Bioecology
Module: Soil Science

Lecture 3.
Soil formation factors and processes

Lovinskaya Anna Vladimirovna
PhD, Senior lecturer
Department of molecular biology
and genetics

Soil formation factors and processes

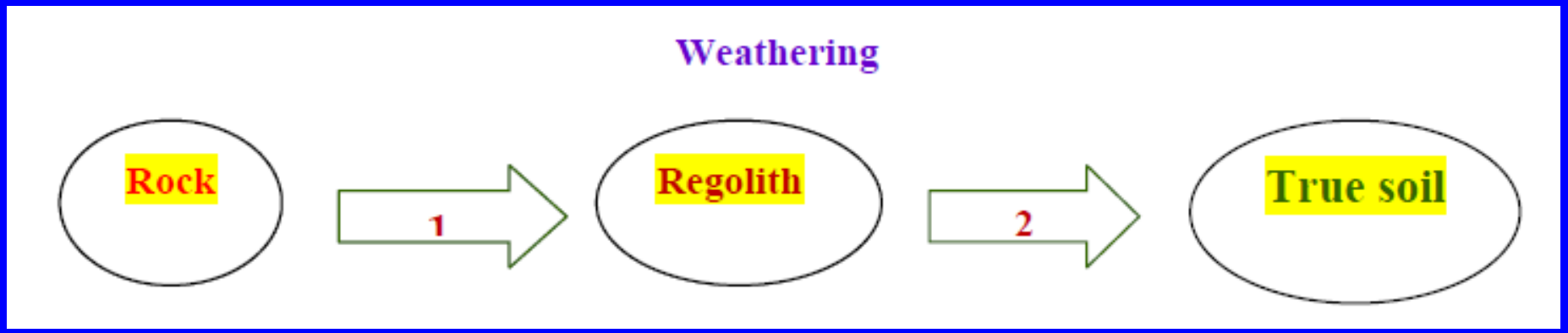
The soil formation is the process of two consecutive stages.

1. The weathering of rock (R) into Regolith

2. The formation of true soil from Regolith

The evolution of true soil from regolith takes place by the combined action of soil forming factors and processes.

- The first step is accomplished by weathering (disintegration & decomposition)
- The second step is associated with the action of Soil Forming Factors



Factors

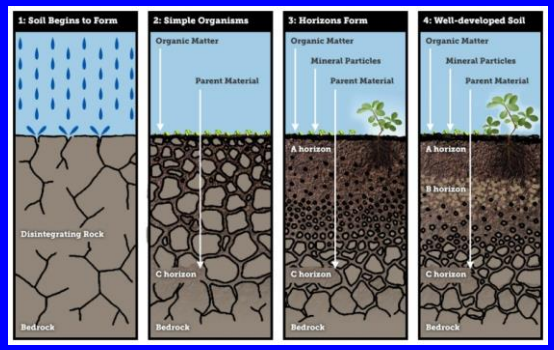
Dokuchaiev (1889) established that the soils develop as a result of the action of soil forming factors:

S = f (P, Cl, O)

Further, Jenny (1941) formulated the following equation:

S = f (Cl, O, R, P, T, …)

Where,
Cl – environmental climate (active factor);
O – Organisms and vegetation (biosphere) (active factor);
R – Relief or topography (passive factor);
P – Parent material (passive factor);
T- Time (passive factor);
… - additional unspecified factors



The five soil forming factors, acting simultaneously at any point on the surface of the earth, to produce soil.

Parent Material

Parent Material - is mass (consolidated material) from which the soil has formed.

Two groups of parent material:

- ✓ Sedentary - Formed in original place. It is the residual parent material. The parent material differ as widely as the rocks
- ✓ Transported The parent material transported from their place of origin. They are named according to the main force responsible for the transport and redeposition:

a) by gravity - Colluvial
b) by water – Alluvial (river), Marine (sea), Locustrine (lak
c) by ice - Glacial
d) by wind - Eolian

The soils developed on such transported parent materials bear the name of the parent material; viz. Alluvial soils from alluvium, colluvial soils from colluvium etc. In the initial stages, however, the soil properties are mainly determined by the kind of parent material.

Soil properties as influenced by parent material: Different parent materials affect profile development and produce different soils, especially in the initial stages.

✓ Acid igneous rocks (like granite, rhyolite) produce light-textured soils (Alfisols).

✓ Basic igneous rocks (basalt), alluvium or colluvium derived from limestone or basalt, produce fine-textured cracking-clay soils (Vertisols).

Alfisols

Vertisol

✓Basic alluvium or aeolian materials produce fine to coarse-textured soils (Entisols or Inceptisols)

✓The nature of the elements released during the decaying of rocks has a specific role in soil formation. (e.g.) Si and Al forms the skeleton for the production of secondary clay minerals.

✓Iron and manganese are important for imparting red colour to soils and for oxidation and reduction phenomena.

✓ Sodium and potassium are important dispersing agents for day and humus colloids.

✓ Calcium and magnesium have a flocculating effect and result in favorable and stable soil structure for plant growth.

Entisol

Inceptisol

Soil formation factors and process

2. Relief or Topography

They denote the configuration of the land surface.
Topography refers to the configuration of the land surface described in four categories:

- the major landform, which refers to the morphology of the whole landscape;
- the position of the site within the landscape;
- the slope form;
- the slope angle.

Hierarchy of major landforms

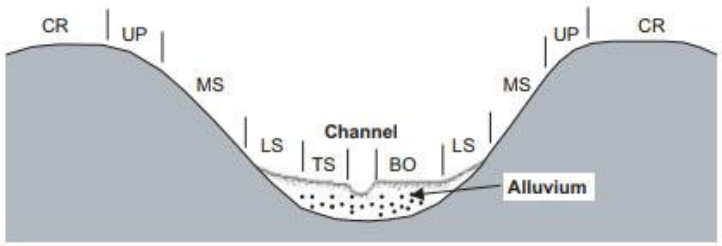
1st level	2nd level	Gradient (%)	Relief intensity (m km^{-1})	Potential drainage density
L level land	LP plain	< 10	< 50	0–25
	LL plateau	< 10	< 50	0–25
	LD depression	< 10	< 50	16–25
	LV valley floor	< 10	< 50	6–15
S sloping land	SE medium-gradient escarpment zone	10–30	50–100	< 6
	SH medium-gradient hill	10–30	100–150	0–15
	SM medium-gradient mountain	15–30	150–300	0–15
	SP dissected plain	10–30	50–100	0–15
	SV medium-gradient valley	10–30	100–150	6–15
T steep land	TE high-gradient escarpment zone	> 30	150–300	< 6
	TH high-gradient hill	> 30	150–300	0–15
	TM high-gradient mountain	> 30	> 300	0–15
	TV high-gradient valley	> 30	> 150	6–15

Subdivisions for complex landforms

CU	= Cuesta-shaped	DO	= Dome-shaped
RI	= Ridged	TE	= Terraced
IN	= Inselberg covered (occupying > 1% of level land)	DU	= Dune-shaped
IM	= With intermontane plains (occupying > 15%)	KA	= Strong karst
WE	= With wetlands (occupying > 15%)		

Source: Updated SOTER, ISRIC, 2005.

FIGURE 2
Slope positions in undulating and mountainous terrain



Note:

Position in undulating to mountainous terrain

CR	= Crest (summit)
UP	= Upper slope (shoulder)
MS	= Middle slope (back slope)
LS	= Lower slope (foot slope)
TS	= Toe slope
BO	= Bottom (flat)

Position in flat or almost flat terrain

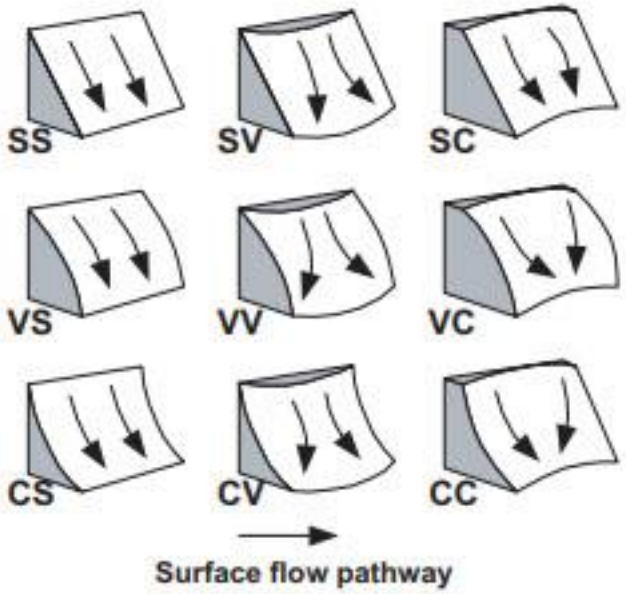
HI	= Higher part (rise)
IN	= Intermediate part (talf)
LO	= Lower part (and dip)
BO	= Bottom (drainage line)

Source: Redrawn from Schoeneberger *et al.*, 2002.

Classification of slope forms

S	straight
C	concave
V	convex
T	terraced
X	complex (irregular)

Slope forms and surface pathways



Source: Redrawn from Schoeneberger *et al.*, 2002.

Slope gradient classes

Class	Description	%
01	Flat	0–0.2
02	Level	0.2–0.5
03	Nearly level	0.5–1.0
04	Very gently sloping	1.0–2.0
05	Gently sloping	2–5
06	Sloping	5–10
07	Strongly sloping	10–15
08	Moderately steep	15–30
09	Steep	30–60
10	Very steep	> 60

Soil formation on flat to almost flat position.

They have normal solum with distinct horizons. But vast and monotonous level land with little gradient often has impaired drainage conditions.

Soil formation on undulating topography.

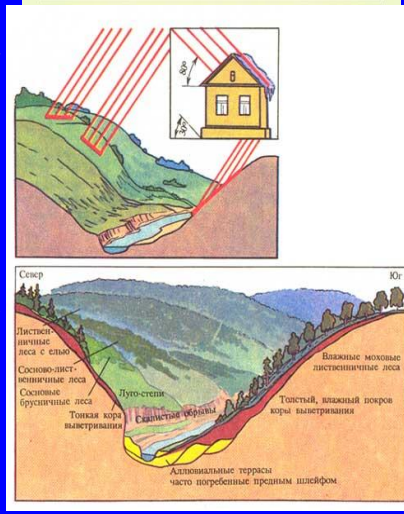
The soils on steep slopes are generally shallow, stony and have weakly- developed profiles with less distinct horizonation.

Soil formation in depression.

The depression areas in semi-arid and sub humid regions reflect more moist conditions than actually observed on level topographic positions due to the additional water received as runoff. Such conditions favour more vegetative growth and slower rate of decay of organic remains. This results in the formation of comparatively dark-coloured soils rich in organic matter (Mollisols).

Soil formation and Exposure/ Aspect.

The southern exposures are warmer and subject to marked fluctuations in temperature and moisture. The northern exposures, on the other hand are cooler and more humid. The eastern and western exposures occupy intermediate position in this respect.



Soil formation factors and process

3. Time.

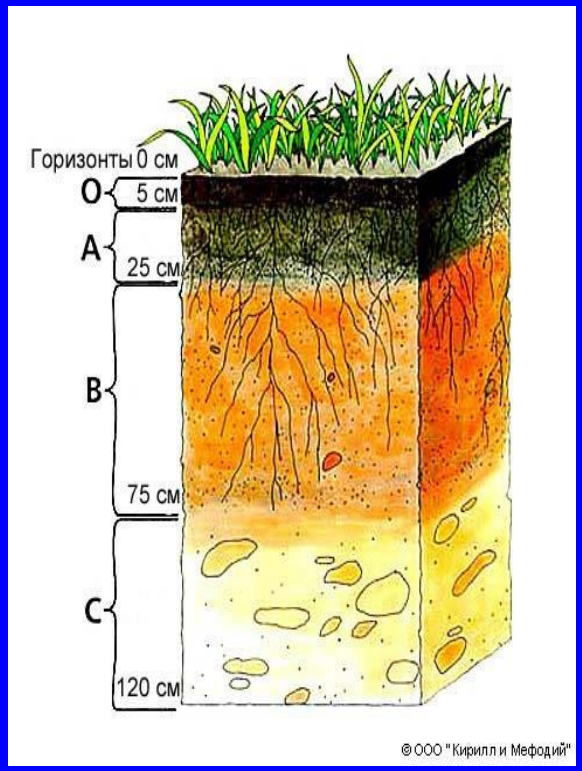
Soil formation is a very slow process requiring thousands of years to develop a mature pedon. The period taken by a given soil from the stage of weathered rock (i.e. regolith) up to the stage of maturity is considered as **Pedologic time**. The **matured soils** mean the soils with fully developed horizons (A, B, C). It takes hundreds of years to develop an inch of soil.

Rocks and minerals disintegrate and/or decompose at different rates

The soil properties also change with time, for instance nitrogen and organic matter contents increase with time provided the soil temperature is not high.

$CaCO_3$ content may decrease or even lost with time provided the climatic conditions are not arid

In humid regions, the H+ concentration increases with time because of chemical weathering.



Soil formation factors and process

Active Soil Forming Factors

The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation.

1. Climate

Climate is the most significant factor controlling the type and rate of soil formation.

Climate

Directly

It affects the soil formation by supplying water and heat to react with parent material.

Indirectly

It determines the fauna and flora activities which furnish a source of energy in the form of organic matter.

Major climatic elements

Precipitation

brings about a redistribution of substances both soluble as well as in suspension in soil body.

Temperature

controls the rate of chemical and biological reactions taking place in the parent material.

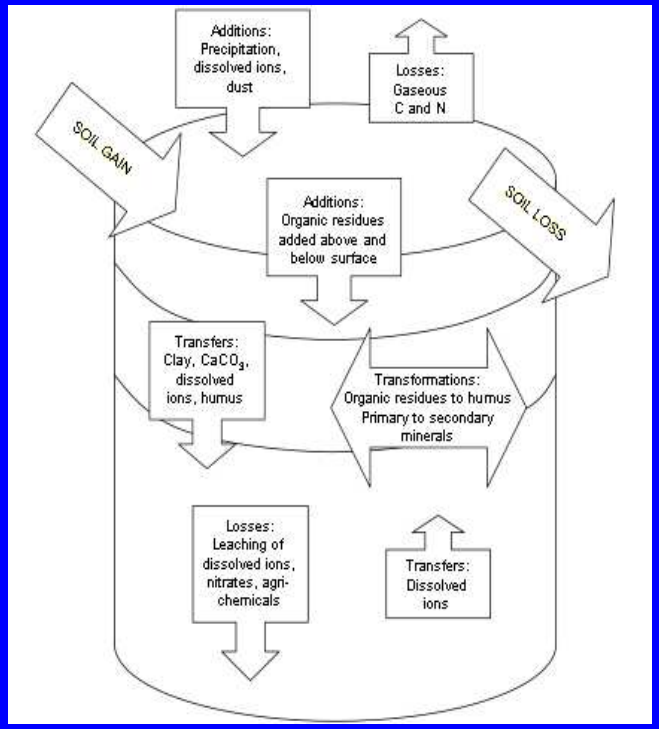
Jenney (1941) computed that in the tropical regions the rate of weathering proceeds three times faster than in temperate regions and nine times faster than in arctic.

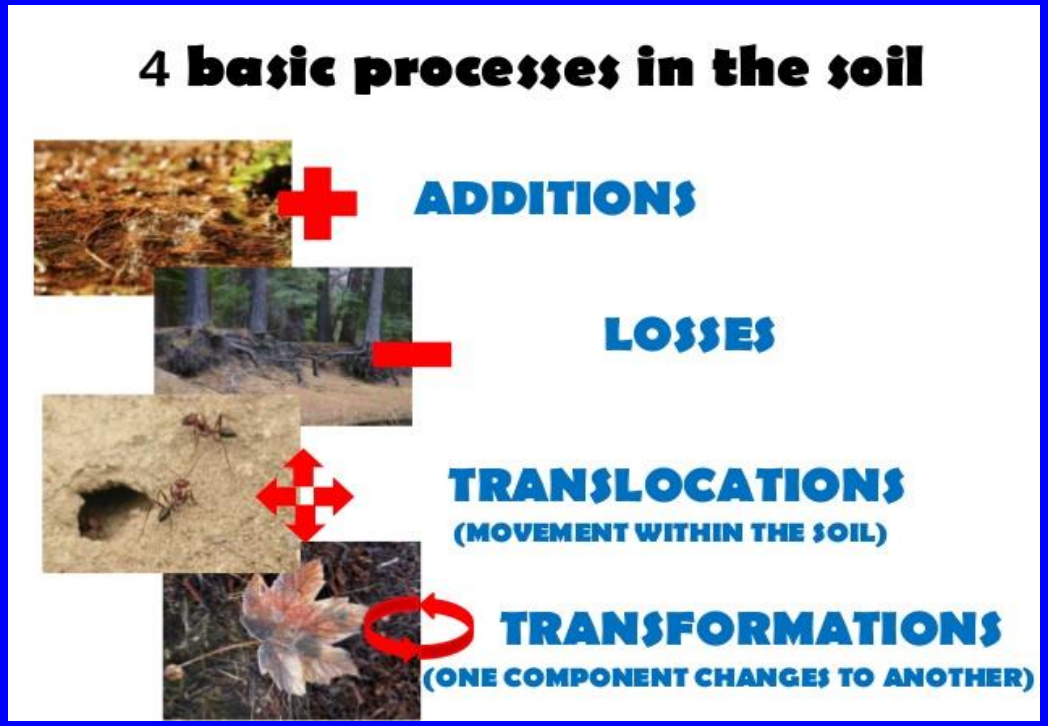
Soil Forming Processes

The basic process involved in soil formation (Simonson, 1959) includes the following:
- Gains or Additions of water, mostly as rainfall, organic and mineral matter to the soil.
- Losses of the above materials from the soil.
- Transformation of mineral and organic substances within the soil.
- Translocation or the movement of soil materials from one point to another within the soil.

It is usually divided into

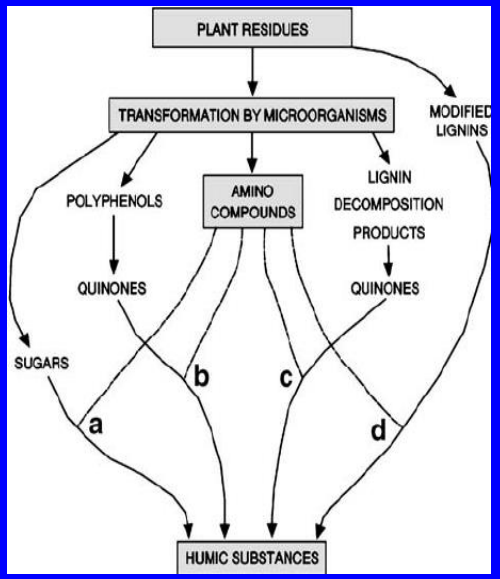
- movement of solution (leaching) and
- movement in suspension (eluviation) of clay, organic matter and hydrous oxides





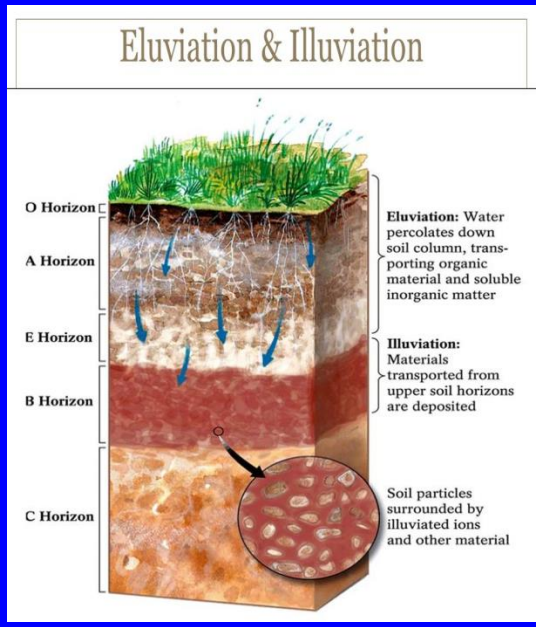
A. Fundamental Soil forming Processes:

Humification is the process of transformation of raw organic matter into humus. It is extremely a complex process involving various organisms.



Eluviation is the mobilization and translocation of certain constituent's viz. Clay, Fe_2O_3, Al_2O_3, SiO_2, humus, $CaCO_3$, other salts etc. from one point of soil body to another. Eluviation means washing out. It is the process of removal of constituents in suspension or solution by the percolating water from the upper to lower layers. The horizon formed by the process of eluviation is termed as eluvial horizon (A2 or E horizon).

Illuviation is the process of deposition of soil materials (removed from the eluvial horizon) in the lower layer (or horizon of gains having the property of stabilizing translocated clay materials). The horizons formed by this process are termed as illuvial horizons (B-horizons, especially Bt) The process leads to textural contrast between E and Bt horizons, and higher fine: total clay ratio in the Bt horizon.

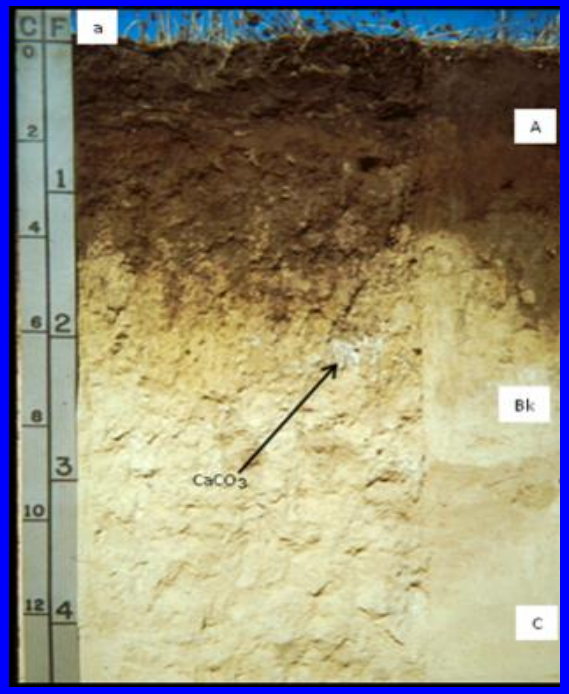


Horizonation is the process of differentiation of soil in different horizons along the depth of the soil body. The differentiation is due to the fundamental processes, humification, eluviation and illuviation.

B. Specific Soil Forming Processes

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

Calcification 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. 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).



Decalcification is the reverse of calcification that is the process of removal of $CaCO_3$ or calcium ions from the soil by leaching.

Podzolization encompasses the downward migration of Al and Fe, together with organic matter, from the surface areas and their accumulation in the profile's deep areas. This process is characterised by a strong acidity (leaching) that causes the slow development of organic matter and an extreme alteration of the mineral phase. It is a process of soil formation resulting in the formation of Podzols and Podzolic soils.

B. Specific Soil Forming Processes

Laterization (Latozation) is the process that removes silica, instead of sesquioxides from the upper layers and thereby leaving sesquioxides to concentrate in the solum. 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% of the total mass, are called laterites or latosols (Oxisols).

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.

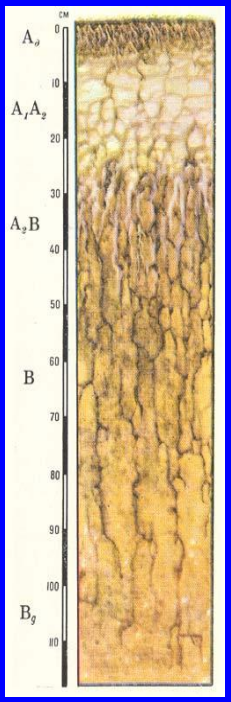
Salinization is the process of accumulation of salts, such as sulphates and chlorides of calcium, magnesium, sodium and potassium, in soils in the form of a salty (salic) horizon. It is quite common in arid and semi arid regions. It may also take place through saline ground water and by inundation with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

B. Specific Soil Forming Processes

Desalinization 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.

Solonization or Alkalization is 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.

Solodization or dealkalization is 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 solonest.



Pedoturbation 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,
- Floral pedoturbation,
- Argillic pedoturbation (the mixing of materials in the solum by the churning process caused by swell shrink clays as observed in deep Black Cotton Soils).

Thank you for attention!