Soil Formation

Soils may be formed in place from rock or formed in weathered rock and minerals that have been transported from where the original rock occurred.

Rocks

Consist of mixtures of minerals.

Igneous
Metamorphic
Sedimentary

Igneous rocks are formed from molten magma and contain primary minerals. Sedimentary rocks are formed by deposition and cementation of weathered products. Metamorphic rocks are formed from igneous or sedimentary rocks by high pressure and temperature.

Weathering

Physical disintegration
Chemical decomposition

Physical disintegration causes decrease in size without appreciably altering composition. Differential stresses due to heating and cooling or expansion of ice break the rock. Abrasion due to water containing sediment or wind carrying debris is another type of physical weathering.

Chemical decomposition and synthesis alter chemical composition. Four types of chemical weathering reactions are: hydrolysis, hydration, acid dissolution and redox (particularly, Fe^{2+} / Fe^{3+}).

Five Factors of Soil Formation

Parent material
Climate
Organisms
Topography
Time

Soils defined -dynamic natural bodies having properties derived from the combined effect of climate and biotic activities, as modified by topography, acting on parent material over time.

Parent Material

Geologic material in which a soil forms.

Residual sedentary

Transported Agent

Colluvial	gravity
Alluvial	water
Marine	water
Lacustrine	water
Glacial	ice
Eolian	wind

Residual

Develops in place from the underlying rock. If soil is young, properties tend to reflect effect of parent material. For example,

Igneous and metamorphic rock, if

Siliceous (granite and granite gneiss)
acid and sandy
Ferromagnesian (basalt and diorite)
nonacid and clayey

Sedimentary, if

Limestone sand or clay impurities lead to sandy or clayey soil

Sandstone shallow if SiO_2 cements but deep if $CaCO_3$ cements particles together

Shale clay minerals in shale give rise to a clayey soil

Colluvial

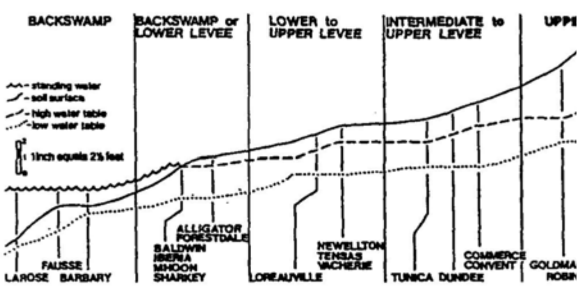
Consists of coarse and stony debris detached from rocks and carried downslope by gravity.

Alluvial

These deposits occur as *alluvial fans*, *flood plains* and *deltas*.

Alluvial fan occurs at the discharge of an upland stream into a broader valley below. Coarse textured material.

Flood plains are adjacent to streams and rivers. During floods, coarse sediment is deposited nearest the existing channel and fine sediment further away, resulting in a *natural levee*. Changes in the course of the stream result in a complex spatial pattern of alternating coarse and fine sediments throughout the flood plain. If there is a change in grade, the stream may cut through existing deposits, thereby forming *terraces*.



Example Mississippi River natural levee showing different soils at different positions on the levee.

Complex soilscape on a flood plain.

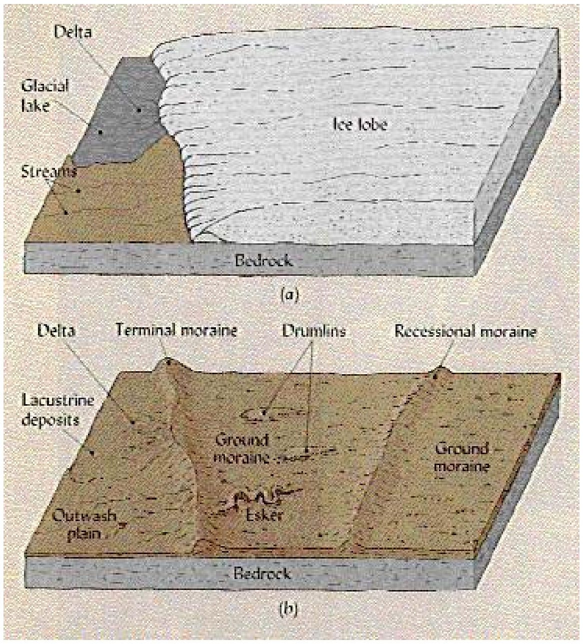
A *delta* occurs at the mouth of river and marks the downstream extent of a flood plain.

Marine Sediments

Unconsolidated marine sediments deposited by streams emptying into oceans may undergo uplift. Common along Atlantic and Gulf coasts. Vary from sandy to clayey.

Glacial Deposits

From a series of glaciations during the Pleistocene epoch. Each advancing ice sheet accumulated a great mass of unconsolidated material which was deposited as *glacial drift* when the glacier melted and retreated. Material directly deposition from the ice is called *glacial till* and occurs in formations called *moraines*. Streams originating in a glacier transported sediment away and produced *outwash plains*. Where regional topography impounded glacial melt, lakes formed and *lacustrine* deposits accumulated. Deltas of coarser materials occur in what was the inflow region whereas finer materials were deposited further away.



Ice sheet melt and resulting topographical features.

Eolian

Deposits consisting of silt and some fine sand plus clay (*loess*) blanketed regions along the Mississippi and Missouri Rivers.

Organic Materials

Accumulate in wet places where plant growth exceeds the rate of residue decomposition. Such organic deposits are known as *peat*. Typical pattern of peat accumulation: 1) sedimentary (*limnic*) peat, from aquatic plants, 2) herbaceous (*telmatic*) peat, from sedges and so forth, then 3) woody (*terrestic*) peat, from trees.

Climate

Through effects of precipitation and temperature, climate affects the rates of biological, chemical and physical processes involved in soil formation. Effects of climate on soil formation include:

High precipitation and low temperature increase organic matter in soil.

Leaching of soluble materials like $CaCO_3$ increases with increasing precipitation.

Movement of clay in soil profile increase with increasing precipitation.

Silicate clay and Al and Fe oxide formation increase with increasing temperature.

Generally, high rainfall and temperature leads to deep weathering and soil leaching. Just contrast weathered profile of humid tropical soils with profile of arid soils from which soluble salts have not been leached.

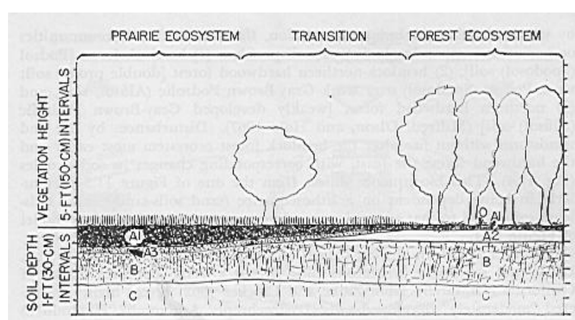
Climate also indirectly influences soil formation by its effect on natural vegetation. For example, trees under humid climate, grasses under semiarid climate and brush under arid climate.

Organisms

Living organisms are responsible for accumulation of organic matter, nutrient cycling and profile mixing.

Difference in profiles of soils developed under grassland and forest vegetation include:

1) development of a high organic matter surface horizon under grass and 2) leached subsurface horizon (E) overlying a more clayey horizon (Bt) under forest.



Idealized prairie - forest transition.

Forest type, deciduous versus coniferous also affects soil development because the higher rate of nutrient cycling in deciduous forest retards leaching of basic cations and soil acidification. For example, compare two soils from a *biosequence* in Louisiana that developed in loess:

	Calhoun	Jeanerette
Cover	pine / hardwood	prairie
Solum	175 cm	125 cm
Clay	weathered	less so
pH	4.5	6.5

Topography

Landscape relief modifies the effects of organisms and climate on soil development. Effects of topography on soil formation include:

Thinner sola and less mature profile development on steeper slopes in humid region because profile development is retarded by erosion or reduced water infiltration.

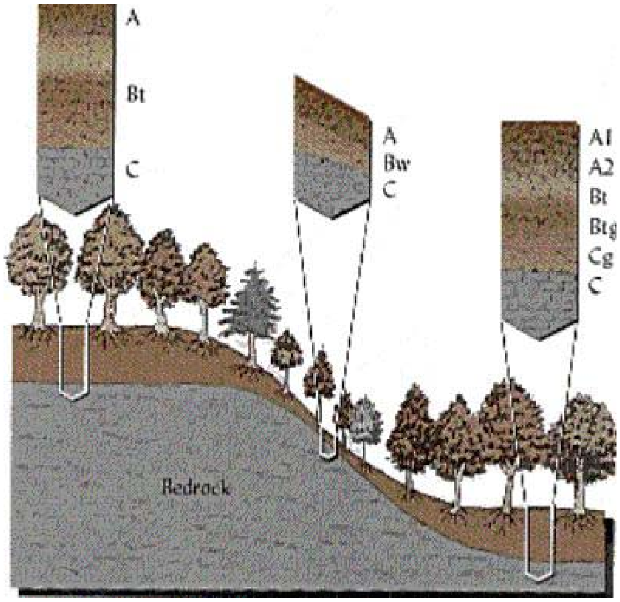
Effect of shallow water table (approximately parallel to the soil surface) on restricting drainage and, therefore, soil development.

Lower organic matter content and more shallow sola on southern slopes due to higher temperature and lower moisture.

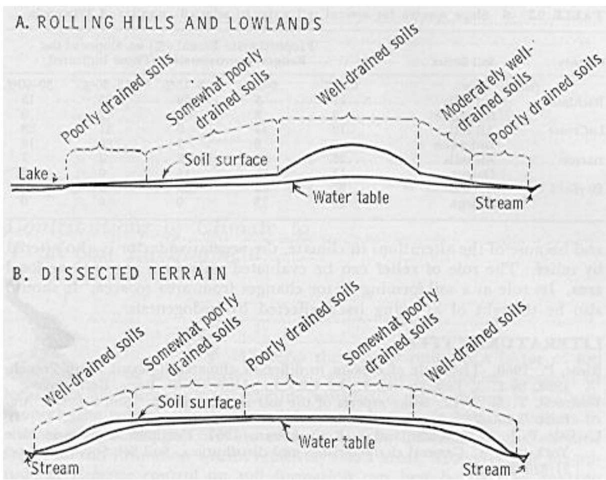
In humid regions, greater wetness in depressional areas leads to accumulation of organic matter.

In arid regions, salt accumulation may occur in depressional areas.

Relative elevation and aspect also affect vegetation. For example, trees tend to occur in lower positions of prairie-forest transition zone and species composition is different on southern (prairie) and northern (forest) facing slopes.



Effect of slope on soil development.



Effect of topography on depth to shallow ground water table and soil drainage.

Time

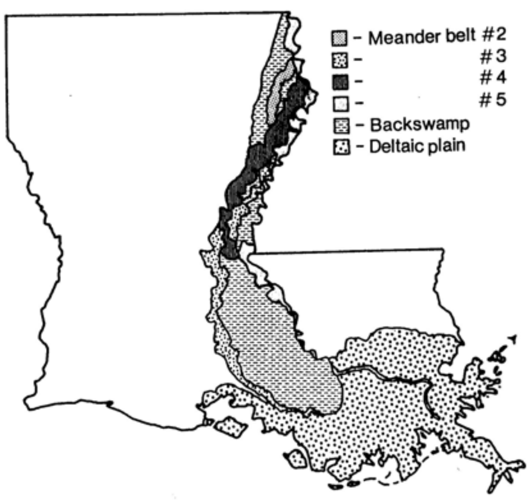
Effects of climate and living organisms, modified by topography, on the development of soil from parent material takes time. Effect of time can be seen by looking at *chronosequences* in Mississippi and Red River alluvium.

The sequence of soils, Severn, Roxanna and Gallion (natural levees of the Red River) exhibits increasing extent of profile development including depth to $CaCO_3$.

Soil	*Channel Age*	*$CaCO_3$ Depth*
Severn	recent	< 50 cm
Roxanna	older	> 50 cm
Gallion	older	leached

Convent, Bruin and Dundee (natural levees of increasingly older channels of the Mississippi River) range from 3,000 to 6,000 years old.

Convent	*Bruin*	*Dundee*
< 3000 yr	> 3000	> 4000
15 cm	45 +	60 +



Meader belts of the Mississippi River in Louisiana.

Processes of Soil Formation

The five factors of soil formation control four general processes responsible for soil formation:

Transformation -weathering / synthesis of minerals and decomposition / synthesis of organic matter.

Translocation -movement of mineral and organic soil constituents in the developing soil profile.

Addition -as of organic matter or by deposition.

Loss -as by leaching of soluble constituents or due to erosion.

Example of Soil Genesis

Assume uniform parent material (loess) at time zero.

1. Production of organic matter by plants. Roots proliferate in the soil and organic debris litters the surface of parent material. Addition.

2. Nonliving organic matter is biochemically altered by microorganisms and physically incorporated into the surface as by earthworms. Transformation.

50 years

3. Weathering and transport of weathering products takes longer. Soluble salts are dissolved and transported downward by percolating water. Depending on rainfall and internal drainage, salts may be lost or precipitated at a lower depth. Organic acids accelerate weathering of minerals and secondary minerals are formed. Accumulation of organic matter extends deeper into the surface soil. Clay minerals are moved by water from near the soil surface to deeper in the developing profile. Transformation and translocation.

2,500 years

4. With sufficient secondary accumulation of clay, structure develops

10,000 years

Designations of Soil Profile Horizons

Besides the five master horizons there are subordinate and transitional horizons.

Subordinate horizons include:

Ap	Plow layer
Bt	Accumulation of silicate clay
Bs	Organic matter and Al and Fe oxides
Bx	Fragipan (dense and brittle)

Transitional horizons are gradations from one master horizon to another such as AE, EB, BE and BC.