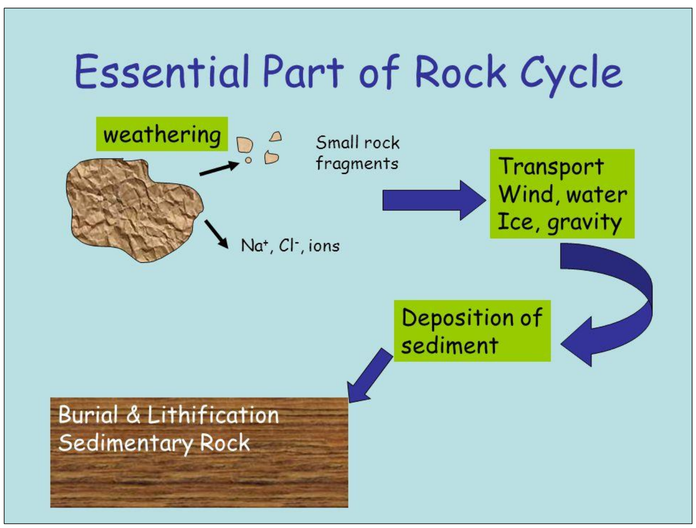
Chapter two (Weathering and soils)

Sedimentary rocks form through a complex set of processes that **begins** with **weathering**, the physical disintegration and chemical decomposition of older rock to produce solid particulate residues (resistant minerals and rock fragments) and dissolved chemical substances (Fig. 2.1). Some solid products of weathering may accumulate in situ to form soils that can be preserved in the geologic record (paleosols). Ultimately, most weathering residues are removed from weathering sites by erosion and subsequently transported to the depositional sites.

Weathering; the breakdown of the rocks at or near-surface by chemical, physical, and biological processes. Or it refers to the group of destructive processes that change the physical and chemical character of the rock at or near-surface. It doesn't involve the removal of rock material (i.e. **Erosion** which means the physical removal and transportation of weathered particles by moving water, wind, ice, or gravity).



(Fig. 2.1) An essential part of the rock cycle explains the formation of sedimentary rocks.

Main causes of weathering:
Plant, animal life, atmosphere, and water are the major causes of weathering.

Types of weathering:

There are two main types of weathering, Physical and Chemical.

I. Physical (Mechanical) Weathering:

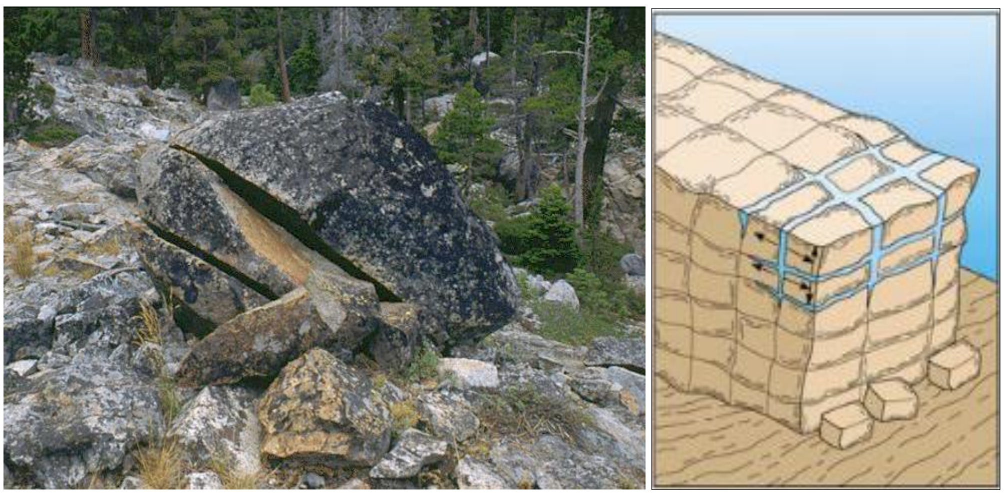
Physical breakdown of solid rock to smaller pieces, but with no change in chemical composition, just disintegration into smaller pieces and increasing the total surface area exposed to weathering processes.

The role of physical weathering

1. Reduces rock material to smaller fragments that are easier to transport.
2. Increases the exposed surface area of rock, making it more susceptible (vulnerable) to further physical and chemical weathering.

Types of physical weathering:

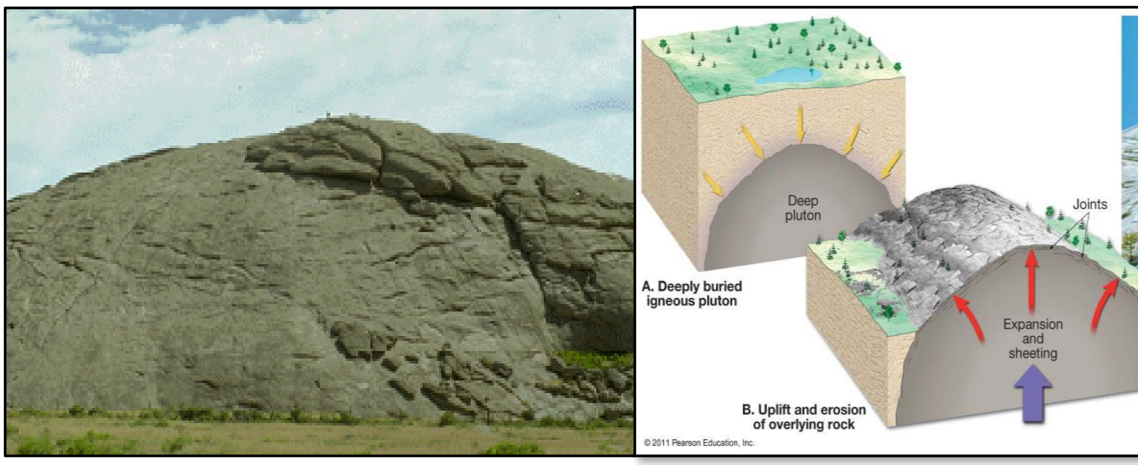
A. Freeze-Thaw (Frost Wedging)
B. Insolation Weathering (thermal expansion/contraction)
C. Salt Weathering (salt crystal growth)
D. Wetting & Drying Weathering
E. Stress Release Weathering (unloading)
F. Other Physical Process



(Fig.2.2) Frost wedging in cold region.

(Fig. 2.3). Breaking of rocks by thermal expansion. (Fig. 2.4). Salt weathering

(Fig. 2.5) Wetting and drying



(Fig. 2.6).Example of unloading “Exfoliation sheets”

(Fig. 2.7). Left; Root wedging. Right; Lichen burrows into the rock.

II. Chemical Weathering:
Breakdown of rocks by chemical reaction, minerals in rocks attacked by water and dissolved gases (O_2, CO_2) caused some components of the minerals to dissolve and be removed in solution. Other minerals recombine *in situ* to form new mineral phases. Water and dissolved gases (oxygen and carbon dioxides) play a major role in chemical weathering (main causes of chemical weathering).

II. Chemical Weathering

A. . Simple Solution

B. Hydrolysis

C. . Oxidation / Reduction

D. . Hydration / Dehydration

E. . Ion Exchange

F. . Chelation

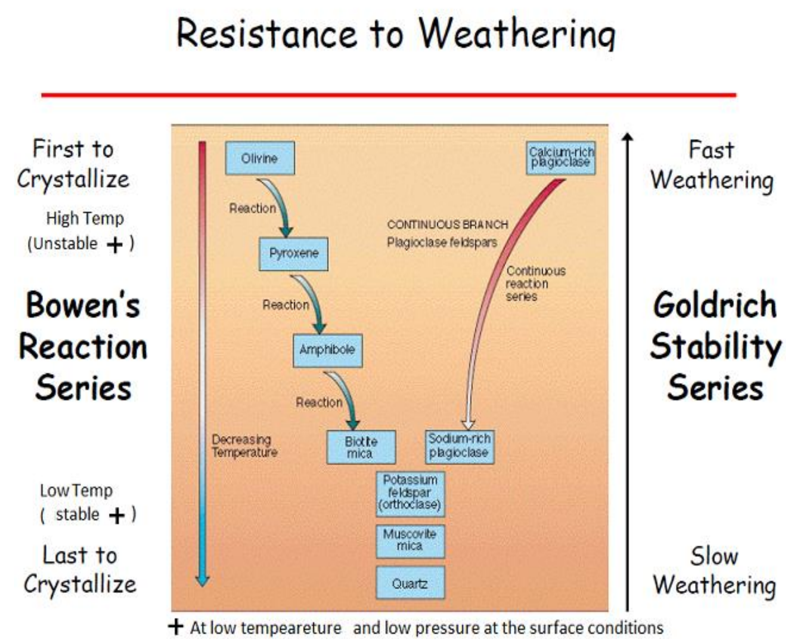
Rates of Weathering:

There is no mathematical solution to precise weathering rates. It is all relative and depending upon the climate and the mineral composition and grain size of the rocks.

Factors affecting the rate of weathering include:

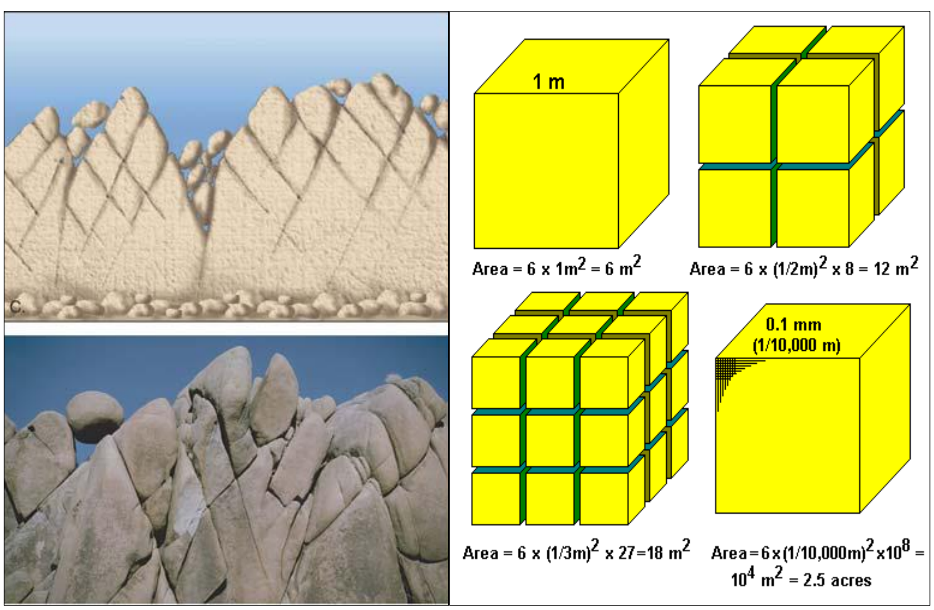
1. Climate; physical weathering processes are more effective in cold climates (frost wedging) or arid climates (salt wedging), whereas chemical weathering processes accelerated in hot, wet climates. Weathering tends to be more effective in low to moderate slope areas as compare to steep slopes.

2. Mineral composition; rock characteristics (composition): Rocks containing calcite (marble and limestone) readily dissolve in weakly acidic solutions. At low temperatures and low pressure at the surface conditions, minerals first to crystallize (e.g. Olivine and Pyroxene) weathered fast, by contrast, minerals last to crystallize (e.g. Quartz and Muscovite) weathered slow (Fig. 2.8).



(Fig. 2.8).Minerals resistance to weathering at the surface conditions.

3. The grain size of the rocks; the role of grain size of the rocks is that the disintegration of particles into smaller pieces by physical weathering increases the relative **surface area** of the rock (Fig. 2.9). So the more surface area, the more contact area for chemical weathering.



(Fig. 2.9). Left; joints in rock are a pathway for water, they can enhance chemical weathering. Right; physical weathering produces more surface area for chemical weathering.

Products of Subaerial Weathering

Three types of weathering products:

1. Source-rock residues - chemically resistant minerals and rock fragments:

• **Igneous/metamorphic parent rocks** - Immature soils - chemically unstable minerals: biotite, pyroxenes, hornblende, Ca-Plag. – Mature soils - quartz, muscovite, maybe K-feldspars

• **Siliciclastic sedimentary parent rocks** – The weathering product of these rocks tend to be depleted in easily weathered mineral (due to recycling) and rich in chemically stable minerals.

• **Limestone parent rocks;** weathering of these rock by solution produces thin soils composed of fine-size insoluble silicates and Fe-oxide residues.

2. Secondary minerals - formed in-situ by chemical recombination:

• **Clay mineral groups** (phyllosilicates) – Immature - *illite, chlorite, smectite* – Mature – *kaolinite.*

• **Iron oxides and hydroxides** (Fe+3 highly insoluble) – *Hematite, goethite (limonite)*

• **Aluminum oxides hydroxides** (Al+3 highly insoluble) – reflect very intense weathering – *laterite* (Fig. 2.10).

(Fig. 2.10). Laterite-humid climate, leached, rich in AL+3 and Fe+3, developed by intensive and prolonged weathering

3. Soluble constituents:

– released by chemical weathering
– transported by rivers & groundwater
– Raw materials for biogenic and chemical precipitates - e.g., *cherts, limestones, evaporates*.

• **Primary soluble products:**
HCO_3^- (bicarbonate), Ca^{+2}, H_4SiO_4 (Silicic acid), SO_4^{-2}, Cl^- , Na^+, Mg^{+2}, K^+ (Most abundant dissolved ions in decreasing abundance).

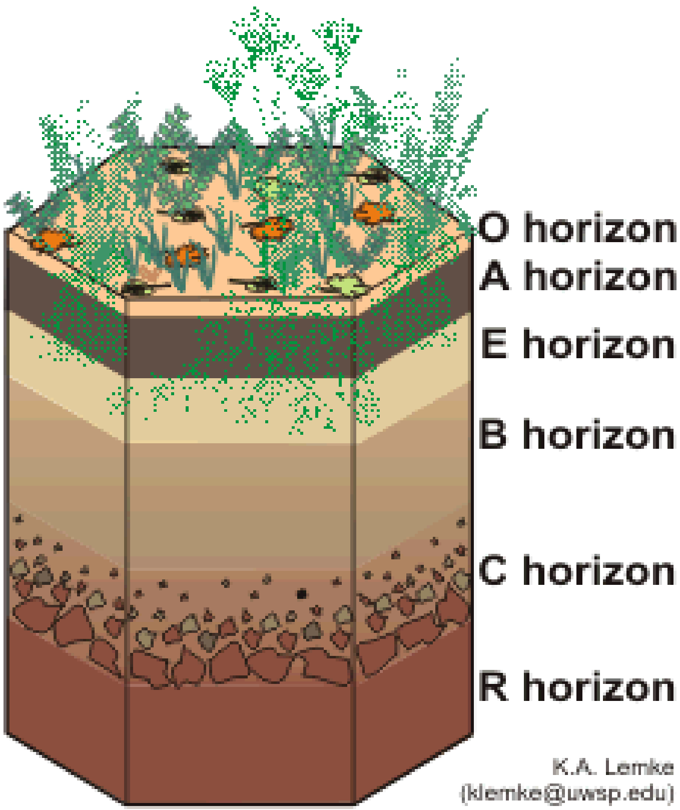
Submarine weathering (Halmyrolysis):

Sediments and rocks on the seafloor that are altered by reaction with seawater. It includes alteration of clay minerals from one type to another (e.g. the formation of glauconite from feldspars, the formation of zeolite minerals from volcanic ash, and dissolution of calcareous and siliceous tests of organisms).It also includes the formation of manganese nodules.

Soils and paleosols

Soil-Forming Processes

1. Additions to the ground surface—Precipitation of dissolved ions in rainwater; the influx of solid particles (dust, etc.); addition of organic matter from surface vegetation (leaf litter, etc.).
2. Transformations
   a. Decomposition of organic matter with soils to produce organic compounds.
   b. Weathering of primary minerals; formation of secondary minerals, including iron oxides.
3. Transfers
   a. Movement of solid or suspended material downward from one soil horizon to a lower horizon (Fig. 2.11) by groundwater percolation (eluviation)
   b. Accumulation of soluble or suspended material in a lower horizon (illuviation)
   c. Transfer of ions upward by the capillary movement of water and precipitation of ions in the soil profile
4. Removals—Removal of substances still in solution to become part of the dissolved constituents in groundwater or surface water.
5. Bioturbation of soil—Soil disrupted by animals (i.e. ants and termites) and plants (Fig. 2.12).



(Fig. 2.11). Soil profile.

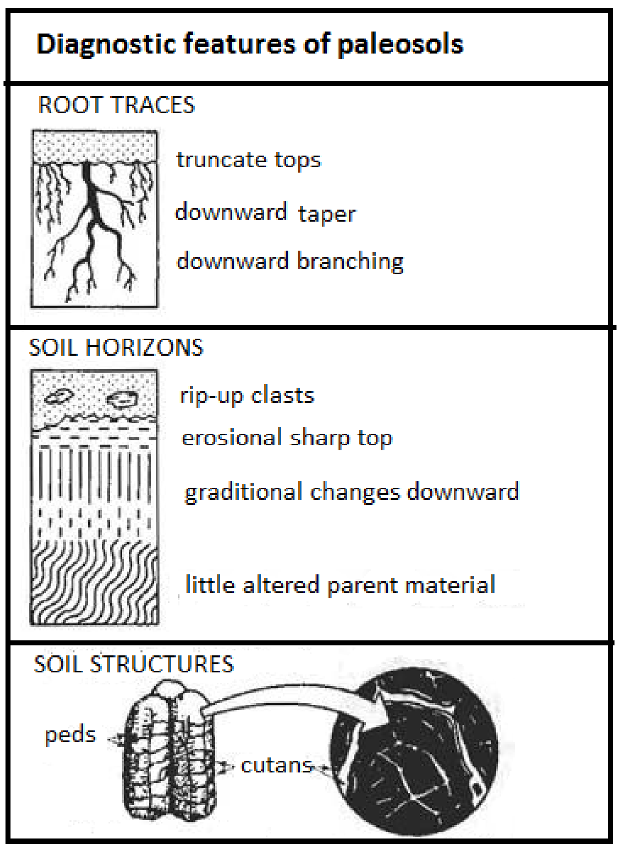
(Fig. 2.12). Disruption of soil by animals.

Paleosols:

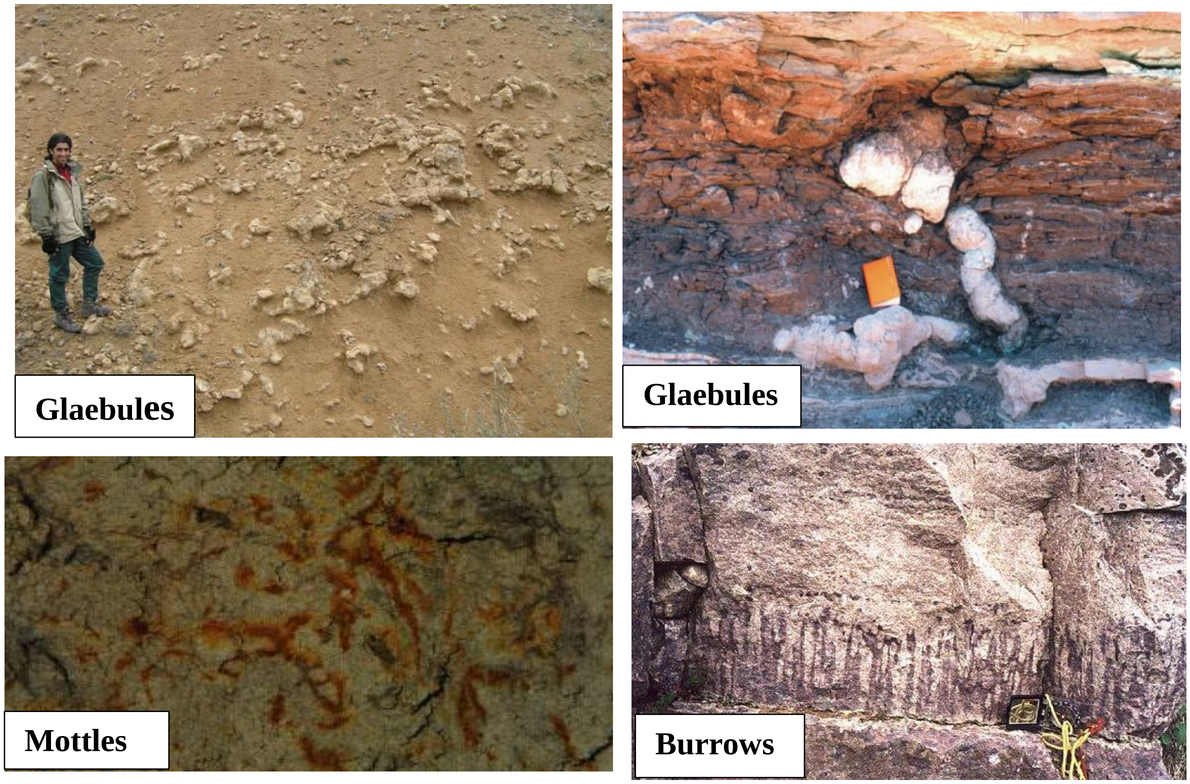
Paleosols (ancient soil); are buried soils or horizons of the geologic past. It occurs in stratigraphic record at major unconformities, as interbeds in sedimentary successions, particularly in alluvial successions. Paleosols are used as powerful indicators of paleoenvironments and ancient climatic conditions.

There are common features useful in recognition of paleosols (Fig. 2.13 and 14):

1. **Trace of life** including root traces which provide diagnostic evidence that rock was exposed to the atmosphere and colonized by plants, thus forming a soil.
2. **Soil horizons** are ancient soil horizons that show gradational changes in texture, color, or mineral content downward into the parent rock.
3. **Soil structures** are soil features developed by bioturbation (plants and animals), wetting and drying at the expense of the original bedding and structures in the parent rock. It includes Cutan (network of irregular planes) surrounded by more stable aggregates of soil materials called Peds. These structures give hackly appearance to the soil. Other soil structures include Glaebules (nodules and concretions).



(Fig. 2.13). Diagnostic features of paleosols.



(Fig. 2.14).Recognition of paleosoils: glaebules, mottles, and burrows.

Types of paleosols:

There are many types of paleosols with variable colors and bioturbation structures, which are generally, obscure the sedimentary structures. These paleosols include several types such as calcisol, oxisol, vertisol and protosol (according to Mack et al., 1993; cited in Kraus, 1999). The types of paleosol are briefly described as follows:

The calicsols are composed of calcite (calcrete) or dolomite (dolocrete) as nodules or thin layer within carbonate horizon, ranging from 5 to 20 cm thick, and having root traces and vertical cracks (Fig. 2-15 and 16) forming prismatic and platy structures, which represent incipient to relatively mature paleosols respectively

Fig. (2-15): Dolocrete layer with root traces and vertical cracks. The Gercus Formation

Fig. (2-16): Thin bed of Calcrete nodules with vertical cracks (Upper part of Gercus Fn. at Shiekan area)

The oxisols occur in brick-red mudstones-silty mudstones exhibiting wavy-irregular lamination with desiccation cracks and containing abundant ferruginous nodules in the form of soil-related pisoids (Fig. 1-17), which point to long-term chemical weathering in semiarid environment with seasonal intense rainfall.

Fig. (1-17): Brick-red mudstone (Oxisol) with wavy-irregular lamination. Gercus Formation

The vertisols are commonly present in purple mudstone and characterized by the complex pattern of fracture and desiccation cracks forming sub-angular blocky structures commonly with slickensided clay (Fig. 1-18).It represents very mature paleosols mainly developed near channel or crevasses splay.

Fig. (1-18): Vertisols in purple mudstone with desiccation cracks forming sub-angular blocky structure.