2. SOIL FORMATION AND PROFILE DEVELOPMENT

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2. SOIL FORMATION AND PROFILE DEVELOPMENT

- **Soil formation** _ production of unconsolidated material by weathering process soil
- **profile development** - changes involved in development of horizons

- Soil formation comprises 2 d/t processes
- **First**, changes from a consolidated mass (rock) not capable of growing plants to the development of unconsolidated (loose) layer of material that can support plants
  - weathering of rocks & minerals which provides basic materials i.e., parent materials for soil formation
- **Second**, the changes occurring within the loose material as time passes
    - This latter process is also called **soil development**
- In general. weathered rock is not soil but has to be turned into soil by the operation of certain **factors** & **processes**

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2.1 Factors of soil formation

- Studies of soils have shown that all kind of soils are formed under the interplay of five factors
- These, factors that control the formation of soils are:
  - Parent material , Climate , Biota, Topography or Relief, Time
    - Climate & biota are **active** soil forming factors, whereas the rests are **passive** factors
    - Soil forming factors do not act in **isolation** but in **combinations**

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Parent material

- Parent material is defined as the **initial state** of the soil system
- Inorganic parent materials can either be formed
  - in place as **residual material** weathered from rock, or
  - transported from one location & deposited **i.e., transported parent materials**

- Most important aspect of parent material is **mineralogical** & **chemical** properties
  - **Mineral** __a naturally occurring homogeneous solid that has a fairly definite internal structure & composition
    - result in fairly definite chemical properties
  - R**ock** ___simply, a complex mineral aggregate

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Based on their genesis & structure, **rocks** classified into 3 groups

i. Igneous rocks___ are formed from crystallization of magma

- According to their mode of occurrence, igneous rocks are separable in to
  - **Volcanic (extrusive, effusive)** rocks_ result from cooling of lava at earth's surface
  - **plutonic (intrusive)** rocks_ crystallize at relatively great depth within the earth's crust
- The common igneous rocks are ***granite, gabarro & basalt***

Igneous Rocks

Granite

Basalt

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- What about Igneous rock forming minerals
  - grouped into felsic & mafic minerals
- Felsic minerals
  - generally light colored in hand specimen
  - Have rather low densities i.e, <2.8 g/cm^3.
  - Typical felsic minerals are quartz & all kinds of feldspars (plagioclase and alkali feldspar groups)
- Mafic minerals
  - are usually dark-coloured
  - Their density is relatively high i.e, >2.8 g/cm^3
  - The chief mafic minerals are ferromagnesian: pyroxenes, amphiboles, biotite, olivine, etc
  - Rocks containing a high proportion of quartz (60-75%) are classified as acidic rock _e.g., granite
  - Those containing < 50% quartz are classified as basic _ e.g., basalt.

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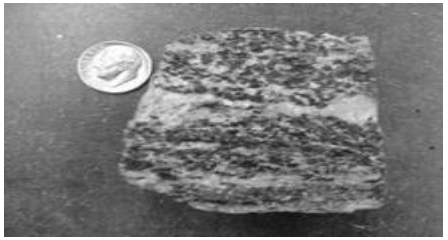
ii. Sedimentary rocks

- are formed from the igneous rocks by the consolidation of fragmentary rock (sediments) deposited by water
- Stratification is the most common feature of these rocks
- The common sedimentary rocks are
    - **conglomerate, sandstone, shale, limestone**

Sandstone

• iii. Metamorphic rocks

- Are formed from the igneous or sedimentary rocks by the action <u>of intense heat & high pressure</u>
- Both resulting in considerable change in the texture & mineral composition
- The common metamorphic rocks are
    - **genesis** from granite,
    - **quartzite** from quartz or sandstone,
    - **marble** from limestone
    - **slate** from shale.



Gneiss

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B. Climate

- Climate is the most influential active factor b/s it determines the nature & intensity of weathering that occurs over large area
- The principal climatic variables influencing soil formation are temperature & precipitation
- Both affect the rates of **physical, chemical and biological processes** of soil formation

Temperature: for every 10^0C ↑ in Temp, speed of chemical rxn ↑ by a factor of

- Same rule applied for weathering of minerals
- The rate of both biological activity within the soil & the breakdown of organic matter are also increased by a rise in temperature

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Moisture: movement of moisture determines the differentiation of horizons

- Moisture entering the soil comes mainly from precipitation as rain and snow and contains appreciable amounts of dissolved CO_2
- Thus, water entering the soil is a dilute acid, which is much more active than pure water
- The role of moisture in soil formation
    - transport agent of ions and other solutes
    - facilitates the activity of microbes
    - facilitates the decay (weathering) of some rock minerals, e.g. Calcite, dolomite & gypsum.

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C. BIOTA: Living Organisms

- Includes of Plants, animals & microbes
- Nearly every organism living on the surface of the earth or in the soil affects the development of soils in one way or another
- The actions of organisms include OM accumulation, profile mixing, nutrient cycling, structural stability of soils, etc.
- For instance, most influential aspect of higher plants through the role of roots,
    - addition of OM
    - Plant roots act as binders & prevent soil from erosion
    - grow into the cracks of rocks forcing the rocks to break apart
    - die & decompose there adding OM to the interior of the soil
- Litter fall, from leaves &trunks, also contribute significant amount of OM

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D. Topography

- configuration of the land surface
- is described in terms of differences in elevation, slope & landscape position
- The work of topography may be **to hasten or delay** the work of climatic forces
- It influence runoff, drainage, soil temperature, and soil erosion and consequently soil formation
- Topography influences soils in such a way.....
- If flat or gently sloping sites, materials remain in place & soil become thick
- If slope ↑, so does erosion, resulting in tiny stony soils

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E. Time- Duration required a soil to be formed

- Soil-forming process takes time to show their effects
- The length of time required for a soil to develop the distinct layers called genetic horizons
- Its length depends upon many interrelated factors
- Soil formation is a very long & slow process requiring thousands of years
- This make impossible for human beings to study the influence of time as it is much longer than the life span of an individual

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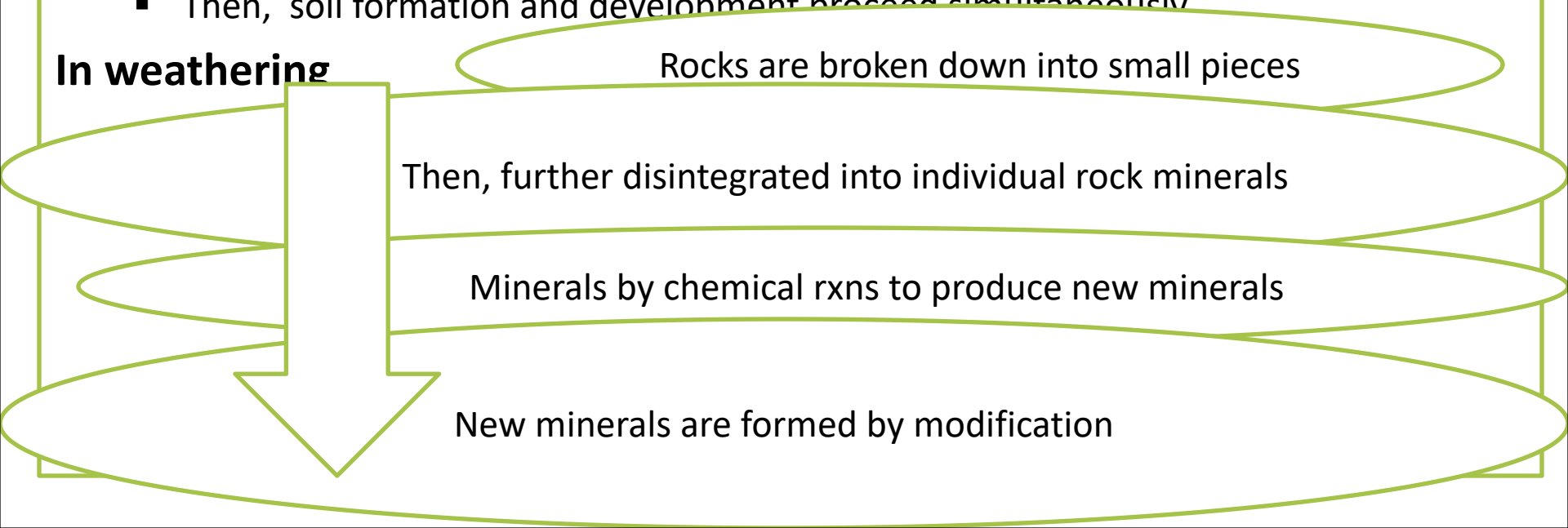
2.2 Soil formation processes

- Soil forming processes form soil after
  - Rocks are weathered
  - Oms are decomposed

2.2.1 Weathering- The initial soil forming process

- **Weathering** is the process of disintegration & decomposition of rocks and minerals
- It could be combination of destruction + syntheses
  - Creates the parent materials over which soil formation takes place
  - Then, soil formation and development proceed simultaneously

In weathering



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2.2.1.1 Types of weathering

a. Physical weathering

- Disintegration of the rock /mineral constituents of a soil under the physical action without any chemical change or formation of new products
- Disintegration results in a decrease in size and increase particle surface area. of rocks and minerals without appreciably affecting their composition
- **The principal agents of physical weathering are**

Temperature:

- Warming (day) & cooling (night) is effective in disintegrating rocks
- Cracks are created b/se of **variation in the coefficient of expansion** of the minerals in the rocks
- The surface of **rocks peels** away because of the lateral differences in temperature
- The phenomenon is called ***Exfoliation*** *(shedding of layer)*

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Water

- heavy rains & flowing **waters dislocate the solid particles** on the rocks and expose the inner portion to the agents of weathering
- The dislodged particles are carried down and deposited elsewhere as alluvium
- **Freeze-thaw:** water expands upon freezing, exerting tremendous force

Wind

- Wind exerts an abrasive action, detaches the particles from the rocks and acts as a carrying agent
    - i.e., has both erosive and transportive action

Organisms

- Plant roots
- Soil animals
- Humans

b. Chemical Weathering

- Decomposition of rock or the mineral constituents of a soil
  - Alters the composition of minerals
  - Conversion of primary minerals into secondary minerals
  - secondary into other secondary minerals

- **is brought about by d/t processes, namely hydrolysis, hydration, carbonation, oxidation, & solution**

Hydrolysis:

- water molecules split into their hydrogen and hydroxyl components
- the hydrogen often replaces a **cation** from the mineral structure
- The most important way in chemical breakdown of rocks

- *E.g.* $KAlSi_3O_8$ (microcline) + $8H_2O$ → $HAlSi_3O_8$ + KOH
- $2HAlSi_3O_8$ + $8H_2O$ → $Al_2O_3\ 3H_2O$ + $6H_2SlO_3$
- KOH → $K^+ + OH^-$

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Hydration: addition of H_2O to a mineral structure

- Intact H_2O may bind to a mineral In soils
- oxides of Fe & Al are commonly undergoing hydration
- The H_2O may hasten decomposition by moving in lattice

E.g. $2FeO_3 + 3H_2O \rightarrow Fe_2O_3.3H_2O$

Hematite (Red) — Limonite (Yellow)

$$5\ Fe_2O_3\ (hematite) + 9H_2O \rightarrow Fe_{10}O_{15} \bullet 9H_2O\ (ferrihydrite)$$

Carbonation:

- One of the acids that increase the solvent action of H_2O considerably is carbonic acid
- H_2CO_3 containing H_2O dissolves almost all carbonates readily

E.g. $CO_2 + H_2O \rightarrow H_2CO_3$

$H_2CO_3 + CaCO_3 \rightarrow Ca^{+2} + 2HCO_3$

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Oxidation and Reduction

- oxidation corresponding to a loss and reduction to a gain of electrons.
- **speed up mineral break down** by making some minerals more soluble

E.g. $3Mg\ FeSiO_4 + 2H_2O \rightarrow H_4Mg_3Si_2O_2 + SiO_2 + 3FeO$

Olivine — Serpentine (solid) — (Solution) — Fe(II) oxide (solid)

Oxidation

$4FeO + O_2 \leftrightarrow 2Fe_2O_3$

Fe(II) oxide — Fe(III) oxide, Hematite

Solution.

- The solvent action of water is an important means of weathering rocks containing soluble salts, e.g. gypsum and limestone
  - $CaSO_4 \bullet 2H_2O$ (gypsum) $\rightarrow Ca^{2+} + SO_4^{2-} + 2H_2O$
- The solvent action is increased in the presence of carbon dioxide and organic acids released during the decomposition OM.

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Complexation Reactions

- Microorganisms and plant roots exude organic acid, anions, e.g., citrate, oxalate, and malate
- These organic acids bond with (chelate) metals, e.g., Al^{3+} & Fe3+, to form soluble complexes
- The metal-organic complex is stable

- Example: Al^{3+} complexation by ketogluconate
  - $Al(OH)3\ (gibbsite) + 3H^{+} \rightarrow Al^{3+} + 3H^{2}O$
  - $Al^{3+} + C_5O_5H_9COO^{-} \rightarrow C_5O_5H_8COOAl^{+} + H+$

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2.2.2. Pedogenic processes: processes of soil forming

- After the parent material has been deposited, differentiation of layers takes place because of the soil forming (pedogenic) processes that act upon the regolith

- **The soil forming processes responsible for horizon differentiation are:**

a. Additions to the soil:
  - Eg. addition of **OM** that creates black layer at the soil surface
  - mineral matter may also be added

b. Losses from the soil:
  - E.g.. losses of salts from the soil by drainage
  - It also includes losses by surface erosion.

c. Transfer (translocation) with in the soil*:*
  - e.g. movement of clay particles, **OM**, ions, etc from A to B-horizon
  - It can also be movement of materials from subsoil upwards

d. Transformations with in the soil:
  - Mineral & **OM** change their form & composition
  - The changes can be physical or chemical modification

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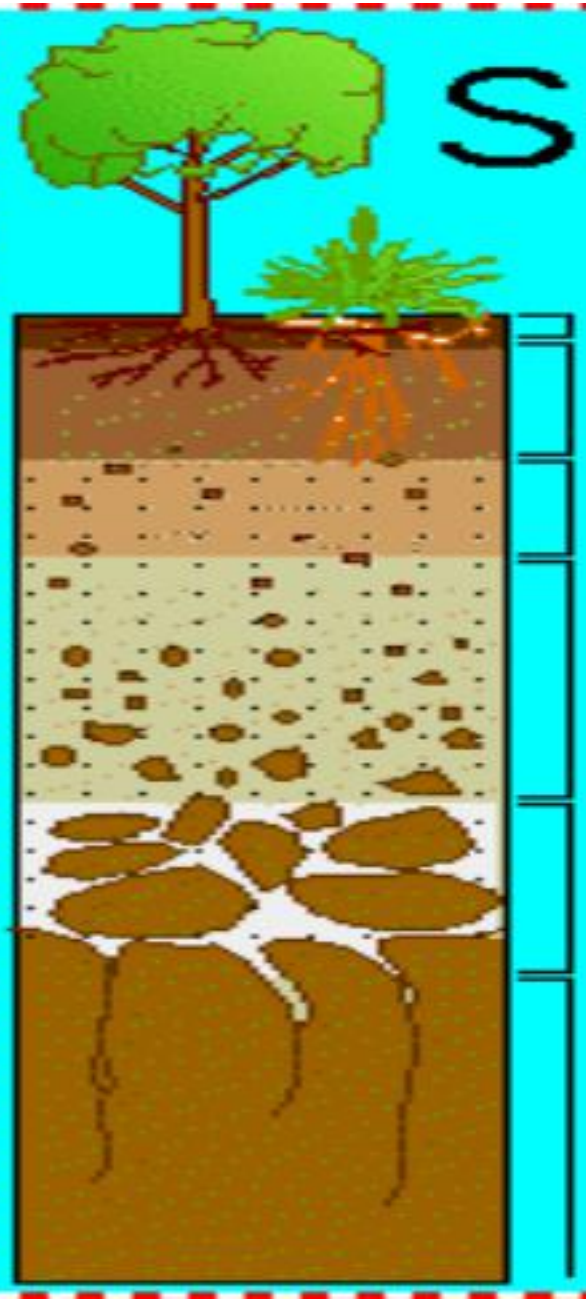
2.3 Soil Profile and Its Horizons

- **Soil profile** defined as a vertical section through the soil in the field
- A soil profile has a distinct morphological appearance that varies gradually with distance
- soil Profile develops through disintegration and synthesis of minerals & show layers approximately parallel to the soil's surface
- These layers, parallel to the ground surface, are termed as **soil horizons**

- Two overlapping trends can be identified in soil development:
  - **Horizonation** includes the processes and conditions by which initial materials are differentiated into soil profiles *with many horizons (layers of distinct characteristics)*
  - **Haploidization** includes processes and conditions by which horizonation is inhibited or decelerated or by which horizons are mixed or disturbed (*homogeneous type of profile)*.

soil horizons



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soil horizons : designated by the ABC system

- Five *master soil horizons* are recognized in a soil profile
- designated using the capital letters O, A, E, B, and C
- They are also sub divided in to smaller layers

***O*(*Organic) horizons**:*

- They form above the mineral soil as a result of litter derived from dead plants and animals
- occur commonly in forested areas and in grassland regions

***A(Admixture) horizon*:**

- is mineral horizon which lies at/near the surface
- It is a strong admixture of humified organic matter
- It is much darker than the underlying horizon

E (Eluvial) *horizon*:

- horizon of maximum **eluviation** (wash) of clay, Fe, Al (oxides)
- It is generally lighter in colour than the A

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B (Illuvial) *horizon*:

- horizon of **illuviation** from above or below has takes place.
- It is a region of maximum accumulation of Fe & Al oxides & silicate clays.
- In arid areas $CaCo_3$, $CaSo_4$ and other salts may accommodate in the lower B.

C- horizon:

- is the unconsolidated material underlying the solum (A and B)
- It is outside the zones of major biological activities
- little affected by solum forming processes

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2.3.1 Soil Terminologies

- **Soil profile:** A vertical section of the soil through all its horizons and extending into the parent material
- **Soil horizon:** A layer of soil, approximately parallel to the soil surface, differing in properties and characteristics from adjacent layers below or above it
- **Solum:** The upper and most weathered part of the soil profile; the A,E, and B horizons
- **Regolith:** The unconsolidated mantel of weathered rock and soil material on the earth's surface lossen earth materials above solid rock
- **Top soil:** The layer of soil moved in cultivation. When a soil is plowed and cultivated, the upper 12 to 25 cm
- **Sub soil:** The B horizons of soils with distinct profiles
- **Pedon:** The smallest volume that can be called a soil .It has three dimensions. It extends downward to the depth of plant roots or to the lower limit of the genetic horizons.

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