as to how physical weathering influences or enhanches chemical weathering.

C. **INFLUENCE ON CHARACTER AND RATES OF WEATHERING**

1. **Factors Influencing Rates**

a. **Particle size** - generally the finer the particle, the more surface area exposed to action of weathering, the faster that it will react and weather (e.g. cube of sugar vs. granulated sugar).

1) Physical Weathering = physical diminution or fragmentation of rock material-----------increases surface area and speeds rate of chemical reaction

b. **Parent Material/Mineral Composition** - different minerals have different resistance to weathering (based on atomic structure, quality of chemical bonds, and temperatures as which mineral crystallize) e.g. granite (quartz, k-spar, and mica) much more resistant to weathering than limestone (sed rock, $CaCO3$).

1) **remember Bowens' reaction series** is also approximation of mineral's resistance to weathering (Olivine - high temp, very unstable in surface env. of earth, weathers very easily).

d. **Climatic factors influence weathering** - e.g. obviously need climate favorable to moisture, freezing and thawing for frost wedging to be effective. Chemical weathering most favored by warm temperatures and abundant moisture.

1) Water and temperature influence

e. **Vegetation**- dependent in part on regional climate zonation.

1) organic/physical root wedging
2) vegetal cover/leaf interception (energy dissipator)
3) organic/humic acids ---- aid in chemical weathering
4) organic matter in soils decays ---- release carbon dioxide and aids in carbonation process

f. **Topography**- slope, elevation and aspect of land have influence on weathering processes

1) high altitudes: freeze/thaw action significant
2) lower altitudes: > vegetative cover, chemical weathering enhanced

3) Slope-drainage- and soil cover

a) flat area: retain soil cover with deep weathering owing to infiltration of water

b) Steeper slopes: infiltration less, and soil erosion greater

4) **Aspect** or slope face direction effects degree of solar insolation to ground: set up of "microclimates"

a) North Slopes: less solar insolation, longer snow cover, higher moisture content, overall cooler temperatures

b) South Slopes: more solar insolation, shorter snow cover, high temps, higher evaporation rates, less soil moisture

c) influences vegetative cover (see above)

g. **Time**: weathering and extent of weathering is dependent on the length of exposure of rocks to the weathering process. Evolution of landforms through time (maturity concept of WM Davis)

1) > length of weathering, > depth of weathering and > degree of alteration of parent material to equilibrated weathering products.

2) attempts have been made to "calibrate" degree and effects of weathering with time using radiometric and geochemical techniques, in essence to derive a semi-quantitative geomorphic dating device

III. END PRODUCTS OF THE WEATHERING PROCESS: CLAY AND SOIL

C. Clay Minerals: layer lattice silicates comprised of an aluminous-hydroxide component i.e. hydrous alumino-silicates ("Phyllosilicates")

Clay mineralogy becomes quite complex, with classification based on the arrangement of tetrahedral and/or octahedral sheets. Analyzed largely through X-ray diffraction techniques.

Clay minerals are the ultimate weathering product, i.e. most stable form of silicate mineral in the low temp., high moisture sedimentary environment.

B. **SOILS AND SOIL FORMING PROCESSES**

DEFINITIONS

A. **Soil**- a weathered mantle of unconsolidated earth material, covering land surfaces of the earth. Comprised of a mixture of mineral and organic matter, derived from the physical, chemical and biologic weathering/decomposition of bedrock.

Soil comprised of unconsolidated finely fragmented mineral particles, plant roots, decomposed organic litter, water, air and an abundance of micro-organisms.

Weathered soil horizons form the primary zones of plant growth on the earth's surface, hence comprise an important economic and/or agricultural resource necessary for production of food, and our very existence.

Plant growth driven by sun's energy, with the soil horizon serving as a growth medium through which plant roots can uptake water and elemental nutrients (P, K, Ca, and trace elements).

C. Regolith- partially weathered, fractured and broken down bedrock, comprised primarily of inorganic mineral material.

Regolith is generally underlain by unfragmented rock below and the soil mantle above (where present).

D. Pedogenesis: a 3-dollar term that generically refers to the process of soil formation.

SOIL COMPOSITION

A. **Inorganic Mineral Matter**

Comprises the bulk of soil composition in the form of mineral matter. The inorganic fraction of soil is classified according to grain size and mineral composition. Mineral components include:

1. clay-sized particles consisting of hydrated aluminosilicates known as clay minerals.

    a. clay mineral properties include: colloidal size (>molecules but smaller than can be viewed with unaided eye), great surface area, sheet-like aluminosilicate crystal structure, net negative ionic charge between clay silicate sheets, high cation exchange potential, high capacity for water retention

2. sand and silt sized particles that may vary in mineral composition according to the composition of the parent bedrock. Quartz, feldspar and mica are common rock-weathered derivatives.

inorganic mineral constituents in soil may either be derived from direct weathering of underlying bedrock or from aerosolic accumulation (i.e. wind blown deposits)

B. Organic Matter: comprises less than 5% of total soil composition, however plays a major role of influencing biochemical soil processes, and rendering soil a highly effective growth medium

1. organic soil constituents include: dead and undecomposed plant and animal tissue, more fully decomposed organic humus, living plant and animal organisms including roots, burrowing organisms, microorganisms and bacteria.

    soil bacteria are responsible for the composting/decomposition process as well as serving as an innoculant for the stimulation of plant nitrogen fixation from the atmosphere.

    plant litter- leaf material, root matter and stems

    humus- dark colored (brown or black), gelatinous, chemically decomposed (hence chemically stable) organic matter.

Humic and organic matter is important for loosening soil texture and improving water retention capacity of soil, hence improving it as a growing medium

C. Porosity/Soil Air

Porosity- the degree of void-space present in the soil, represented by an open interstitial network of void spaces between soil particles.

A loose, "average" soil is composed of 40-50% porosity

Porosity is essential for the infiltration of surface water/precipitation into the soil, making it available for plant use.

Void spaces are filled with a varying combination of air and/or water depending upon climatic and slope conditions.

Soil air: generally found in voids which are lined by a zone of hydration, generally rich in carbon dioxide and poor in oxygen as related to plant physiology and respiration. Carbon dioxide eventually diffuses into the atmosphere.

D. Soil Water- soil moisture content generally varies in direct relation to climatic conditions, surface vegetation and the physical structure of the soil.

1. Infiltration- water largely recharged to the soil via surface infiltration from precipitation and/or from upward capillary draw from groundwater regime below.

2. Soil water loss- water lossed from soil regime via evapotranspiration and/or downward percolation into the groundwater system.

3. Water properties:

a. universal solvent that mobilizes soil elements and nutrients, making available for uptake through plant root/vascular system.

1) leaching- process of water dissolution of ions/nutrients from soil, may actually result in ionic depletion of certain soil horizons depending on conditions of water migration.

b. soil water also important constituent for clay chemistry and driving biochemical systems of microorganisms.

c. percolating soil water may also act to physically alter the texture of the soil through particle transport

1) eluviation- process of removing soil particles by the action of downward percolating soil water

2) illuviation- prcess of particle deposition and accumuation by percolating soil water

SOIL PROPERTIES

A. Color: Indicative of chemical and mineralogic nature of soil

1. 175 gradations of soil color recognized (Munsell color chart)
   a. Black = humic content
   b. Red or Yellow = iron oxide staining
   c. Gray or White = indicative of ion leaching or depleted soils
      White in arid climate = alkali precipitates (carbonates)

B. Texture: based on sieve analysis identifying sand, silt and clay composition of soil

1. Loam = equal admixtures of each
2. clay loam, silty clay, sandy clay, sand loam, silt loam, etc.

   a. effects engineering properties of soil/moisture-drainage

C. Structure: shape and character of aggregate soil masses or "peds"

1. size, shape and cohesion of peds influences drainage, aeration, soil porosity, and soil permeability

SOIL PROFILES

A. Soil Horizons: Throug the weathering process, soil tends to segregate into vertically characteristic layers in response to chemical and physical processes

1) Horizons: distinctively recognizable soil layers with unique chemical and physical properties

Horizonation - soil horizons form as a function of gravity-driven processes

-downward percolation of water
-translocation of fine particles
-translocation of dissolved ions
-precipitation of dissolved ions

2) Soil growth and formation viewed as progressing in a downward direction, i.e. thickness of soil profile increases from surface downward with time (thickening downward).

Soil Accumulation mechanisms
-rock weathering (downward increase in soil thickness)
- cumulic soils (soils that accumulate by deposition)
*eolian soils

*fluvial / floodplain soils
*volcanic soils

B. Soil Profile: characteristic horizons

1. O horizon: immediate surface layer composed of organic matter

2. A horizon: organic + mineral horizon, dark brown to black in color

3. E horizon: zone of leaching or "eluviation", lighter in color, leached of iron and aluminum.

4. B horizon: zone of accumulation or "illuviation", receiving zone of transported iron, aluminum and clay from above, often a reddish clayey horizon.

5. C horizon: regolith or unconsolidated parent material, below root zone, weathered bedrock, in decay

6. R horizon: consolidated bedrock

PEDOGENIC REGIMES

A. Laterization: common in areas of warm, moist climates (tropics), soils characteristically red and iron/aluminum rich, rapid decomposition of organic matter and extensive leaching (rainforest soils)

B. Podozolization: cold winter/seasonal climates, northern latitudes, abundant moisture, leaching predominant, however signigicantly developed O horizon. Well developed B horizon.

C. Gleization: waterlogged, cool climate soils, poor drainage, abundant organic matter, oxygen deficient conditions, gray B horizon (wetlands soils)

D. Calcification/Salinization: arid, high evaporation climates, little leaching/through flow of soil water, chemical weathering/clay alteration minimal, calcium carbonate build-up in B horizon (caliches or white horizons)

SOIL TAXONOMY/SOIL CLASSIFICATION - USDA CLASSIF. SYSTEM

Soil Orders

A. Entisols: Soils without distinct horizons, immaturely developed, "recent" soils

B. Vertisols: soils subject to clay swelling (hydration) with dessication cracking upon drying,

C. Inceptisols: soils with weakly developed horizons, "Brown Forest Soils"

D. Aridisols: desert soils with carbonate horizon (caliche)

E. Mollisols: soils with dark, organic rich A horizon, moist, "Chestnut" soils

F. Spodosols: "podzolic" soils, northern latitude soils

G. Ultisols: highly leached soils, red soils, southern climates

H. Oxisols: "laterites" tropical, highly leached soils

I. Histosols: highly organic "peat" soils, bog soils

J. Andisols - soils developed on recent volcanic material (tephra deposits)

Percentage of Soil Distribution throughout U.S. and World

	U.S.	World
Alfisols	13.4	14.7
Aridisols	11.5	19.2
Entisols	7.9	12.5
Histosols	0.5	0.8
Inceptisols	18.2	15.8
Mollisols	24.6	9.0
Oxisols	----	9.2
Spodosols	5.1	5.4
Ultisols	12.9	8.5
Vertisols	1.0	2.1

In-Class Exercise - Soil Texture Analysis

(1) In groups, measure approximately 200 grams of soil sample, divide into two 100-gram aliquots.

(2) Place one of the 100-g samples in a plastic bag, shake and disaggregate the peds.

(3) Select a set of sieves: use the following sizes (stacked from top to bottom)

-2 mm (-1 phi) mesh opening	(> 2 mm = "gravel", < 2 mm = sand and finer)
-0.625 mm (4 phi) mesh opening	(>0.625 mm = "sand", <0.625 mm = silt and finer)
0.0039 mm (8 phi) mesh opening	(>0.0039 mm = "silt", < 0.0039 mm = "clay")
Pan on Bottom	(Pan catches all clay)

(4) Place the sample in the stack of sieves, shake vigorously, take sieves apart and determine the mass for each size fraction. Fill in the following table:

Sieve Size (Phi)	Mass (grams)	Weight % (Col 2 / Total x 100%)
-1 phi	____________	___________
4 phi	____________	___________
8 phi	____________	___________
pan	____________	___________
Total	____________	___________

(5) Plot your data in terms of %sand-silt-clay on the attached triangular diagram.

(6) Classify your soil sample in terms of texture (derive from plot on triangular diagram).

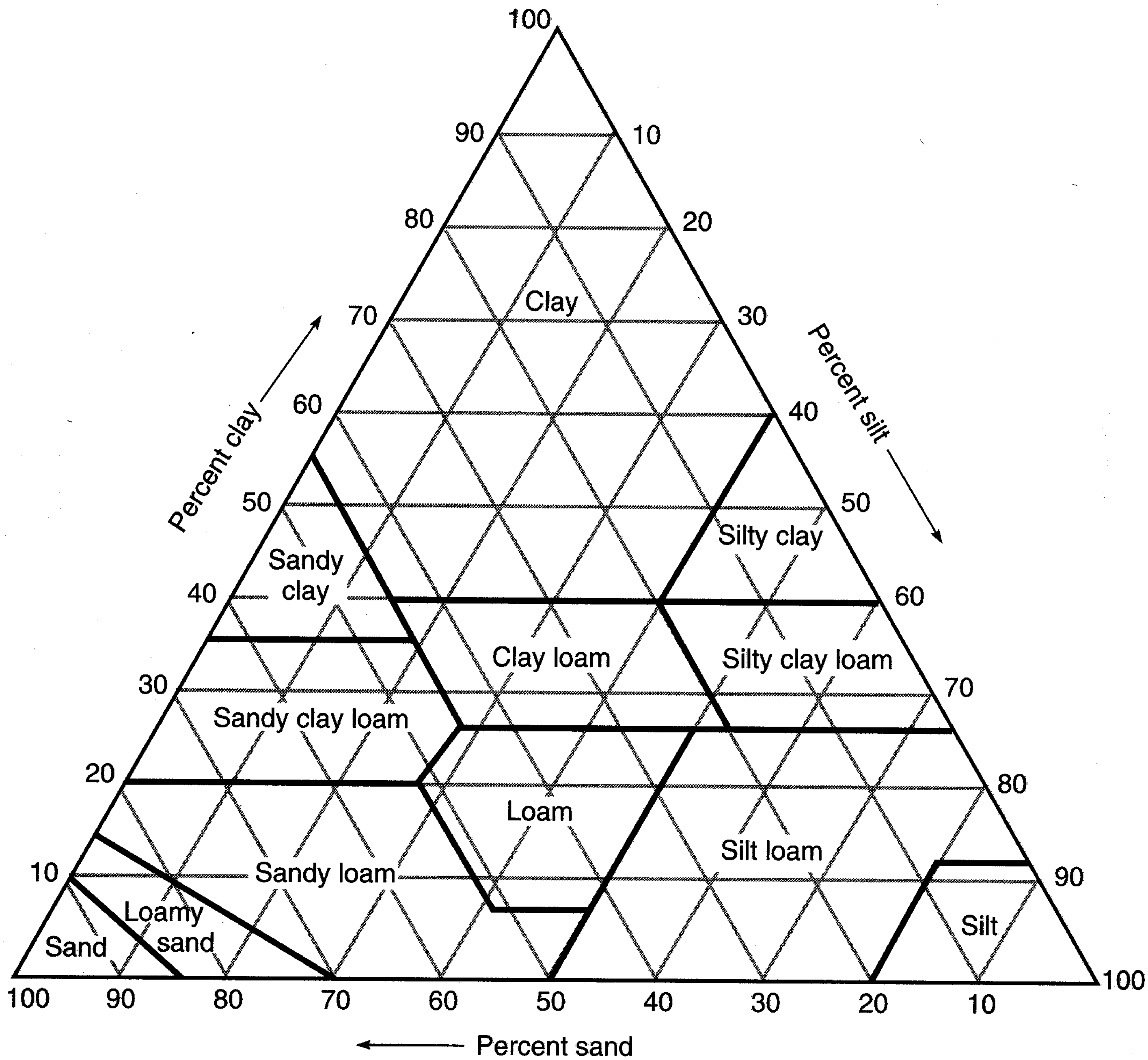
(7) Disaggregate your second 100-gram sample. Record the following observations:

A. Degree of "grittiness" between your fingers.

B. Cohesiveness when wet.

C. Color (use Munsell color chart)

wet color:
dry color:


100
90
80
70
60
50
40
30
20
10
Percent clay
Percent silt
Percent sand
Clay
Silty clay
Sandy clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Silt loam
Sandy loam
Loamy sand
Sand
Silt

Class Exercise in Basic Soil Observation:

Examine the example soil profile and fill in the data chart below:

Depth to Horizon	Soil Texture	Munsell Soil Color	Other Components (rock material, organic, etc.)
________	___________	___________	___________________________
________	___________	___________	___________________________
________	___________	___________	___________________________
________	___________	___________	___________________________
________	___________	___________	___________________________
________	___________	___________	___________________________
________	___________	___________	___________________________

(1) Based on your class notes and text book, determine horizon names for each part of the profile (A, B, etc.). Write your horizon designations next to the data columns above.

(2) Briefly discuss how you used color and texture to make your horizon designations.

(3) Based on your text and p. 34-35 of the notes, identify the soil order that best describes this soil.

(4) Comment on the age of this soil... how long has it been forming? What factors will influence your guesstimate?