EENS 1110	Physical Geology
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Weathering and Soils

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Earth is covered by a thin "veneer" of sediment. The veneer caps igneous and metamorphic "basement." This sediment cover varies in thickness from 0 to 20 km. It is thinner (or missing) where igneous and metamorphic rocks outcrop, and is thicker in sedimentary basins.

In order to make this sediment and sedimentary rock, several steps are required:

- Weathering – Breaks pre-existing rock into small fragments or new minerals
- Transportation of the sediments to a sedimentary basin.
- Deposition of the sediment
- Burial and Lithification to make sedimentary rock.

Each Step in the process of forming sediment and sedimentary rocks leaves clues in the sediment. These clues can be interpreted to determine the history of the sediment and thus the history of the Earth.

Weathering

Geologists recognize two categories of weathering processes

1. ***Physical Weathering*** - disintegration of rocks and minerals by a physical or mechanical process.
2. ***Chemical Weathering*** - chemical alteration or decomposition of rocks and minerals.

Although we separate these processes, as we will see, both work together to break down rocks and minerals to smaller fragments or to minerals more stable near the Earth's surface.Both types are a response to the low pressure, low temperature, and water and oxygen rich nature of the earth's surface.

Physical Weathering

The mechanical breakup or disintegration of rock doesn't change mineral makeup. It creates broken fragments or "detritus." which are classified by size:

- Coarse-grained – Boulders, Cobbles, and Pebbles.
- Medium-grained – Sand
- Fine-grained – Silt and clay (mud).

Physical weathering takes place by a variety of processes. Among them are:

- Development of ***Joints*** - Joints are regularly spaced fractures or cracks in rocks that show no offset across the fracture (fractures that show an offset are called faults).
    - Joints form as a result of expansion due to cooling or relief of pressure as overlying rocks are removed by erosion.

- Igneous plutons crack in onion like "exfoliation" layers. These layers break off as sheets that slide off of a pluton. Over time, this process creates domed remnants. (See figure B.4 in your text) Examples: Half-Dome (CA.) (see figure 22.12a in your text) and Stone Mountain (GA.).

- Joints form free space in rock by which other agents of chemical or physical weathering can enter.

- Crystal Growth - As water percolates through fractures and pore spaces it may contain ions that precipitate to form crystals. As these crystals grow they may exert an outward force that can expand or weaken rocks.

- Thermal Expansion - Although daily heating and cooling of rocks do not seem to have an effect, sudden exposure to high temperature, such as in a forest or grass fire may cause expansion and eventual breakage of rock. Campfire example.

- Root Wedging - Plant roots can extend into fractures and grow, causing expansion of the fracture. Growth of plants can break rock - look at the sidewalks of New Orleans for example.

- Animal Activity - Animals burrowing or moving through cracks can break rock.

- ***Frost Wedging*** - Upon freezing, there is an increase in the volume of the water (that's why we use antifreeze in auto engines or why the pipes break in New Orleans during the rare freeze). As the water freezes it expands and exerts a force on its surroundings. Frost wedging is more prevalent at high altitudes where there may be many freeze-thaw cycles.

Chemical Weathering

Since many rocks and minerals are formed under conditions present deep within the Earth, when they arrive near the surface as a result of uplift and erosion, they encounter conditions very different from those under which they originally formed. Among the conditions present near the Earth's surface that are different from those deep within the Earth are:

- Lower Temperature (Near the surface T = 0-50°C)

- Lower Pressure (Near the surface P = 1 to several hundred atmospheres)

- Higher free water (there is a lot of liquid water near the surface, compared with deep in the Earth)

- Higher free oxygen (although O_2 is the most abundant element in the crust, most of it is tied up bonded into silicate and oxide minerals - at the surface there is much more free oxygen, particularly in the atmosphere).

Because of these differing conditions, minerals in rocks react with their new environment to produce new minerals that are stable under conditions near the surface. Minerals that are stable under P, T, H_2O, and O_2 conditions near the surface are, in order of most stable to least stable:

- Iron oxides, Aluminum oxides - such as hematite Fe_2O_3, & gibbsite $Al(OH)_3$.
- Quartz*
- Clay Minerals
- Muscovite*
- Alkali Feldspar*
- Biotite*
- Amphiboles*
- Pyroxenes*
- Ca-rich plagioclase*
- Olivine*

Note the minerals with a *. These are igneous minerals that crystallize from a liquid. Note the minerals that occur low on this list are the minerals that crystallize at high temperature from magma. The higher the temperature of crystallization, the less stable are these minerals at the low temperature found near the Earth's surface (see Bowen's reaction series in the igneous rocks chapter).

The main agent responsible for chemical weathering reactions is water and weak acids formed in water.

- An acid is solution that has abundant free H^+ ions.
- The most common weak acid that occurs in surface waters is carbonic acid.
- Carbonic acid is produced in rainwater by reaction of the water with carbon dioxide (CO_2) gas in the atmosphere.

$$\underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2} \longrightarrow \underset{\text{carbonic acid}}{H_2CO_3} \longrightarrow \underset{\text{hydrogen ion}}{H^+} + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

H^+ is a small ion and can easily enter crystal structures, releasing other ions into the water.

Types of Chemical Weathering Reactions

- ***Hydrolysis*** - H^+ or OH^- replaces an ion in the mineral. Example:

$$\underset{\text{Orthoclase}}{4KAlSi_3O_8} + \underset{\text{Hydrogen ion}}{4H^+} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{Potassium ion}}{4K^+} + \underset{\text{Kaolinite (clay mineral)}}{Al_4Si_4O_{10}(OH)_8} + \underset{\text{quartz}}{8\ SiO_2}$$

- ***Leaching*** - ions are removed by dissolution into water. In the example above we say that the K^+ ion was leached.