FAKTOR PEMBENTUK TANAH

$$S = f\,(cl,\ r,\ o,\ p,\ t)$$

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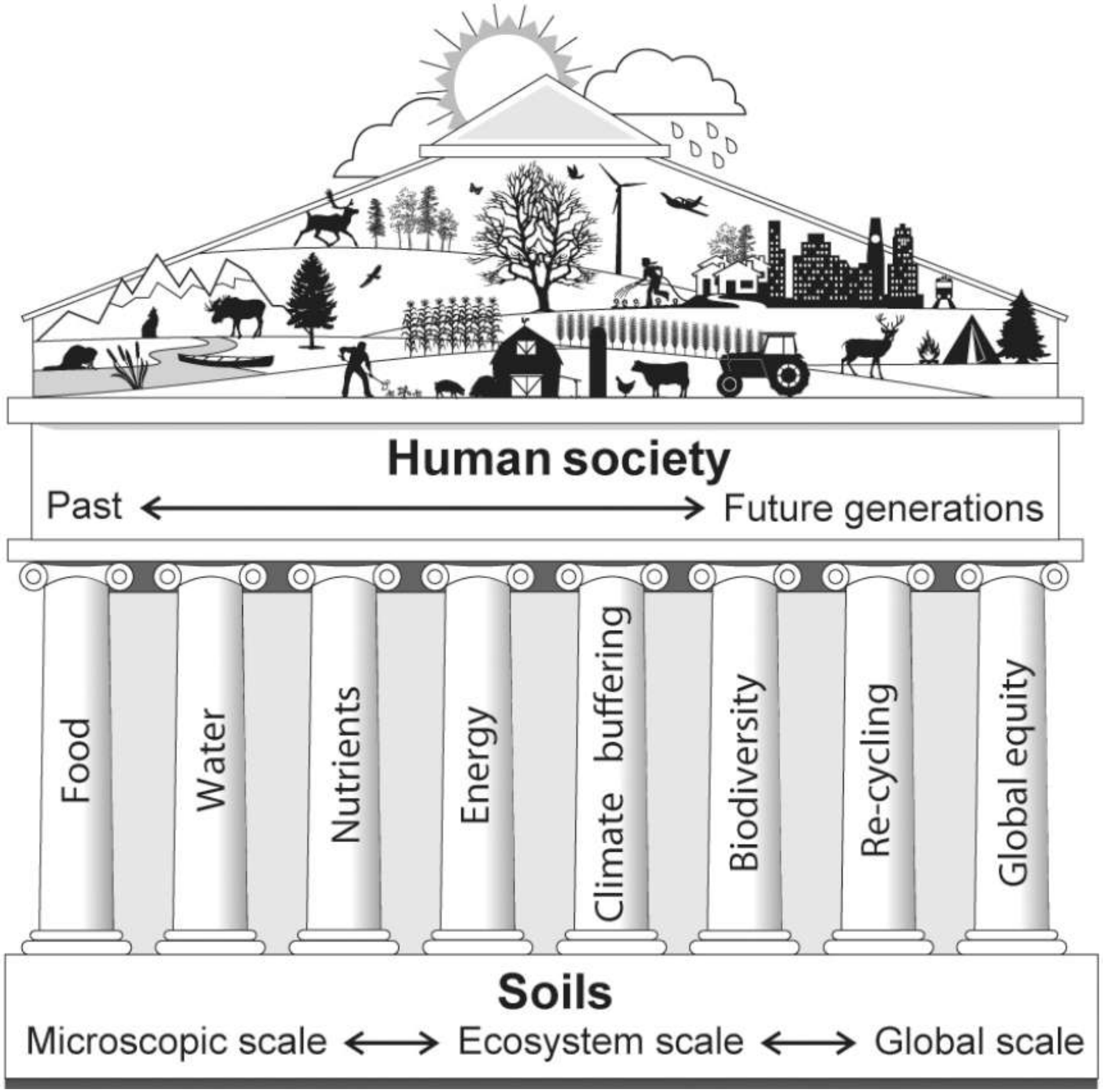
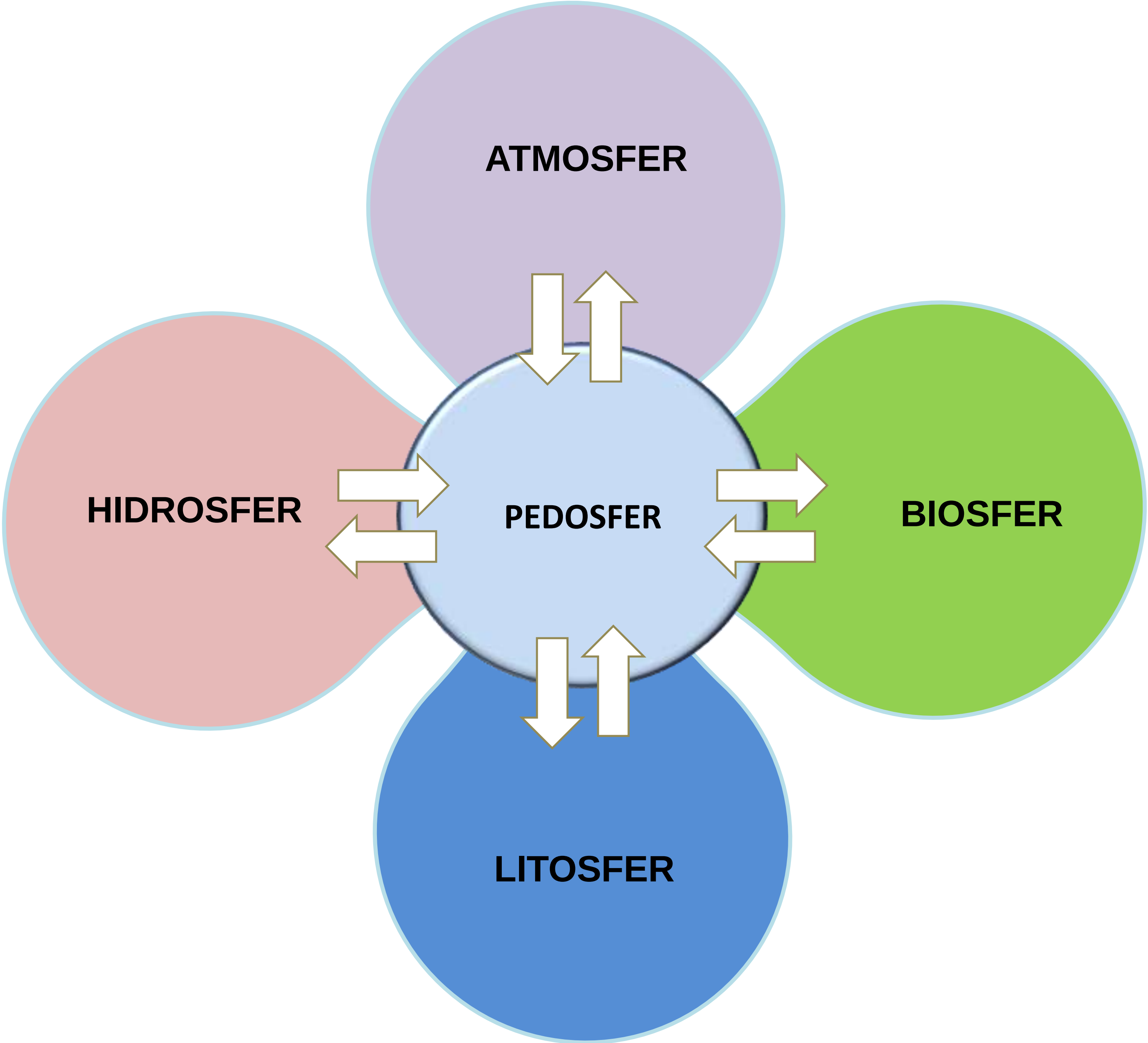


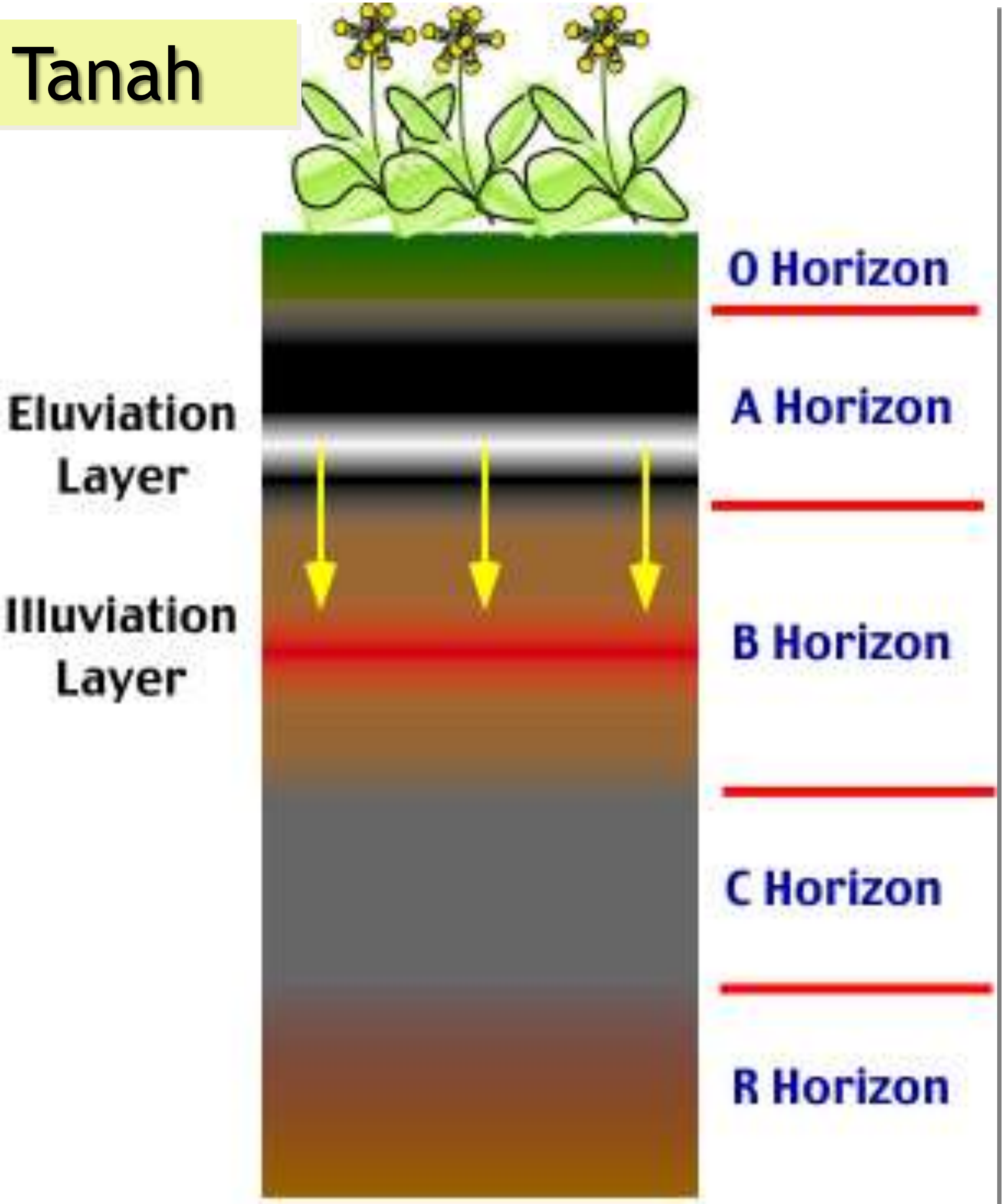
Some ways in which soils support societal aims, now and into the future.


ATMOSFER
HIDROSFER
PEDOSFER
BIOSFER
LITOSFER

Soil From Rocks

- Where does Soil Come From?
- Soil is every where!
- But how does it develop?
- What causes one soil to be productive and another to be poor?
- What are the rocks doing in this soil?

Profil Tanah



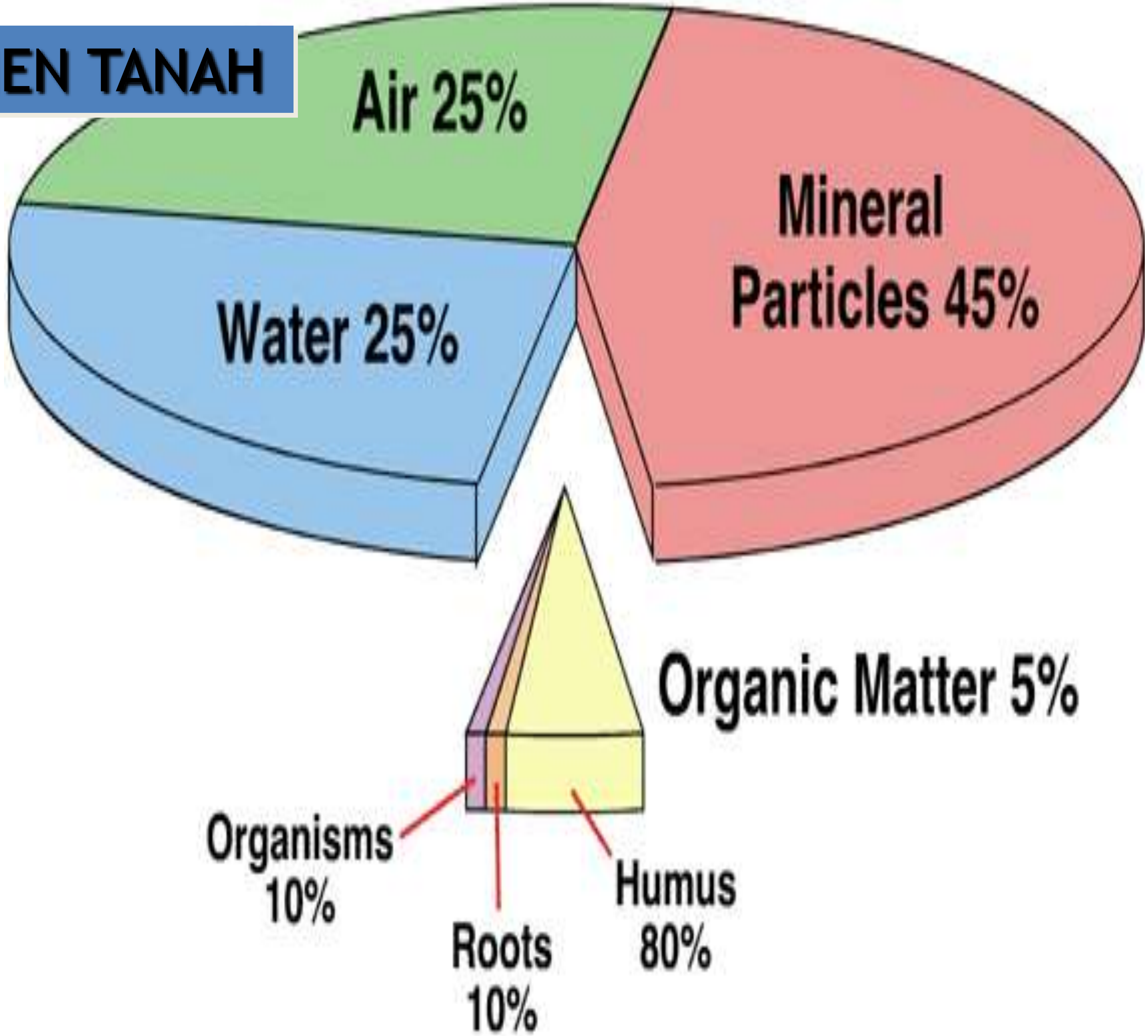
top soil

sub-soil

bahan induk

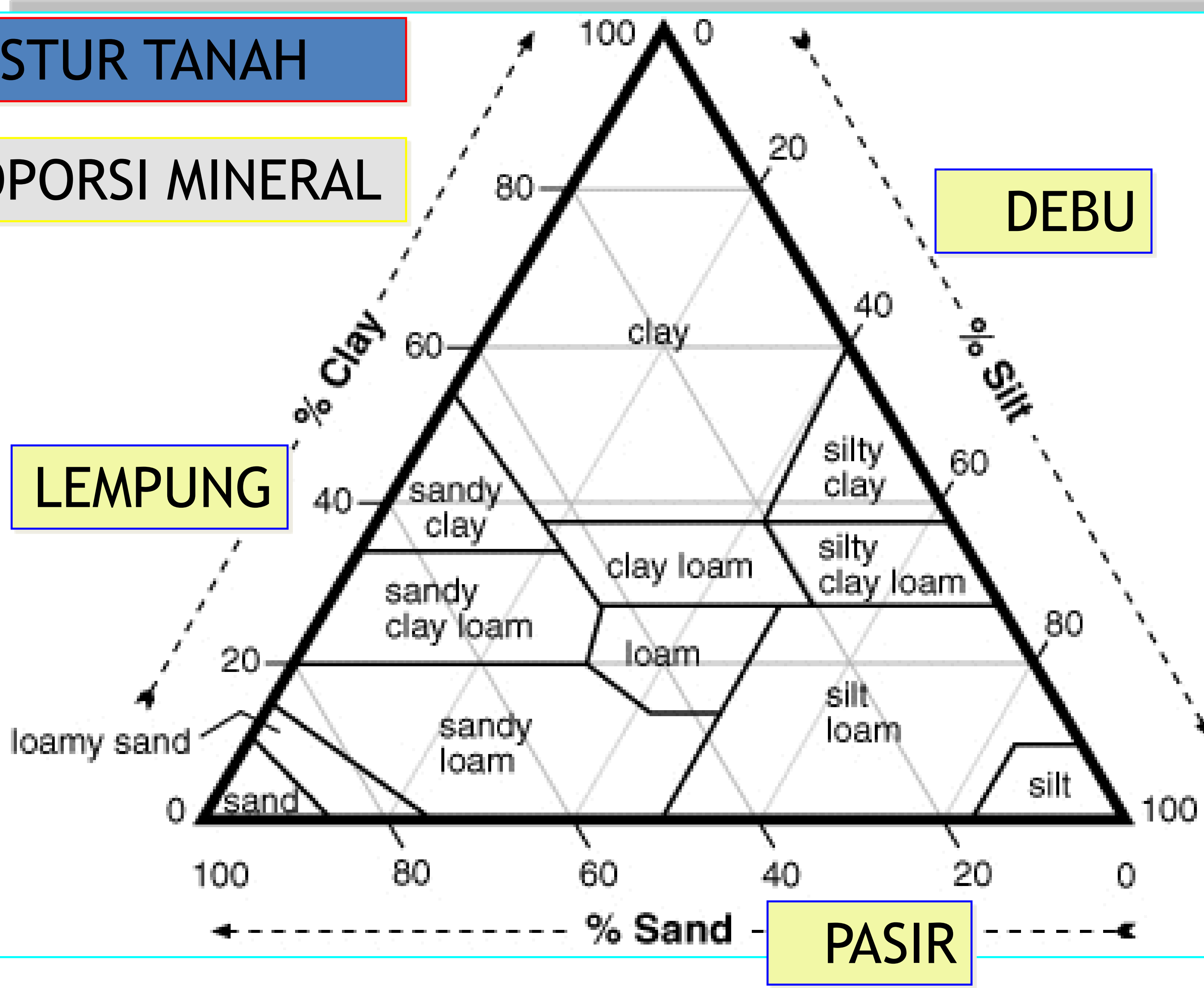
batuan

KOMPONEN TANAH



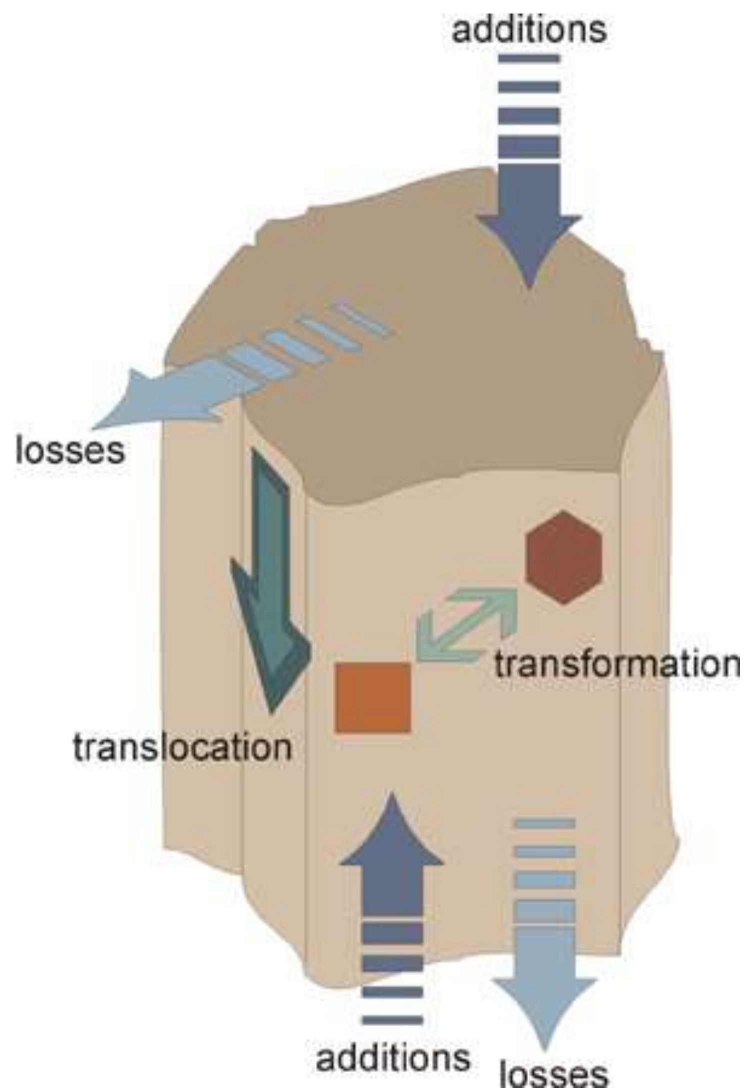
TEKSTUR TANAH

PROPORSI MINERAL

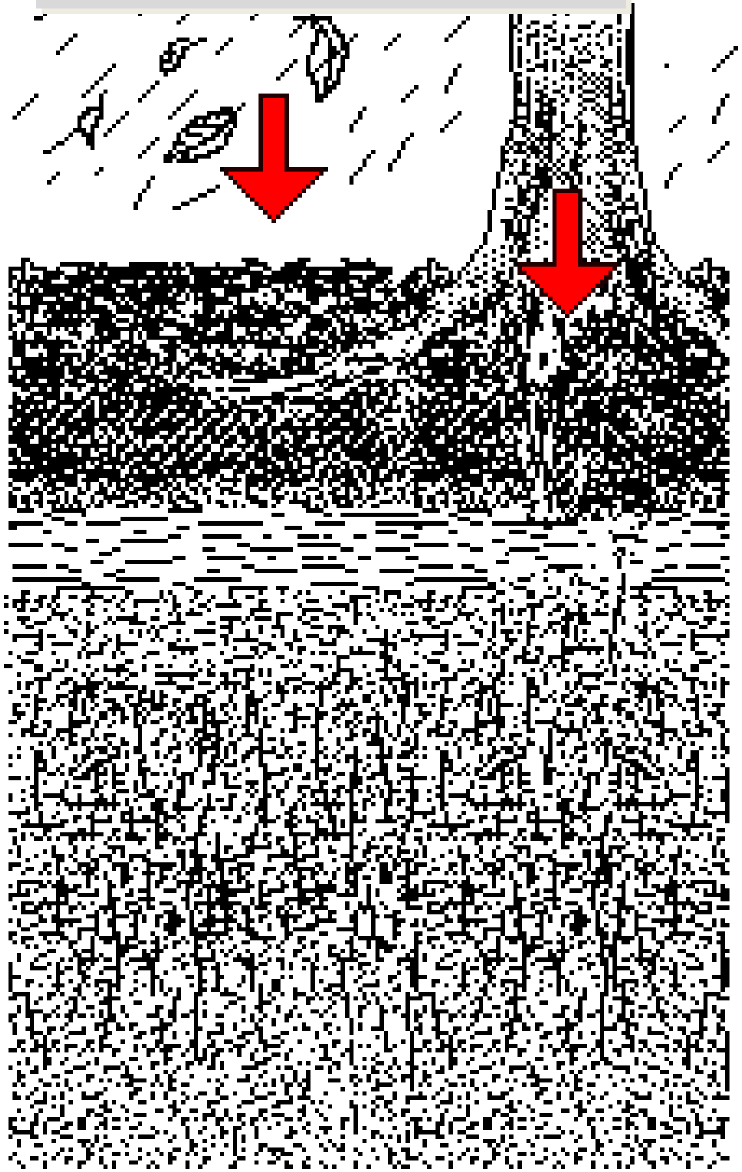


PROSES PEMBENTUKAN TANAH

- Addition (penambahan)
- Removal (penghilangan)
- Mixing (pencampuran)
- Translocation (alih tempat)
- Transformation (alih rupa)

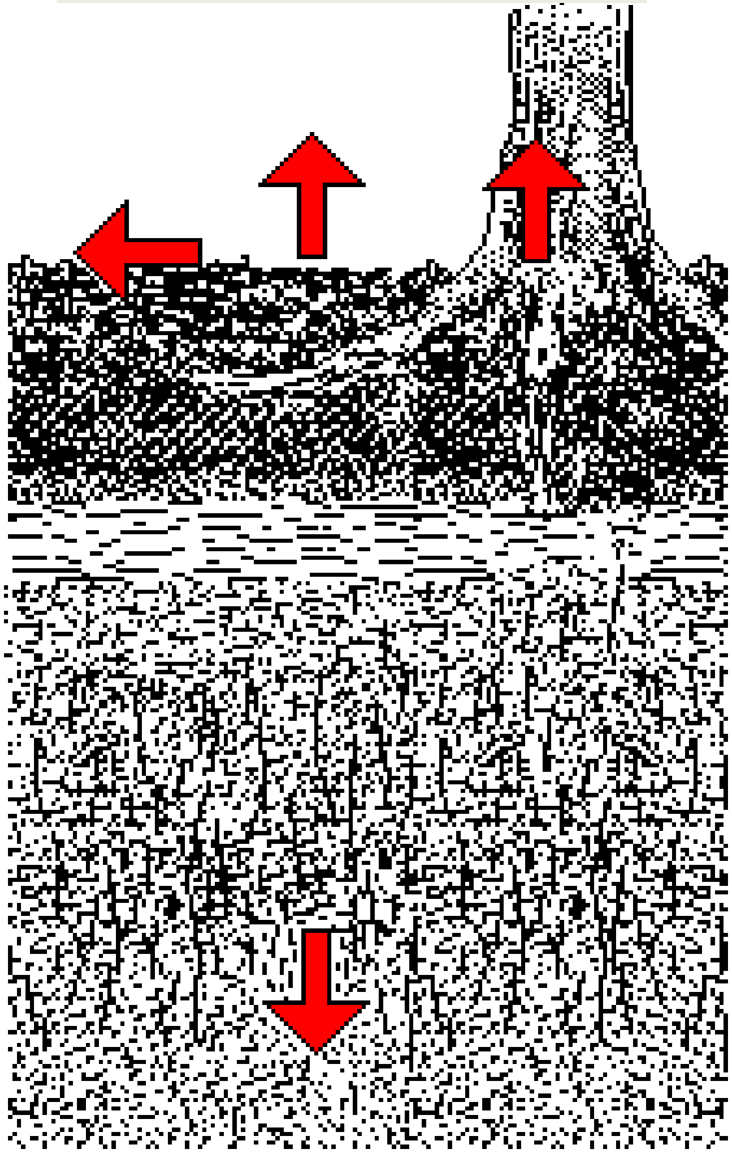


ADDITION



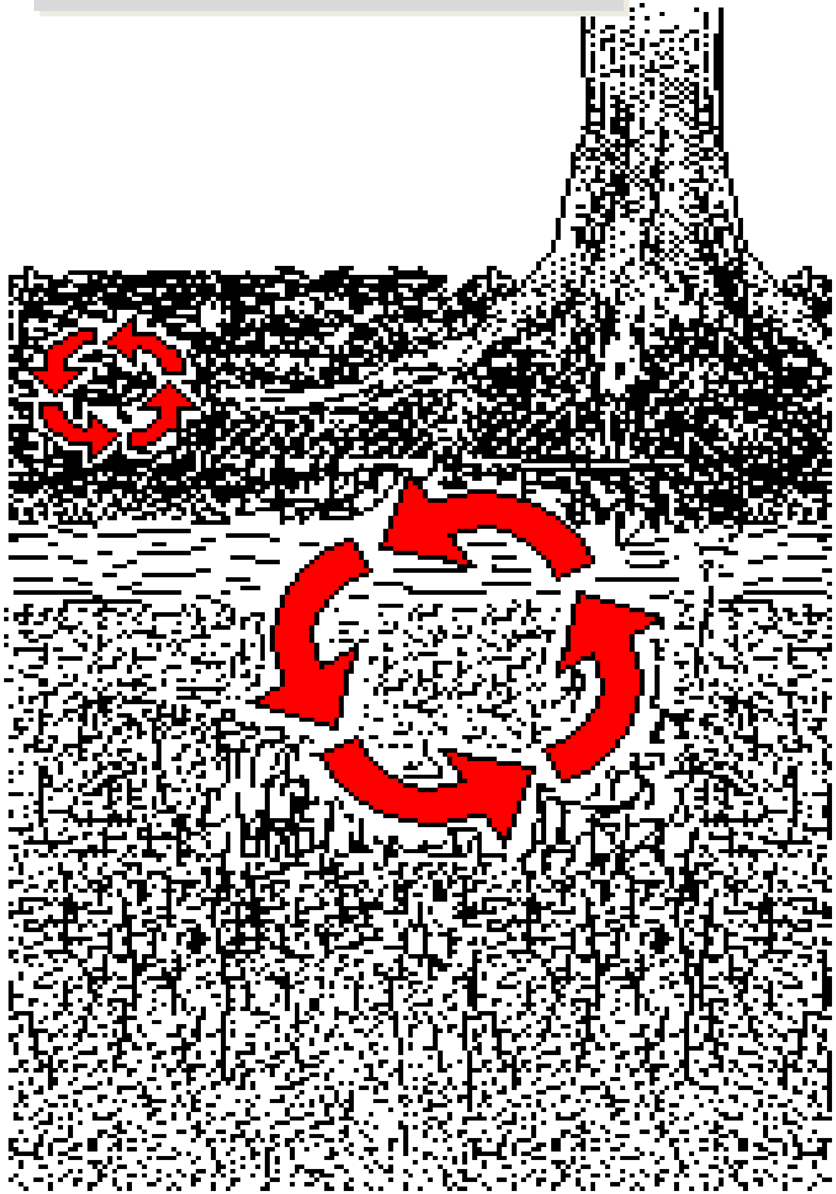
- water (from the surface, and by ground water discharge)
- suspended and dissolved materials carried by water
- solids transported by wind
- gases from the air
- energy from the sun
- organic carbon by plants in form of roots and root-derived material
- organic carbon by photoautotrophic bacteria
- organic nitrogen by nitrogen-fixing bacteria
- plant and animal remains on and in the soil.

REMOVAL



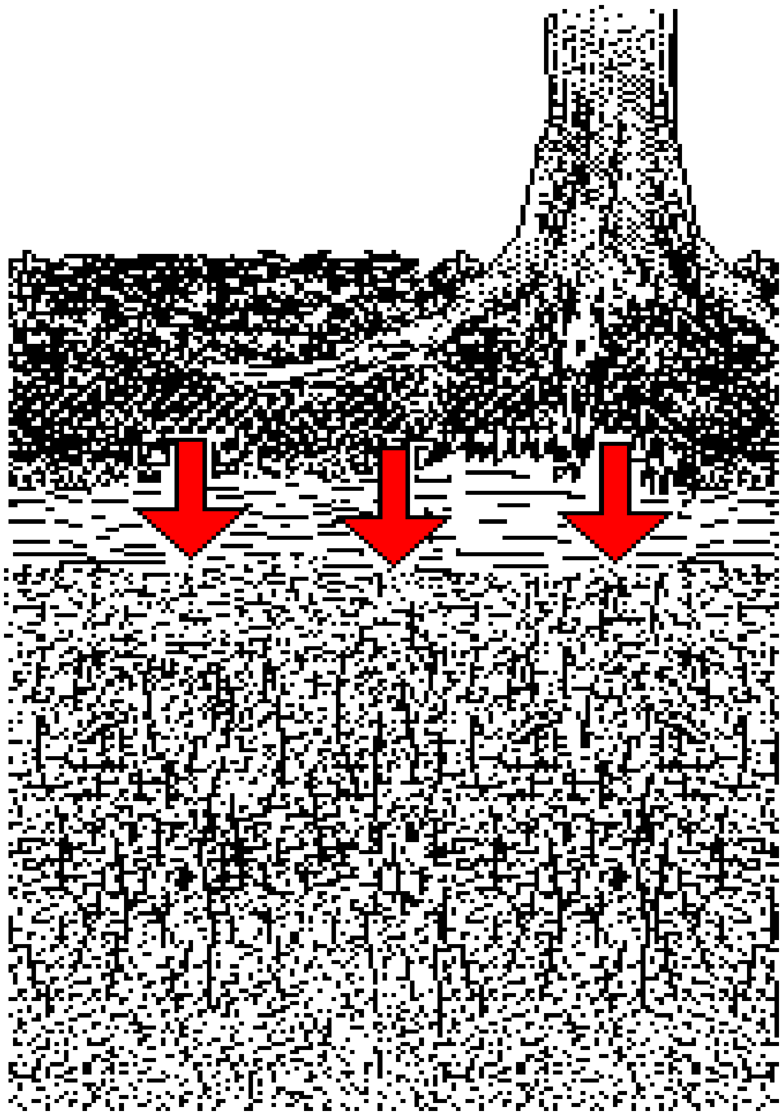
- materials removed by wind erosion
- material removed by water erosion
- dissolved and suspended material may be leached out from the bottom of a soil profile
- uptake of nutrients from the soil by plants
- carbon dioxide gas produced by plant root, microbial and faunal respiration
- other gases such as nitric oxide, nitrous oxide and nitrogen produced by denitrifying bacteria
- other gases such as methane which are produced under anaerobic conditions

MIXING



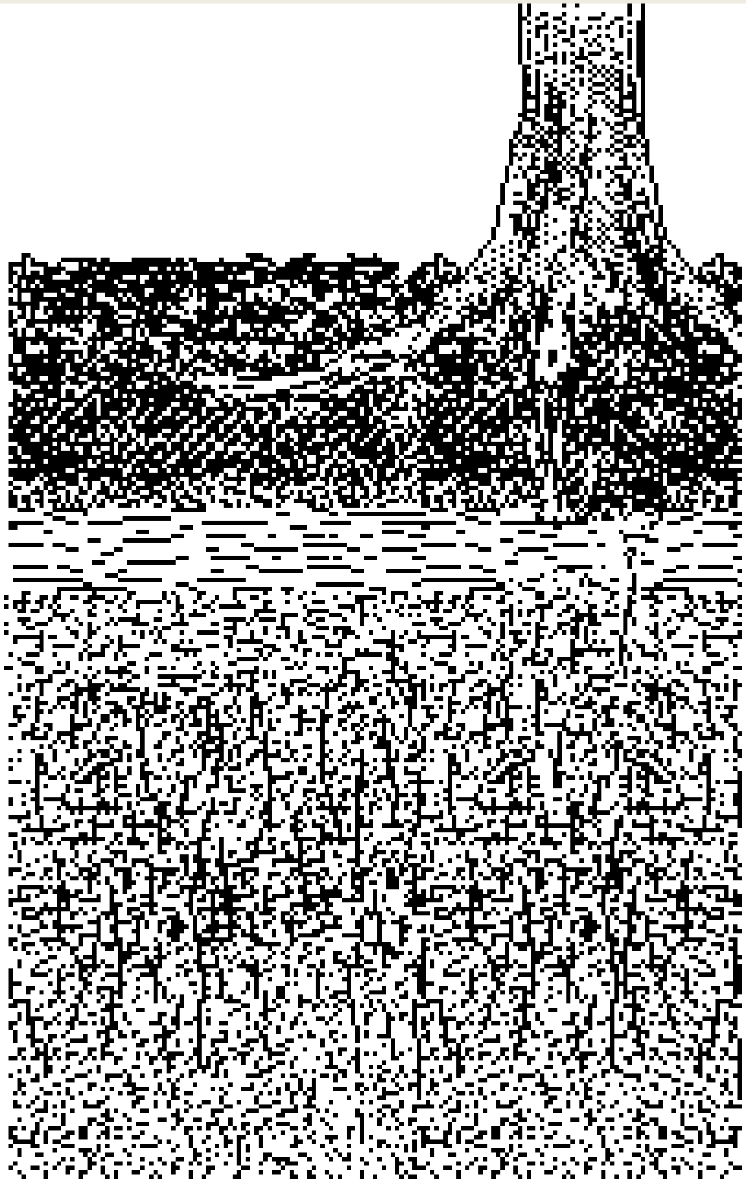
- soil animals
- tree fall and gravity
- shrinking and swelling due to water content changes
- freezing and thawing

TRANSLOCATION

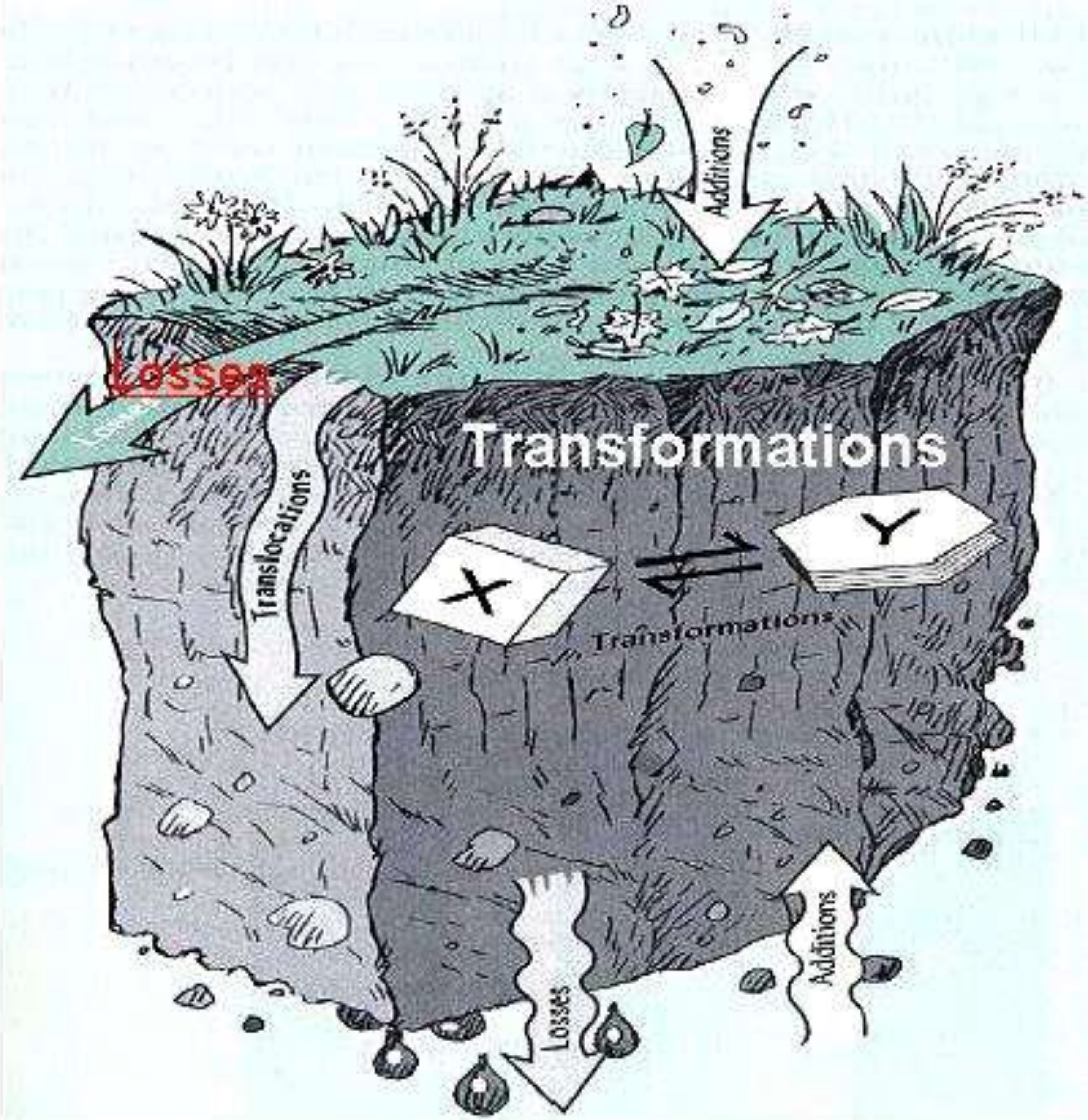


- Translocation of materials within the soil profile is primarily due to gradients in water potential and chemical concentrations within the soil pores.
- Soluble minerals, colloidal material, organic compounds, and iron may move up or down the profile, between horizons, with water movement.
- Biological activity may cause gradient in the chemical composition of the water and air-filled pores of the soil.

TRANSFORMATION



- Soil components are transformed by chemical and biological reaction.
- Organic compounds decay, some minerals dissolve, other minerals precipitate.
- These transformation result in the development of soil structure, and in changes in colour, relative to the parent material.



Soil Horizon Forming Processes

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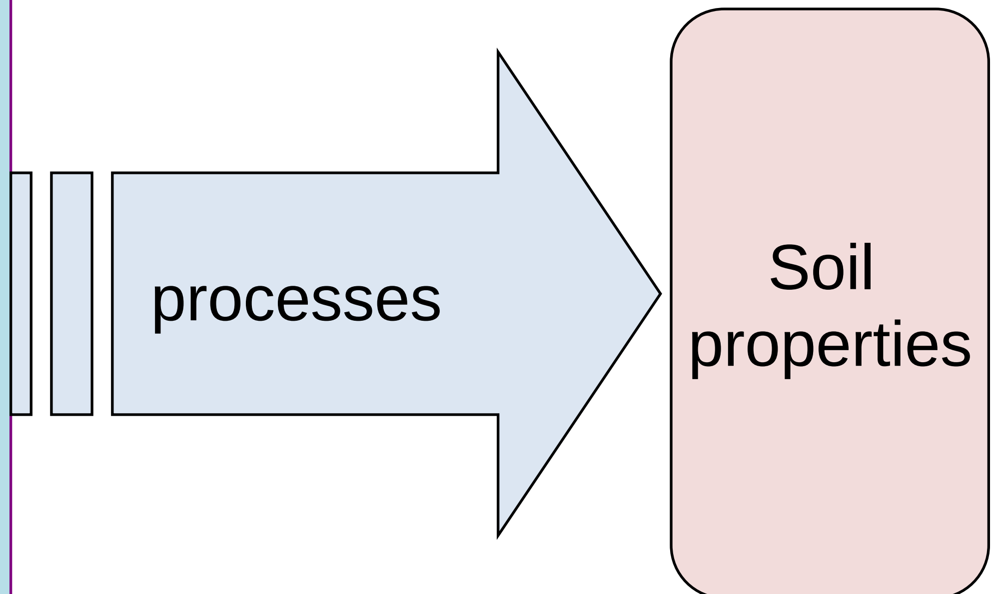
- parent material
- climate
- organism/ biota
- topography
- time



Soil Sequences

1. If the soils of a particular area have all of the soil-forming factors in common, then the morphological, chemical, physical, and mineralogical character of these soils should be very similar.
2. If, however, the soils differ in one of the factors, it is clear that the effect of the factor on the formation of the soils can be studied.
3. A series of soils having all soil forming factors in common except topography, is said to form a **toposequence** of soils.
4. A **lithosequence** of soils differs only in the soil-forming factor of parent material.
5. A **chronosequence** of soils differs in age.
6. A **climosequence** of soils differs in the climatic soil-forming factor
7. A **biosequence** contains soils that usually vary in the vegetation present.

Parent material

- The primary material from which the soil is formed.
- Soil ***parent material*** is the material that soil develops from, and may be rock that has decomposed in place, or material that has been deposited by wind, water, or ice.

- Soil parent material could be: bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.
- The character and chemical composition of the parent material plays an important role in determining soil properties, especially during the early stages of development.

Five basic types of parent material:

1. **Alluvium**: Alluvial parent material is transported and deposited by water.
2. **Colluvium**: Colluvial material is transported primarily by gravity. These deposits are unconsolidated debris found on hillslopes, toeslopes, and at the base of cliffs. Talus is a common type of colluvial deposit.
3. **Eolian (loess)**: Eolian material is transported by the wind. Eolian material refers to material of all sizes that is capable of being moved by the wind. Loess refers strictly to silt-sized or smaller material that is wind transported.
4. **Lacustrine and marine sediments**: These sediments are parent materials carried by streams and deposited in fresh or salt-water basins. The former are referred to as lacustrine deposits and the latter as marine deposits.
5. **Residual materials**: Residual parent materials are those that develop or weather in place from underlying bedrock. These materials are not transported.

- Soils developed on parent material that is coarse grained and composed of minerals resistant to weathering are likely to exhibit coarse grain texture.
- Fine grain soil develop where the parent material is composed of unstable minerals that readily weather.

- Parent materials rich in soluble ions- calcium, magnesium, potassium, and sodium, are easily dissolved in water and made available to plants.
- Limestone and basaltic lava both have a high content of soluble bases and produce fertile soil in humid climates.

- If parent materials are low in soluble ions, water moving through the soil removes the bases and substitutes them with hydrogen ions making the soil acidic and unsuitable for agriculture.
- Soils developed over sandstone are low in soluble bases and coarse in texture which facilitates leaching.

- Parent material influence on soil properties tends to decrease with time as it is altered and climate becomes more important.

Original mineral

NAME	CHEMICAL FORMULA
Quartz	SiO_2
Microcline	$KAlSi_3O_8$
Orthoclase	$KAlSi_3O_8$
Na-Plagioclase	$NaAlSi_3O_8$
Ca-Plagioclase	$CaAlSi_3O_8$
Muscovite	$KAlSi_3O_{10}$
Biotite	$KAl(Mg\text{-}Fe)_3Si_3O_{10}\ (OH)_2$
Horneblende	$Ca_2Al_2Mg_2Fe_3,\ Si_6O\ (OH)_2$
Augite	$Ca_2(Al\text{-}Fe)_4(Mg\text{-}Fe)_4Si_6O\ 24$

Secondary mineral

NAME	CHEMICAL FORMULA
Calcite	$CaCo_3$
Dolomite	$CaMg(CO_3)_2$
Gypsum	$CaSO_4$-$2H_20$
Apatite	$Ca_5(PO_4)_3$ - (Cl, F)
Limonite	Fe_2-O_3-$3H_20$
Hematite	Fe_2O_3
Gibbsite	Al_2-O_3-$3H_2O$
Clay Minerals	Al silicates

Igneous Rocks

	Granite	Gabbro	Basalt
SiO_2	**73.9**	**48.4**	**50.8**
TiO_2	0.2	1.3	2.0
Al_2O_3	13.8	16.8	14.1
Fe_2O_3	0.78	2.6	2.9
FeO	1.1	7.9	9.0
MnO	0.05	0.18	0.18
MgO	0.26	8.1	6.3
CaO	**0.72**	**11.1**	**10.4**
Na_2O	**3.5**	**2.3**	**2.2**
K_2O	**5.1**	**0.56**	**0.82**
H_2O+	0.47	0.64	0.91
P_2O_5	0.14	0.24	0.23

Climate

- Weathering forces such as heat, rain, ice, snow, wind, sunshine, and other environmental forces, break down parent material and affect how fast or slow soil formation processes go.

Soil moisture

- The form and intensity of precipitation (water, snow, sleet)
- Its seasonal variability
- The transpiration and evaporation rate
- Slope
- Aspect
- Depth of soil profile
- Soil texture / permeability of the parent material

Soil moisture regime Characteristics

- **Dry**→ Soil moisture content less than the amount retained at 15 atmospheres of tension (1500 kPa - permanent wilting point). 'In most years' - 6 out of 10 years
- **Xeric**→ Soils of temperate areas that experience moist winters and dry summers (i.e. mediterranean climates)
- **Aridic/Torric**→ Soils are dry more than half the time (in arid climatic zone)

- **Perudic**→ In most years precipitation exceeds evapotranspiration every month of the year Udic In most years soils are not dry more than 90 consecutive days
- **Ustic**→ In most years soils are dry for 90 consecutive days and moist in some part for half the days the soil temperature is above 5°C (i.e., during potential growing season)
- **Aquic**→ Soils that are sufficiently saturated, reducing conditions occur.

Temperature

- Temperature varies with lattitude and altitude, and the extent of absorption and reflection of solar radiation by the atmosphere
- Temperature affects the rate of mineral weathering and synthesis, and the biological processes of growth and decomposition

Temperature regime	Mean annual temperature (^oC)
Pergelic	< 0
Cryic	0 -8
Frigid	< 8
Mesic	8 - 15
Thermic	15 - 22

- Soils tend to show a strong geographical correlation with climate, especially at the global scale. Energy and precipitation strongly influence physical and chemical reactions on parent material.
- Climate also determines vegetation cover which in turn influences soil development. Precipitation also affects horizon development factors like the translocation of dissolved ions through the soil.
- As time passes, climate tends to be a prime influence on soil properties while the influence of parent material is less.

- Climate affects both vegetative production and the activity of organisms. Hot, dry desert regions have sparse vegetation and hence limited organic material available for the soil. The lack of precipitation inhibits chemical weathering leading to coarse textured soil in arid regions.

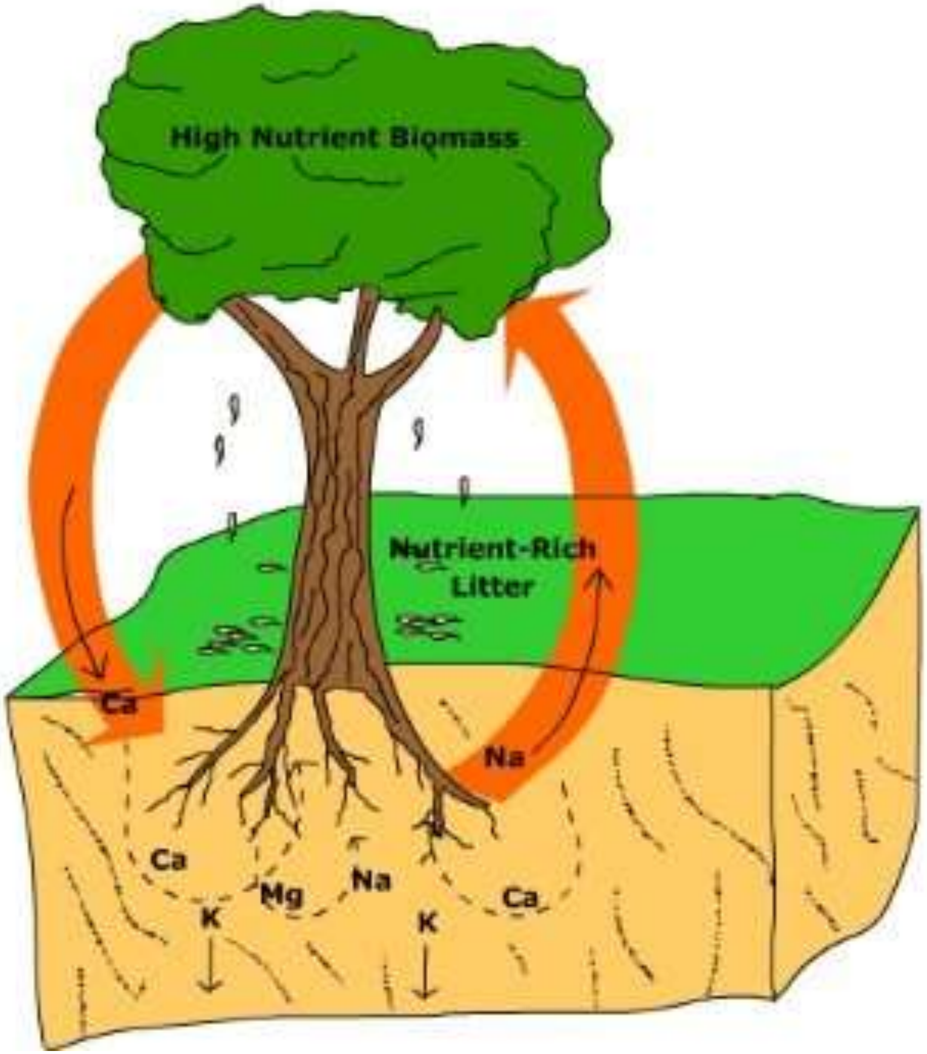
- Bacterial activity is limited by the cold temperatures in the tundra causing organic matter to build up. In the warm and wet tropics, bacterial activity proceeds at a rapid rate, thoroughly decomposing leaf litter.
- Under the lush tropical forest vegetation, available nutrients are rapidly taken back up by the trees. The high annual precipitation also flushes some organic material from the soil. These factors combine to create soils lacking much organic matter in their upper horizons.

Organism/Biota

- All plants and animals living in or on the soil (including micro-organisms and humans!).
- The amount of water and nutrients, plants need affects the way soil forms. The way humans use soils affects soil formation. Also, animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile.
- On the soil surface remains of dead plants and animals are worked by microorganisms and eventually become organic matter that is incorporated into the soil and enriches the soil.

Vegetation

- The primary succession of plants that colonize a weathering rock culminates in the development of a climax community, the species composition of which depends on the climate and parent material, but which, in turn, has a profound influence on the soil that is formed.
- Differences in the chemical composition of leaf leachates can partly account for a divergent pattern of soil formation. For example acid litter of pines or heather favors the development of acid soils with poor soil structure, whereas litter of decidious trees favors the development of well structured soils.



High Nutrient Biomass
Nutrient-Rich
Litter
Ca
Na
Ca
Mg
Na
Ca
K
K

Meso-/Macrofauna

- Earthworms are the most important of the soil forming fauna in temperate regions, being supported to a variable extent by the small arthropods and the larger burrowing animals (rabbits, moles).
- Earthworms are also important in tropical soils, but in general the activities of termites, ants, and beetles are of greater significance, particularly in the subhumid to semiarid savanna of Africa and Asia.

- Earthworms build up a stone-free layer at the soil surface, as well as intimately mixing the litter with fine mineral particles they have ingested. The surface area of the organic matter that is accessible to microbial attack is then much greater. Types of the mesofauna comprise arthropods (e.g. mites, collembola) and annelids (e.g earthworms, enchytraeids).

Earthworm biomass	**[kg/ha]**
Hardwood and mixed woodland	370 - 680
Coniferous forest	50 - 170
Pasture	500 - 1500
Arable land	16 - 760

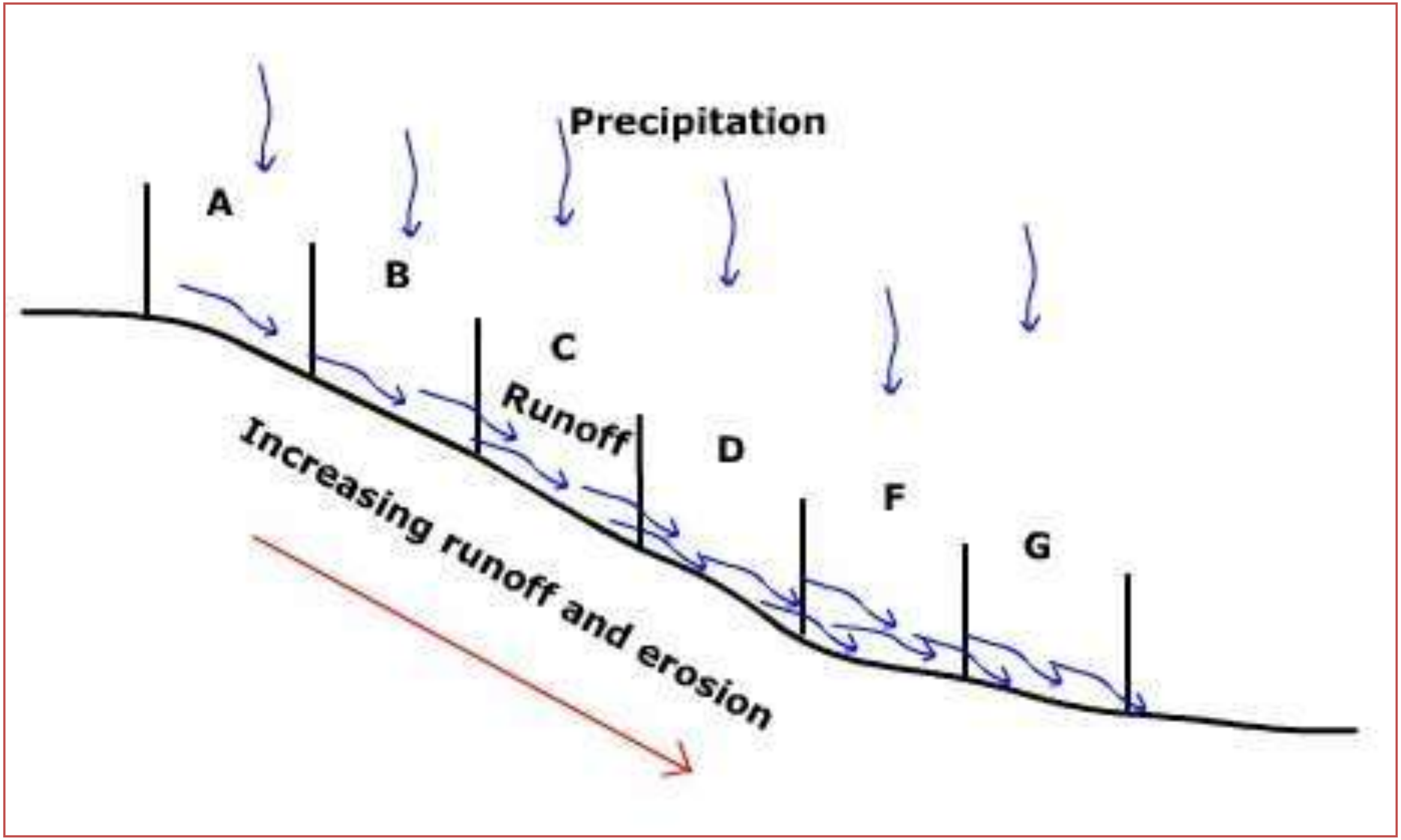
Topography

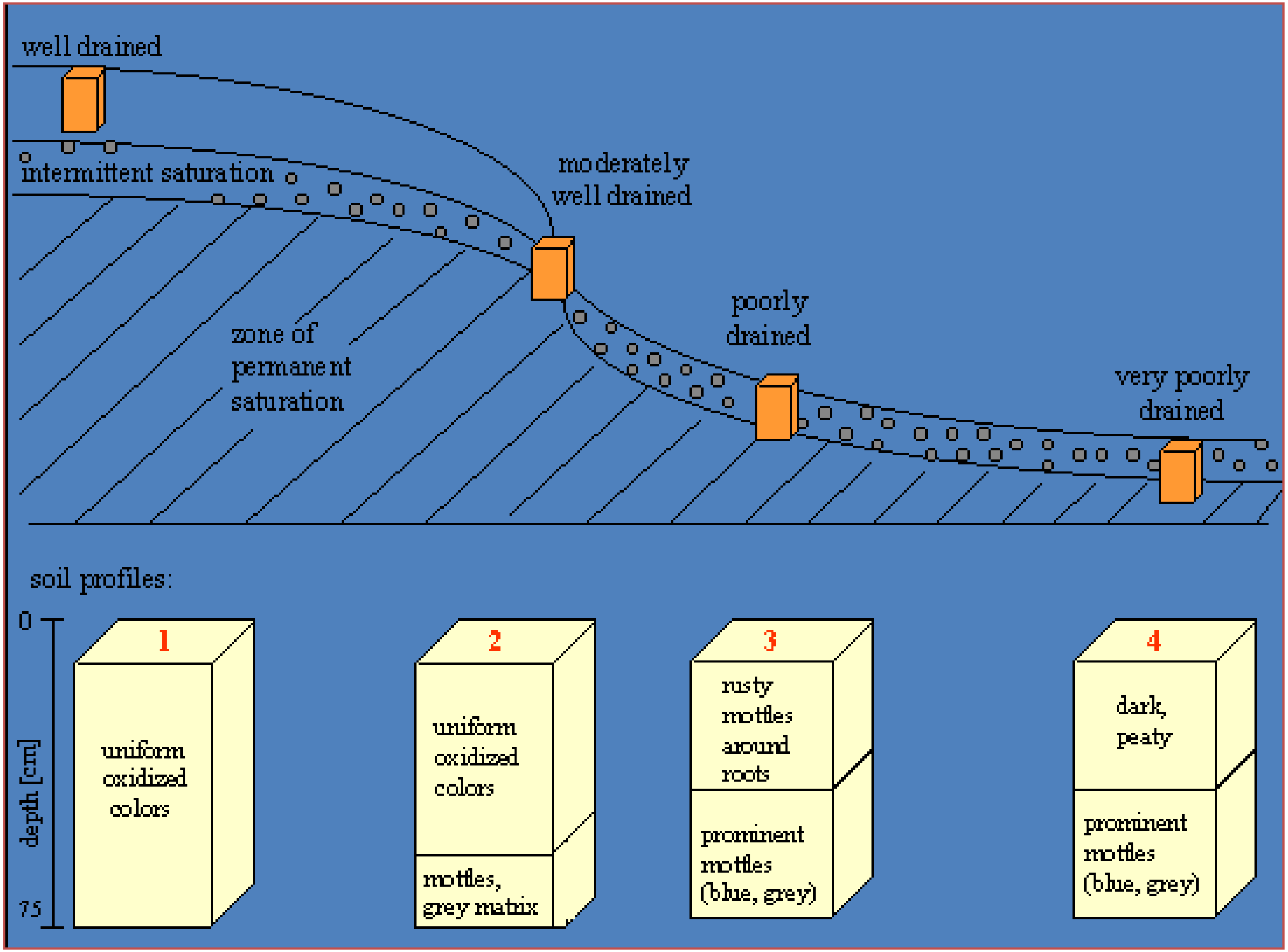
- The location of a soil on a landscape can affect how the climatic processes impact it.
- Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not.
- Also, mineral accumulations, plant nutrients, type of vegetation, vegetation growth, erosion, and water drainage are dependent on topographic relief.

- Topography has a significant impact on soil formation as it determines runoff of water, and its orientation affects microclimate which in turn affects vegetation.
- For soil to form, the parent material needs to lie relatively undisturbed so soil horizon processes can proceed.
- Water moving across the surface strips parent material away impeding soil development. Water erosion is more effective on steeper, unvegetated slopes.

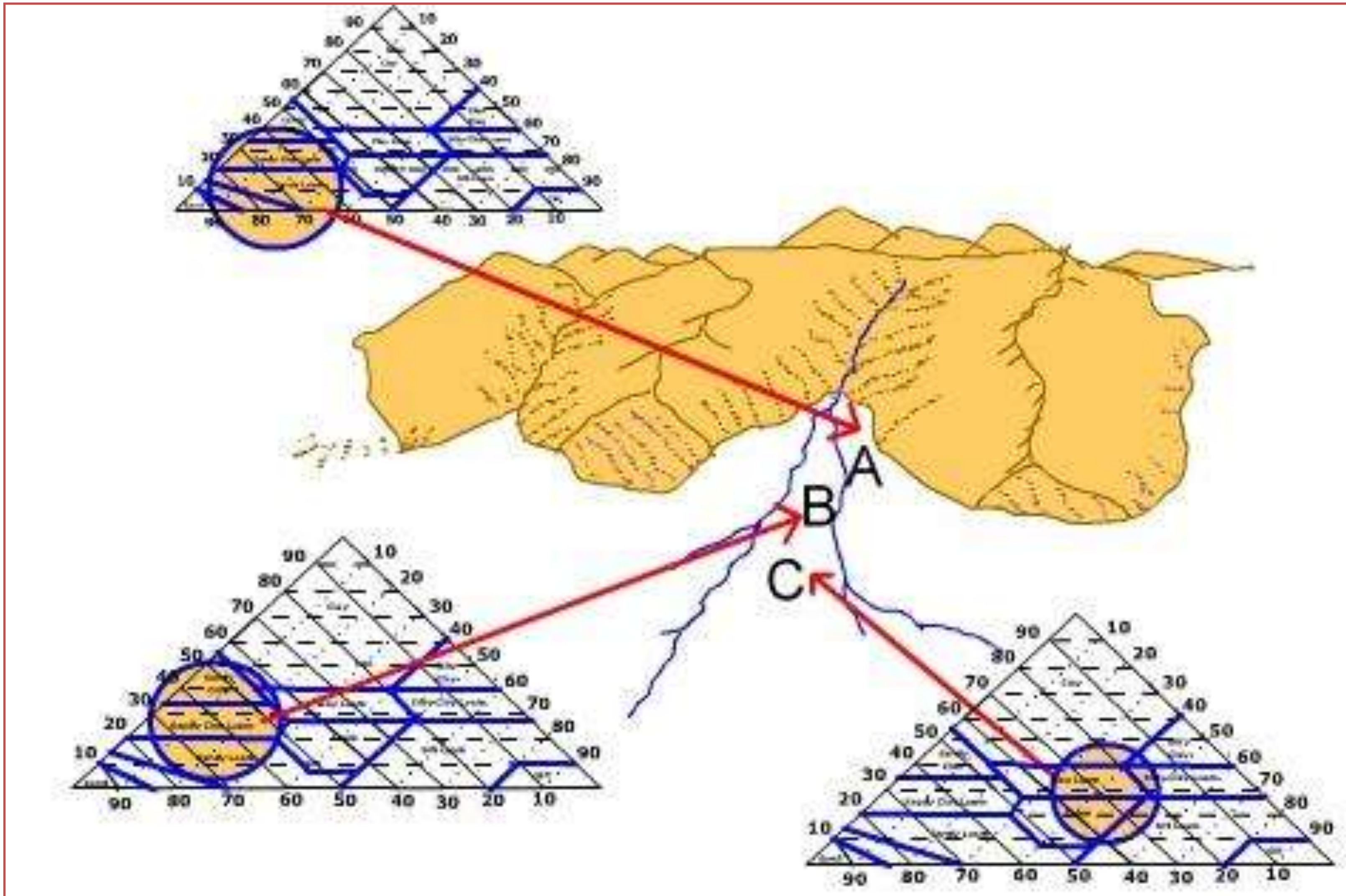
increase in slope is associated with a reduction in:

- Leaching
- Organic matter content
- Clay translocation
- Mineral weathering
- Horizon differentiation
- Solum thickness


Precipitation
A
B
C
Runoff
D
F
G
Increasing runoff and erosion



well drained
intermittent saturation
moderately
well drained
zone of
permanent
saturation
poorly
drained
very poorly
drained
soil profiles:
0
depth [cm]
75
1
uniform
oxidized
colors
2
uniform
oxidized
colors
mottles,
grey matrix
3
rusty
mottles
around
roots
prominent
mottles
(blue, grey)
4
dark,
peaty
prominent
mottles
(blue, grey)


A
B
C

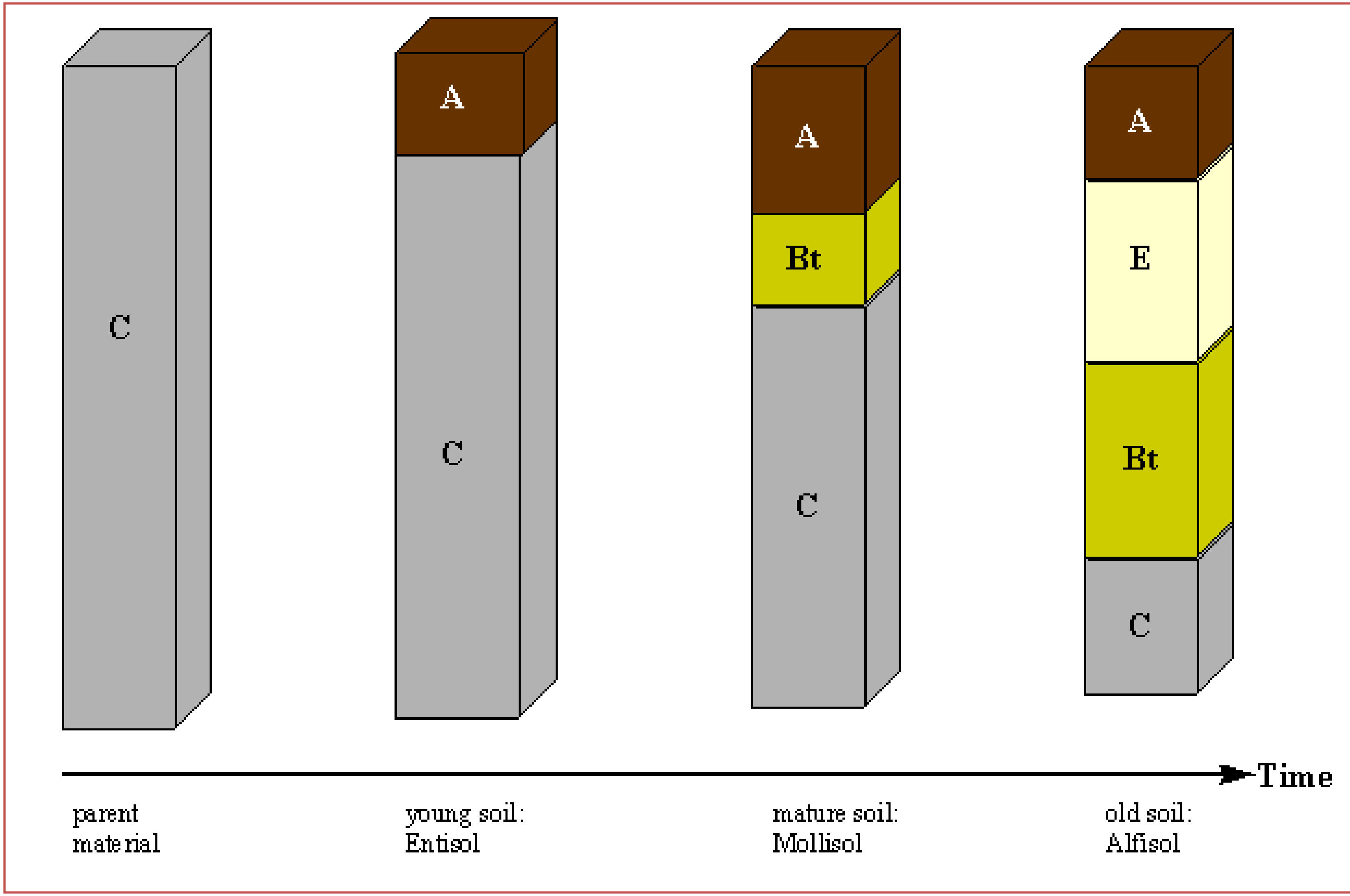
Time

- All of the above factors assert themselves over time, often hundreds or thousands of years.
- Soil profiles continually change from weakly developed to well developed over time.

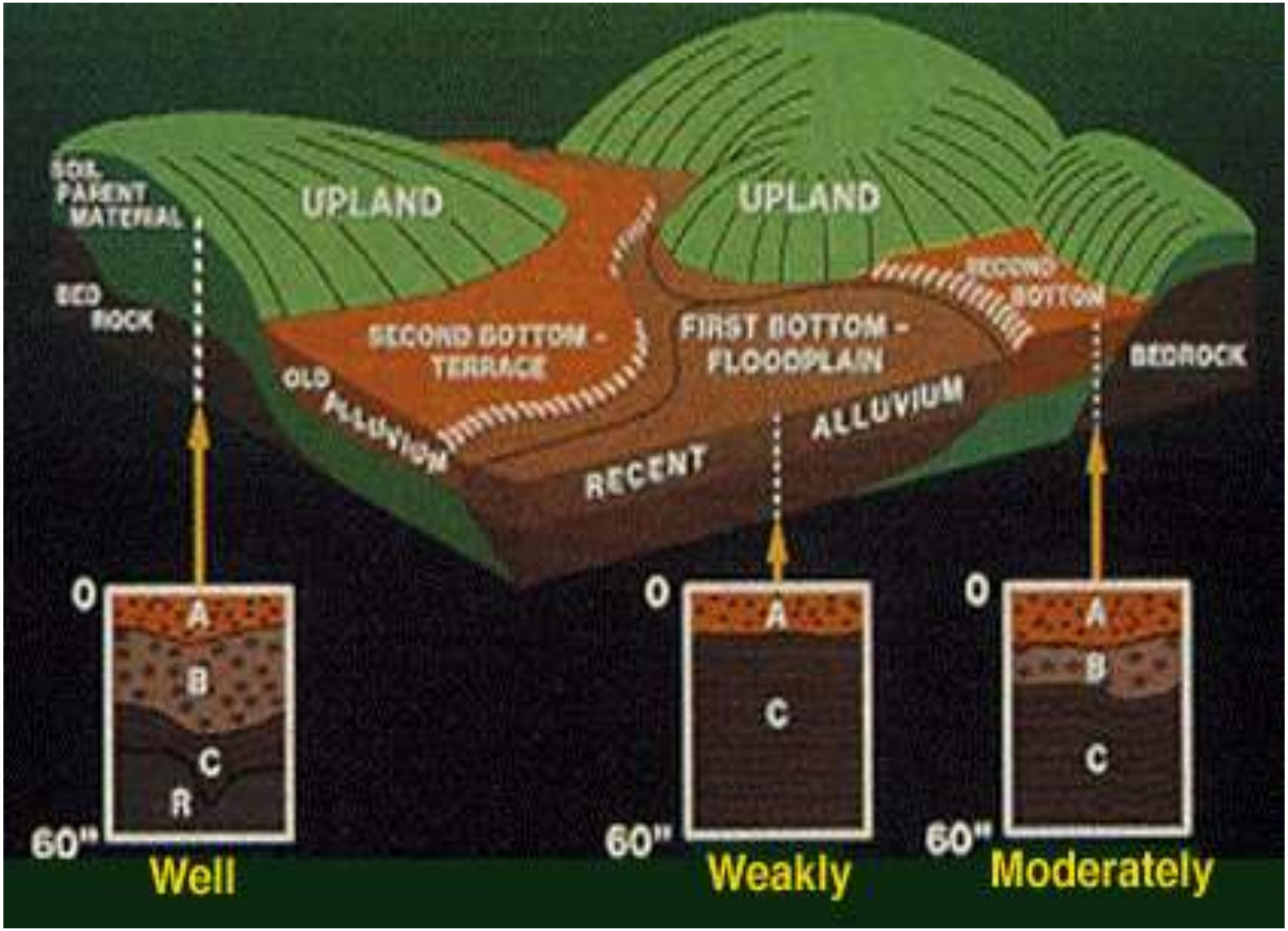
Time acts on soil formation in two ways:

- The value of a soil forming factor may change with time (e.g. climatic change, new parent material).
- The extent of a pedogenetic reaction depends on the time for which it has operated.

- Monogenetic soils are those that have formed under one set of factor values for a certain period of time.
- Soil that have formed under more than one set of factor values are called polygenetic.
- Very old soils are formed on weathered consolidated rocks (e.g. granite, basalt), where the rocks were formed more than 500 million years ago (Paleozoikum). In Africa or Australia such old soils may be found.



Stages of development of soils


UPLAND
UPLAND
SOIL PARENT MATERIAL
BED ROCK
SECOND BOTTOM - TERRACE
FIRST BOTTOM - FLOODPLAIN
SECOND BOTTOM
BEDROCK
OLD ALLUVIUM
RECENT ALLUVIUM
0
A
B
C
R
60"
Well
0
A
C
60"
Weakly
0
A
B
C
60"
Moderately