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ASAC 1101 : FUNDAMENTALS OF SOIL SCIENCE (2+1)

Level : B.Sc (Ag), I semester

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Topic

Soil formation-Fundamental and specific Soil forming factors

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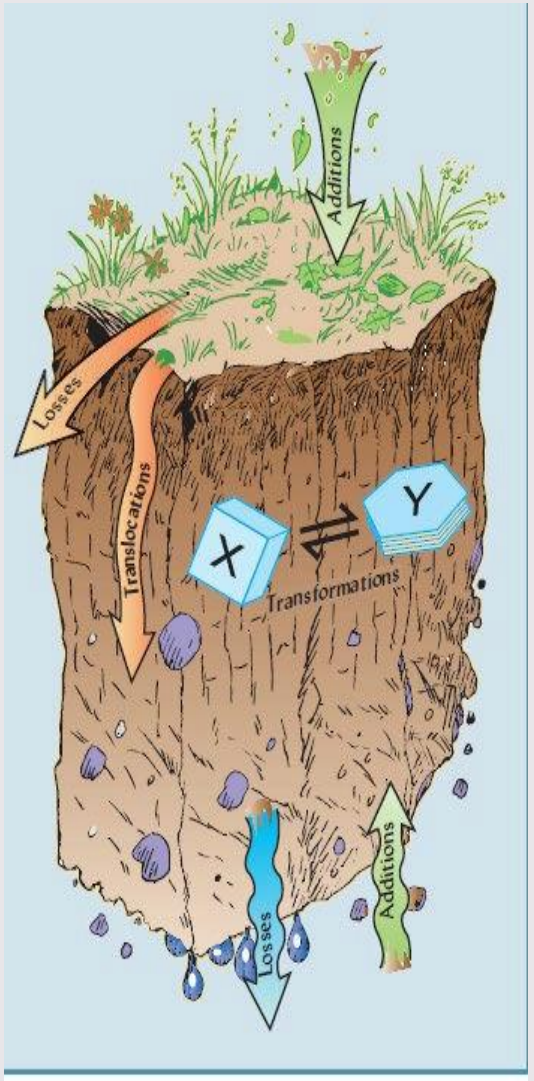
Soil formation

Soil formation is brought about by four basic pedogenic processes

- ❑ **Additions**
- ❑ **Losses**
- ❑ **Transformations**
- ❑ **Translocations**



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Additions

- Input of materials to the developing soil profiles from outside sources
  - Rain adds water
  - Dust adds minerals
  - Animals add nutrients and organic matter
  - Humans add fertilizers
  - Evaporation of groundwater adds salts

https://gardeningandhome.com/fallen-leaves-garden-gold-not-enemy/

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Losses

- Evaporation carries away water
- Erosion carries away soil particles
- Organic matter decomposes
- Nutrients and minerals leach

Clemson university

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Carla staver

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Transformations

- Process of modification and/or destruction of existing soil components
- Results in synthesis of new products
  - Weathering synthesizes secondary minerals from primary
  - Weathering alters size of minerals
  - Dead leaves transform to humus

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Translocations

- Horizontal or vertical movement of materials
  - Water translocated by gravity or capillary action
  - Evaporation translocates salts to surface
  - Organisms carry materials from one place to another

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B. Specific Soil Forming Processes

The basic pedologic processes provide a framework for later operation of more specific processes

Calcification

It is the process of precipitation and accumulation of calcium carbonate ($CaCO_3$) in some part of the profile. The accumulation of $CaCO_3$ may result in the development of a calcic horizon. Calcium is readily soluble in acid soil water and/or when CO_2 concentration is high in root zone as:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + Ca \rightarrow Ca(HCO_3)_2 \text{ (soluble)}$$

$$\xrightarrow{\text{Temp.}}$$

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2 \text{ (precipitates)}$$

$$\downarrow$$

$$CO_2$$

The process of precipitation after mobilization under these conditions is called calcification and the resulting illuviated horizon of carbonates is designated as Bk horizon (Bca).

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Podzolization

It is a process of soil formation resulting in the formation of Podzols and Podzolic soils.

In many respects, podzolization is the negative of calcification. The calcification process tends to concentrate calcium in the lower part of the B horizon, whereas podzolization leaches the entire solum of calcium carbonates.

Apart from calcium, the other bases are also removed and the whole soil becomes distinctly acidic. In fact, the process is essentially one of acid leaching.

The process operates under favorable combination of the following environments.

i) **Climate:** A cold and humid climate is most favorable for podzolization.

ii) **Parent material:** Siliceous (Sandy) material, having poor reserves of weatherable minerals, favor the operation of podzolization as it helps in easy percolation of water.

iii) **Vegetation:** Acid producing vegetation such as coniferous pines is essential

iv) **Leaching and Translocation of Sesquioxide:** In the process of decomposition of organic matter various organic acids are produced. The organic acids thus formed act with Sesquioxide and the remaining clay minerals, forming organic- Sesquioxide and organic clay complexes, which are soluble and move with the percolating water to the lower horizons (Bh, Bs).

Aluminium ions in a water solution hydrolyze and make the soil solution very acidic.

$$2Al + 6H_2O \longrightarrow 2\,Al(OH)_3 + 6H^+$$

As iron and aluminium move about, the A horizon gives a bleached grey or ashy appearance. The Russians used the term Podzols (pod means under, the zola means ash like i.e. ash-like horizon appearing beneath the surface horizon) for such soils.

To conclude, the Podzolization is a soil forming process which prevails in a cold and humid climate where coniferous and acid forming vegetations dominate. The humus and Sesquioxide become mobile and leached out from the upper horizon s and deposited in the lower horizon.

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Laterization

The term laterite is derived from the word later meaning brick or tile and was originally applied to a group of high clay Indian soils found in Malabar hills of Kerala, Tamil Nadu, Karnataka and Maharashtra.

It refers specifically to a particular cemented horizon in certain soils which when dried, become very hard, like a brick. Such soils (in tropics) when massively impregnated with sesquioxides (iron and aluminium oxides) to extent of 70 to 80 per cent of the total mass, are called laterites or latosols (Oxisols). The soil forming process is called Laterization or
Latozation.

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Laterization is the process that removes silica, instead of sesquioxides from the upper layers and thereby leaving sesquioxides to concentrate in the solum. The process operates under the following conditions.

i) Climate

Unlike podzolization, the process of laterization operates most favorable in warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature (25°C) throughout the year.

ii) Natural vegetation

The rain forests of tropical areas are favorable for the process.

iii) Parent Material

Basic parent materials, having sufficient iron bearing ferromagnesian minerals (Pyroxene, amphiboles, biotite and chlorite), which on weathering release iron, are congenial for the development of laterites.

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Gleization

The term *glei* is of Russian origin means blue, grey or green clay. The Gleization is a process of soil formation resulting in the development of a glei (or gley horizon) in the lower part of the soil profile above the parent material due to poor drainage condition (lack of oxygen) and where waterlogged conditions prevail. Such soils are called hydro orphic soils. The process is not particularly dependent on climate (high rainfall as in humid regions) but often
on drainage conditions.

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6. Salinization

It is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of a salty (salic) horizon. It is quite common in arid and semi arid regions. It may also take place through capillary rise of saline ground water and by inundation with seawater in marine and coastal soils. Salt accumulation may also result from irrigation or seepage in areas of impeded drainage.

7. Desalinization

It is the removal by leaching of excess soluble salts from horizons or soil profile (that contained enough soluble salts to impair the plant growth) by ponding water and improving the drainage conditions by installing artificial drainage network.

8. Solonization or Alkalization

The process involves the accumulation of sodium ions on the exchange complex of the clay, resulting in the formation of sodic soils (Solonetz).

All cations in solution are engaged in a reversible reaction with the exchange sites on the clay and organic matter particles.

The reaction can be represented as

$$Ca.Mg.2NaX \longrightarrow Ca^{++} + Mg^{++} + 2Na^{+} + x^{-6} + 3CO_3^{2-} \longrightarrow Na_2CO_3 + MgCO_3 + CaCO_3$$

(Where X represents clay or organic matter exchange sites)

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Solodization or dealkalization

The process refers to the removal of Na^{+} from the exchange sites. This process involves dispersion of clay. Dispersion occurs when Na^{+} ions become hydrated.

Much of the dispersion can be eliminated if Ca^{++} and or Mg^{++} ions are concentrated in the water, which is used to leach the soonest. These Ca and Mg ion can replace the Na on exchange complex, and the salts of sodium are leached out as :

$$2NaX + CaSO_4 \longrightarrow Na_2SO_4 + CaX$$

(leachable)

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10. Pedoturbation

Another process that may be operative in soils is pedoturbation. It is the process of mixing of the soil.

Mixing to a certain extent takes place in all soils. The most common types of pedoturbation are:

- **Faunal pedoturbation:** It is the mixing of soil by animals such as ants, earthworms, moles, rodents, and man himself
- **Floral pedoturbation :** It is the mixing of soil by plants as in tree tipping that forms pits and mounds
- **Argillic pedoturbation:** It is the mixing of materials in the solum by the churning process caused by swell shrink clays as observed in deep Black Cotton Soils.

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Factors affecting soil formation processes

- Similar environmental conditions yield similar soils
- clorpt equation of soil formation developed by Jenny, 1941

$$S_i = f(cl, o, r, p, t)$$

where S_i = soil property, cl = climate, o = organisms, r = relief, p = parent, materials, t = time

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Factors affecting soil formation

CLimate

Organism

Relief

Parent material

Time

The soil we see is a function of five factors

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Factors affecting soil formation

- The factors themselves act interdependently on soil
- Sometimes however, one particular factor predominates, others being constant

Dominating factor	Soil type
Climate	Climosequence
Organism	Biosequence
Relief	Toposequence
Parent material	Lithosequence
Time	Chronosequence

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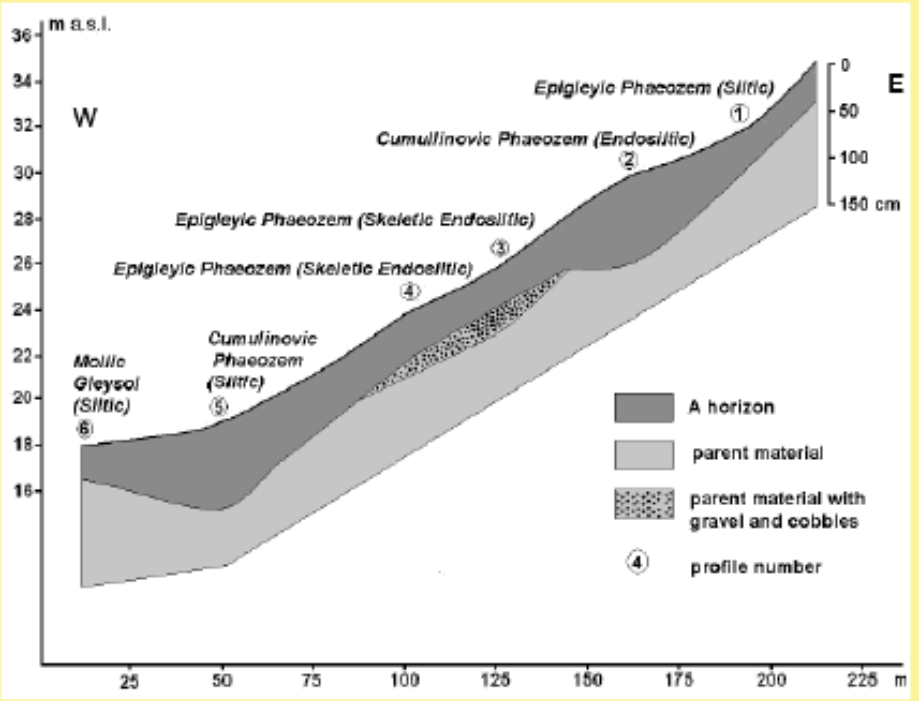
Toposequence

- Adjacent soils that show differing profile characteristics reflecting the influence of local topography are called **toposequences.**



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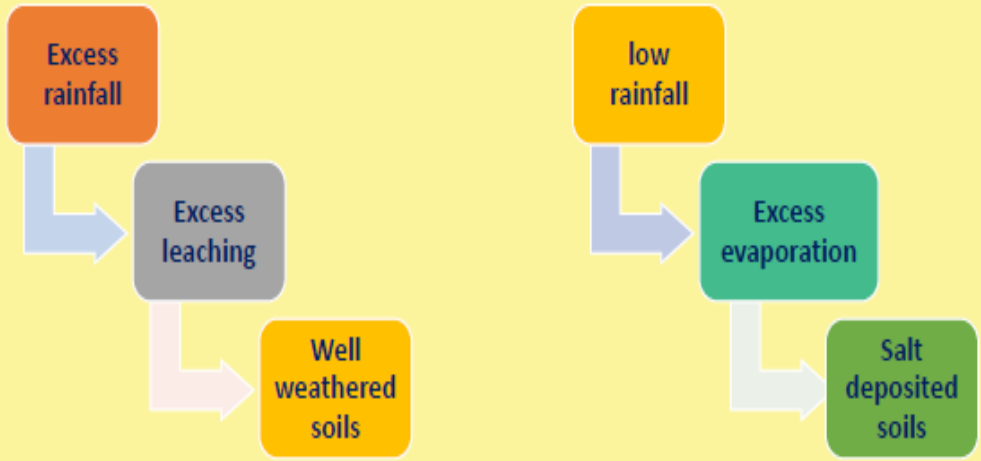
Climate - precipitation

- Most influential factor – affects weathering
- Effective precipitation and temperature - two major climate factors



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Climate - precipitation

A highly leached podzol

Salt affected arid soils

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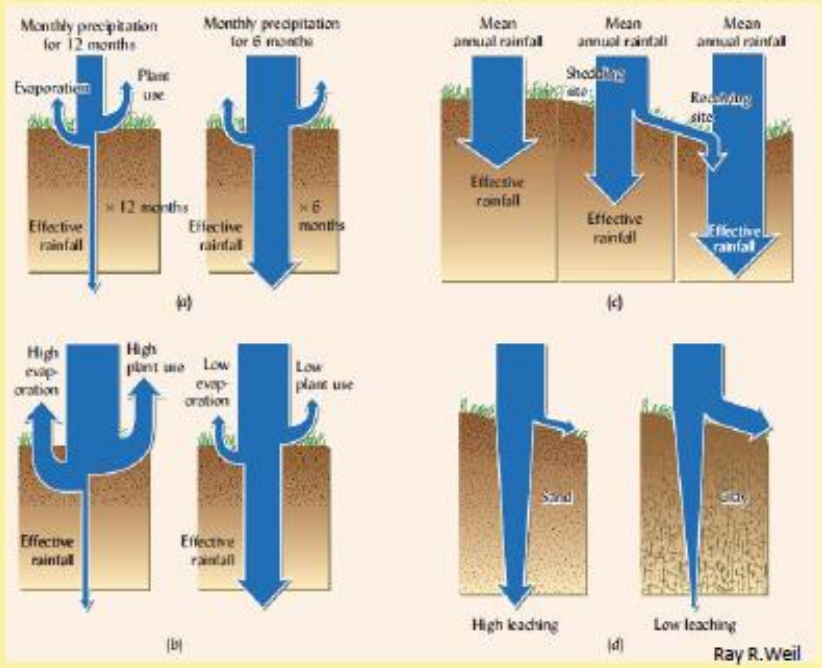
Climate - precipitation

(a) Seasonal rainfall distribution (c) Site topography



(b) Evaporative demand (d) Soil permeability

Keeping other factors constant, increasing precipitation increases clay, organic matter content and acidity

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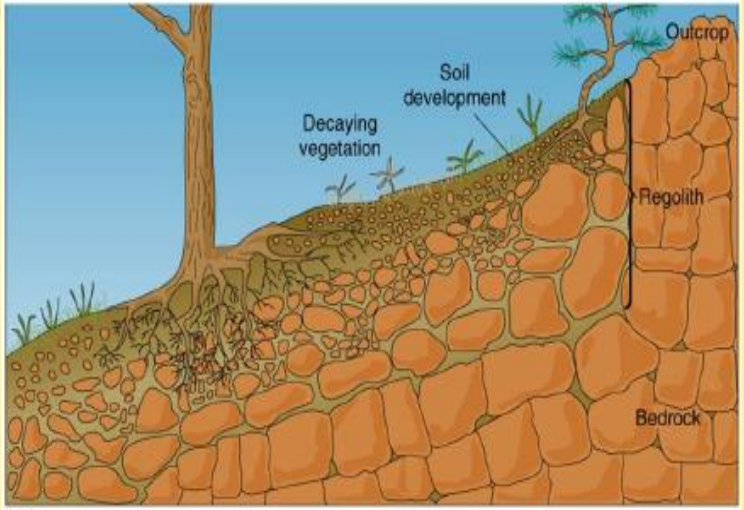
Regolith

Soils and Regolith



(a)

A region of loose unconsolidated rock and dust that sits atop a layer of bedrock

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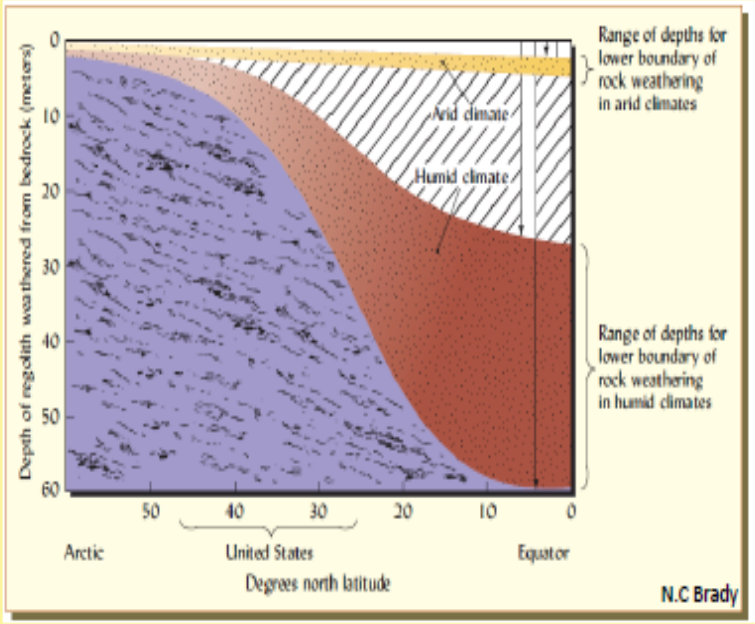
Climate - temperature

- Microbial activity is enhanced at high temperatures

High temperatures + high effective rainfall $\xrightarrow{\text{microbes}}$ high weathering



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Organisms

- Microbes enhance biochemical weathering
- Vegetative cover reduces erosion
- Dead leaves accumulate Al and Fe
- Vegetation influences the soil type and vice versa

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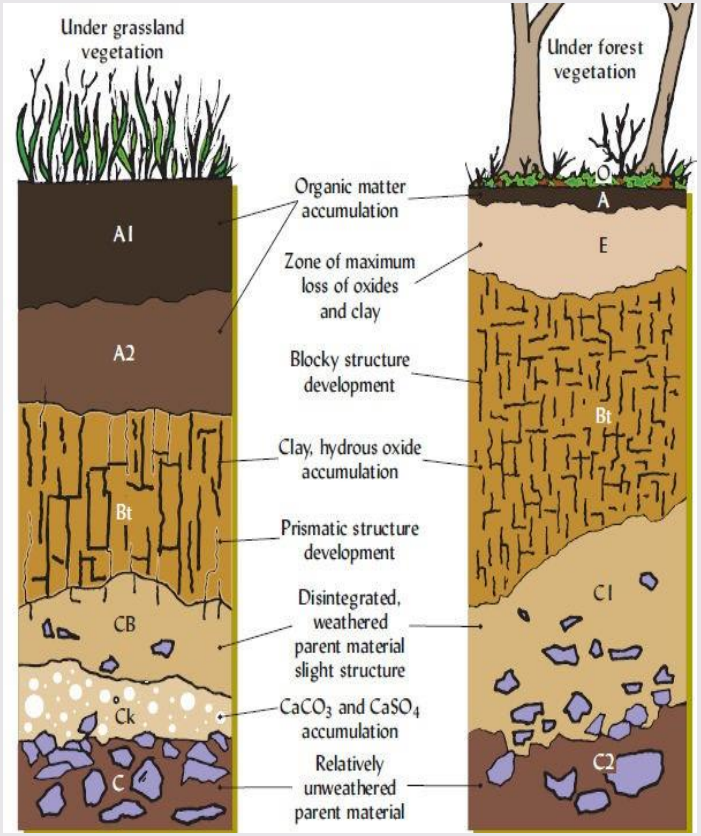
Organisms - vegetation



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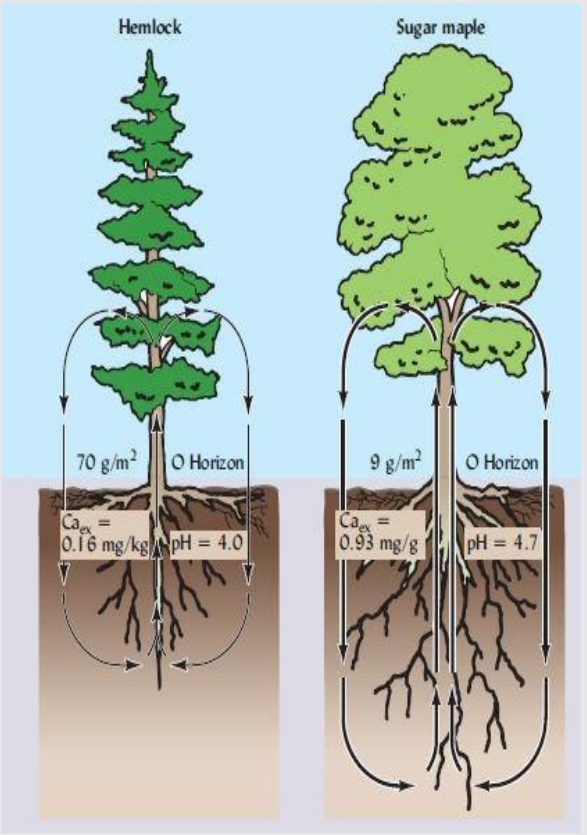

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Organisms - animals

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https://www.no-tillfarmer.com

- Pedoturbation – mixing activities of animals
- Enhances weathering

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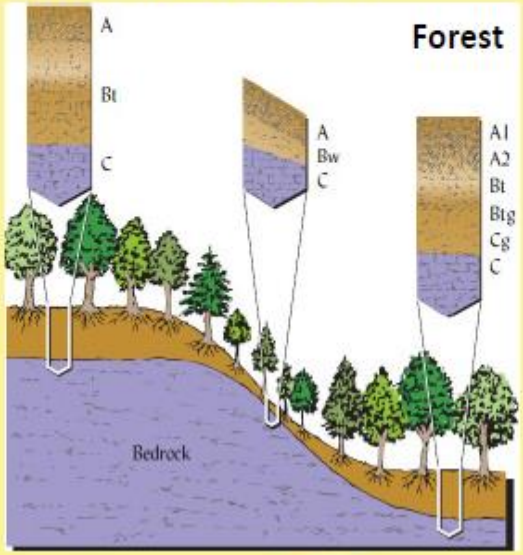
Topography

- Topography – configuration of land surface in terms of elevation, slope and landscape position



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Topography

- Depressed areas experience high weathering
- South facing slopes tend to be warmer, hence more weathering
- Low lying arid areas have high salt buildup

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Parent materials

- Soils greatly resemble their parent material

Eg: sandy soils often develop from granite or sandstone

- The mineralogical composition of parent materials influence the physical and chemical weathering.

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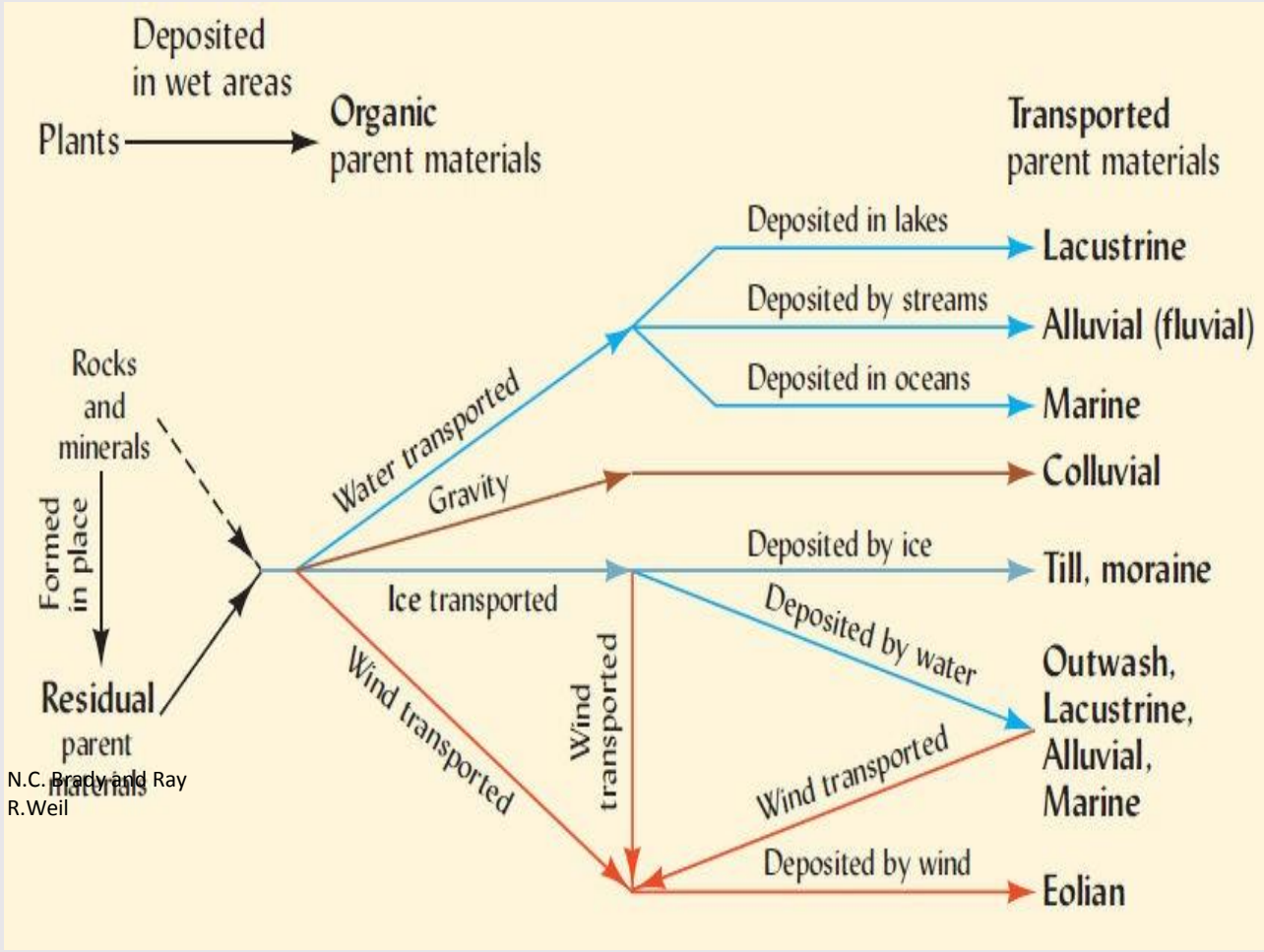
Types of parent materials

Parent materials are classified based on their mode of placement in their current location



N.C. Brady and Ray R.Weil

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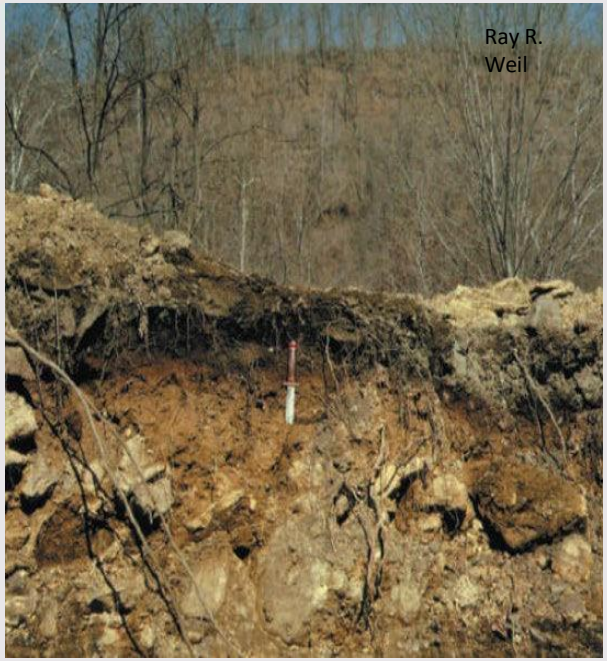
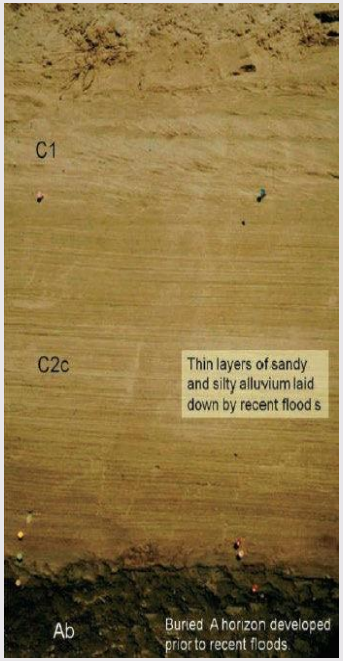
Types of parent material



Colluvial parent material



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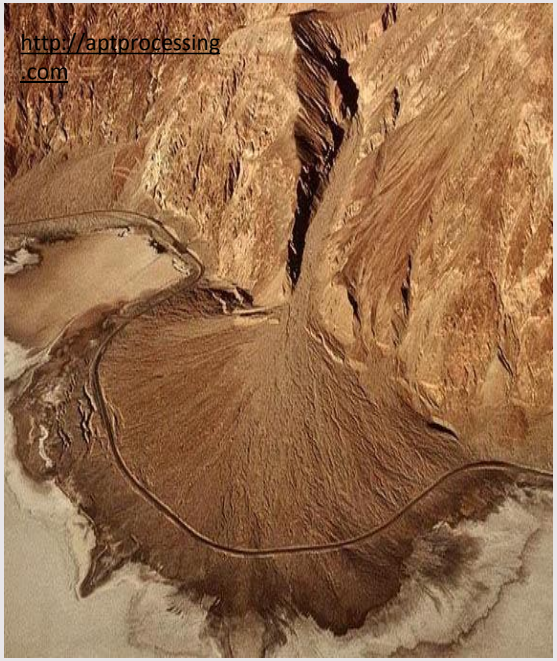
Flood plains



Alluvial fans

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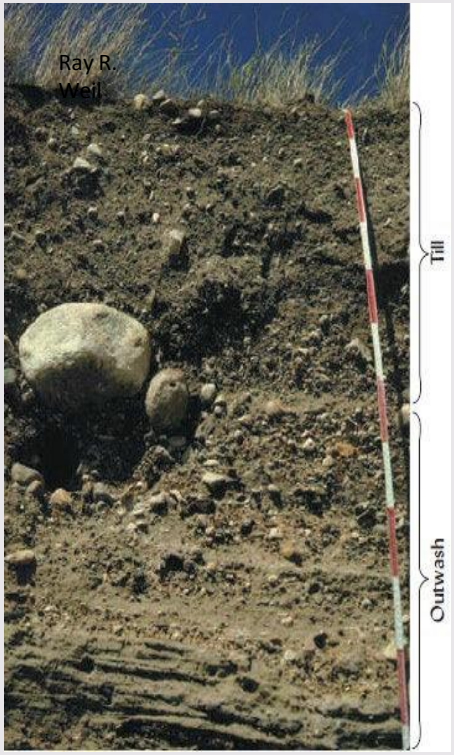
Types of parent materials



Glacial till

Loess

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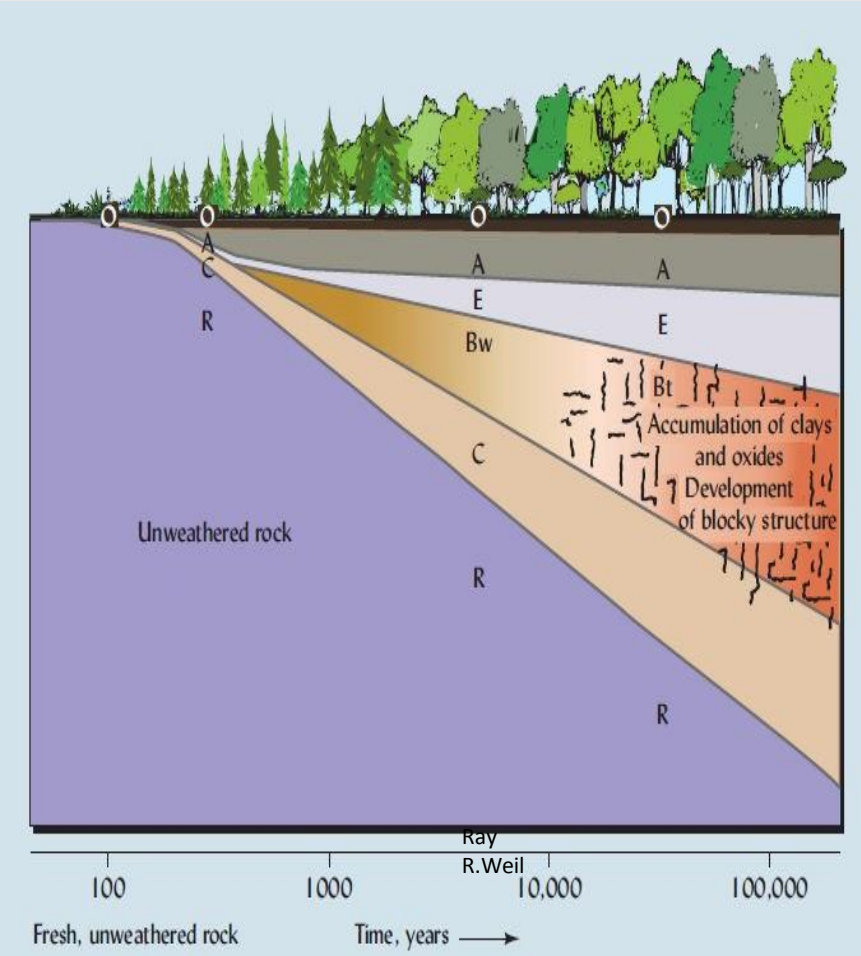
Time



- Younger soils tend to have properties of their parent material
- As they age, they tend to change, sometimes, to a different soil type

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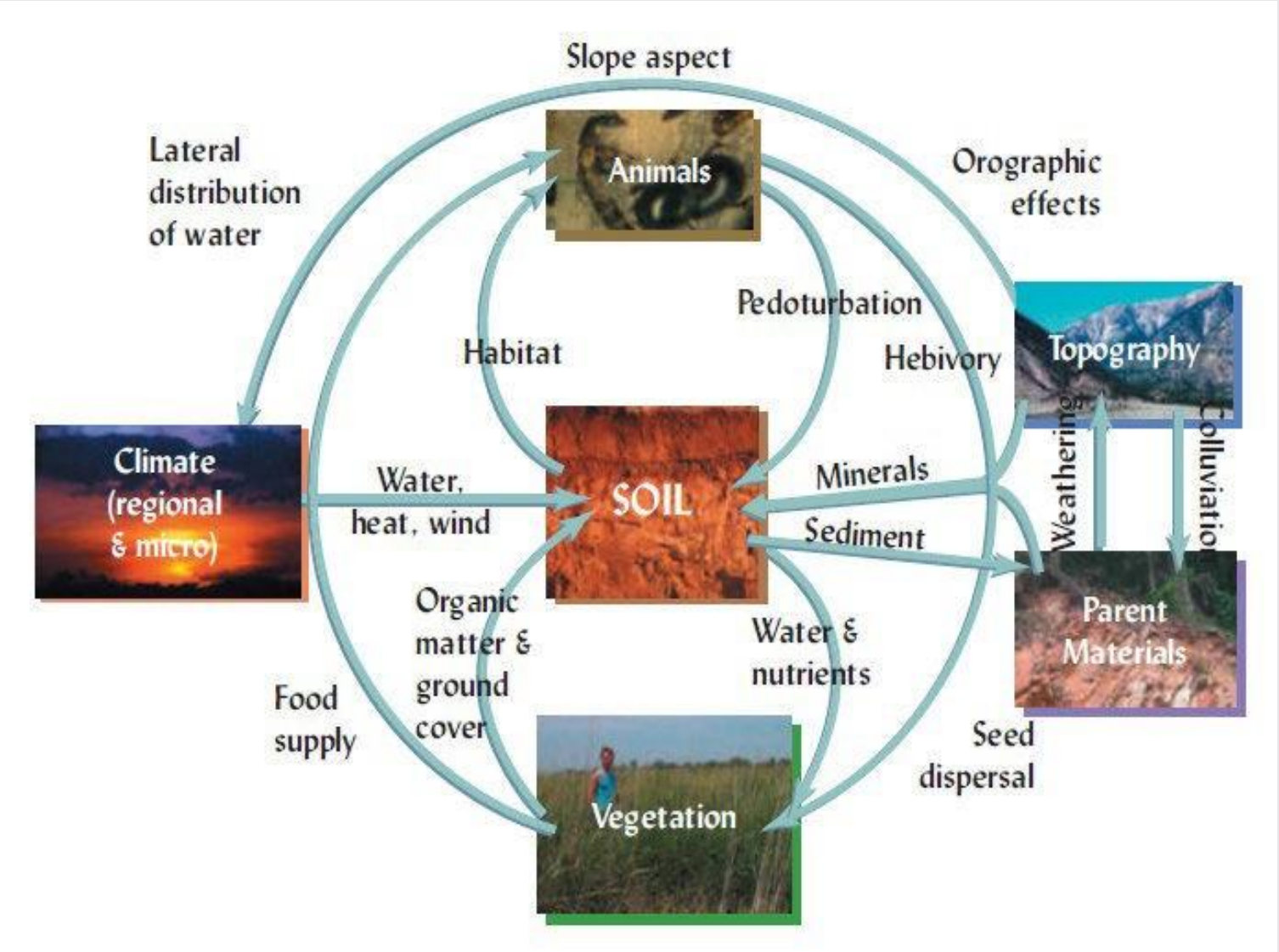
Summary of soil forming factors



Monger and Bestelmyer (2006)

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End of session