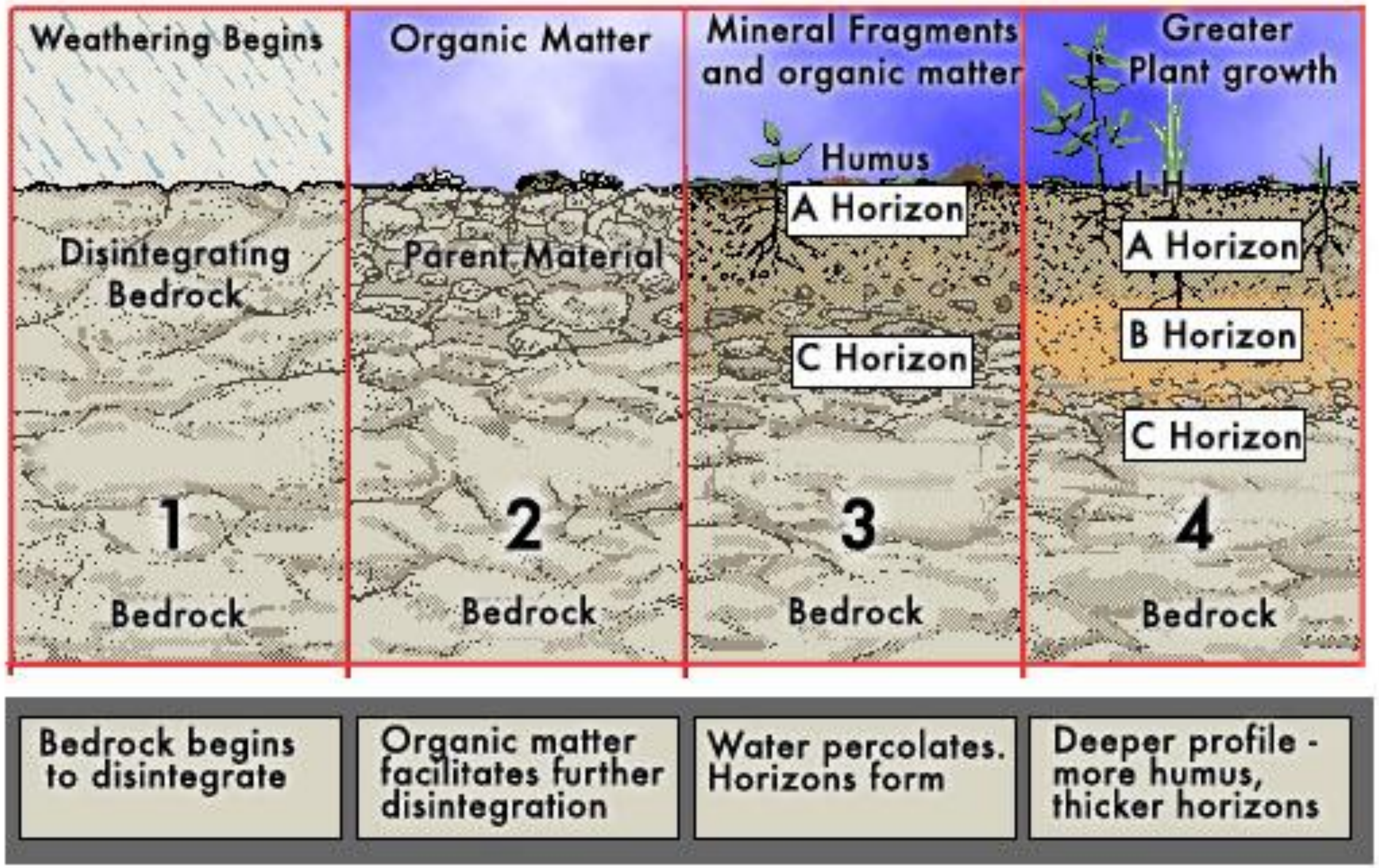
The Lithosphere

OUTLINE

Reflection 3

This week we review the difference between short and long wave radiation and the effects they can have on the surface of the Earth. We reviewed how the difference in the chemical make-up of the atmosphere can dictate the absorption rate of the solar radiation which in turn affects the temperature on the surface of the Earth, human health, and environmental function. We discuss how humans are altering the chemical make up of the atmosphere. Even though carbon dioxide has a residence life of 5 years, it will take hundreds of years to return to our prior steady state. We as humans are altering the steady state of the chemical make up of our atmosphere by creating a new steady state. This happens because the speed of the removal of carbon dioxide is dependent on the processes that are removing it. Carbon that is removed by photosynthesis is more readily available because it is trapped in organic material vs carbon dioxide that is mineralized. The process of releasing carbon dioxide that was mineralized takes place over a longer time frame. We then run into the issue of inputs, many human induced, being greater than the outputs. The human induced inputs include releasing large amounts of Nitrogen which affect how carbon dioxide interacts with ozone altering the stoichiometry. Even though we have increased the inputs, the outputs of mineralization do not necessarily speed up. Additionally, we can consider the current rate at which carbon dioxide mineralizes a steady state.

Soil Formation



Soil-forming processes

1. Soil enrichment
2. Removal
3. Translocation
4. Transformation

TABLE 4.1 Approximate Mean Composition of Earth's Continental Crust

Constituent	Percentage composition
Si	28.8
Al	7.96
Fe	4.32
Ca	3.85
Na	2.36
Mg	2.20
K	2.14
Ti	0.40
P	0.076
Mn	0.072
S	0.070

Source: Data from Wedepohl (1995).

Physical and Chemical Weathering

Siever (1974) proposed a basic equation to summarize the close linkage between the Earth's atmosphere and its crust:

$$\text{Igneous Rocks} + \text{Acid Volatiles} = \text{Sedimentary Rocks} + \text{Salty Oceans.} \tag{4.1}$$

This formula recognizes that through geologic time the primary minerals of the Earth's crust have been exposed to reactive, acid-forming C, N, and S gases of the atmosphere. The products of the reaction are carried to the oceans, where they accumulate as dissolved salts or in ocean sediments (Li 1972). Large amounts of sedimentary rock have formed through geologic time; indeed, about two-thirds of the rocks now exposed on land are sedimentary rocks that have been uplifted by tectonic activity (Durr et al. 2005, Suchet et al. 2003, Wilkinson et al. 2010). With their uplift, these sedimentary rocks are subject to further weathering reactions with acid volatiles, in accord with Siever's basic equation. Eventually, geologic processes, known as subduction, carry sedimentary rocks to the deep Earth, where CO_2 is released and the solid constituents are converted back to primary minerals under great heat and pressure (Figure 1.3; see also Siever 1974).

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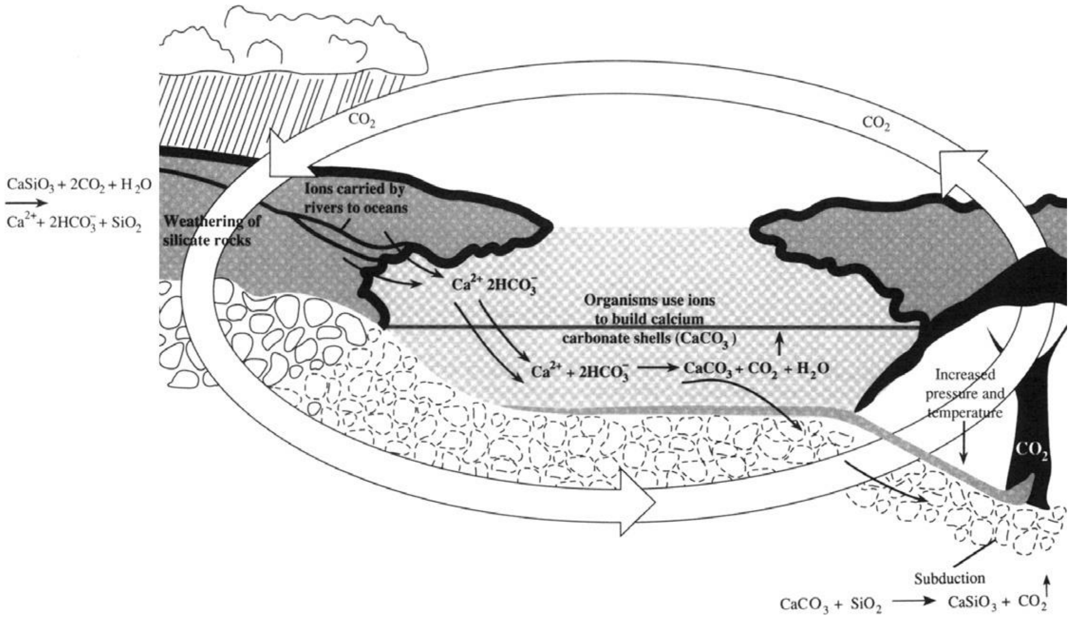


FIGURE 1.3 The interaction between the carbonate and the silicate cycles at the surface of Earth. Long-term control of atmospheric CO_2 is achieved by dissolution of CO_2 in surface waters and its participation in the weathering of rocks. This carbon is carried to the sea as bicarbonate (HCO_3^-), and it is eventually buried as part of carbonate sediments in the oceanic crust. CO_2 is released back to the atmosphere when these rocks undergo metamorphism at high temperature and pressures deep in Earth. *Source: Modified from Kasting et al. (1988).*

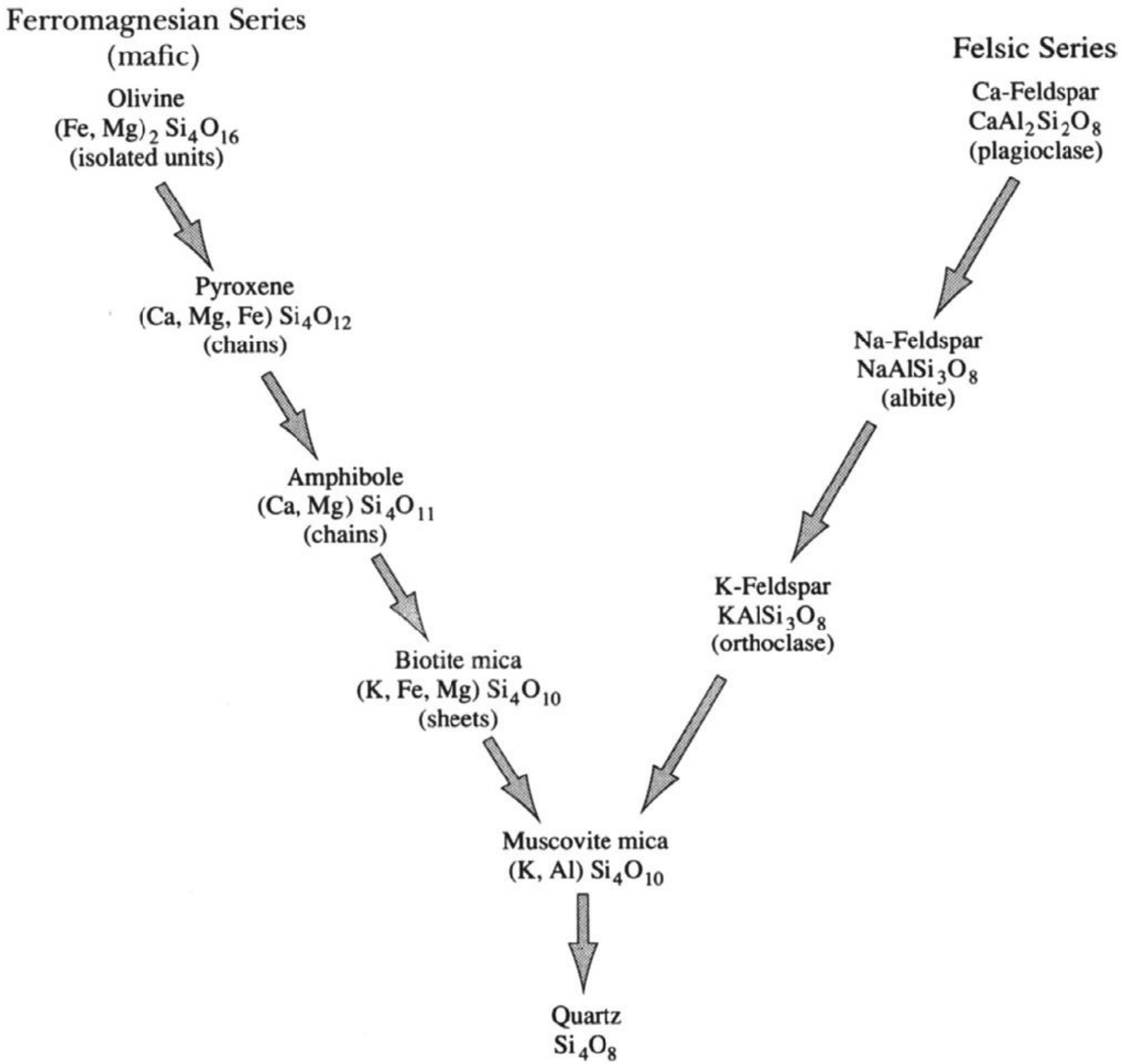
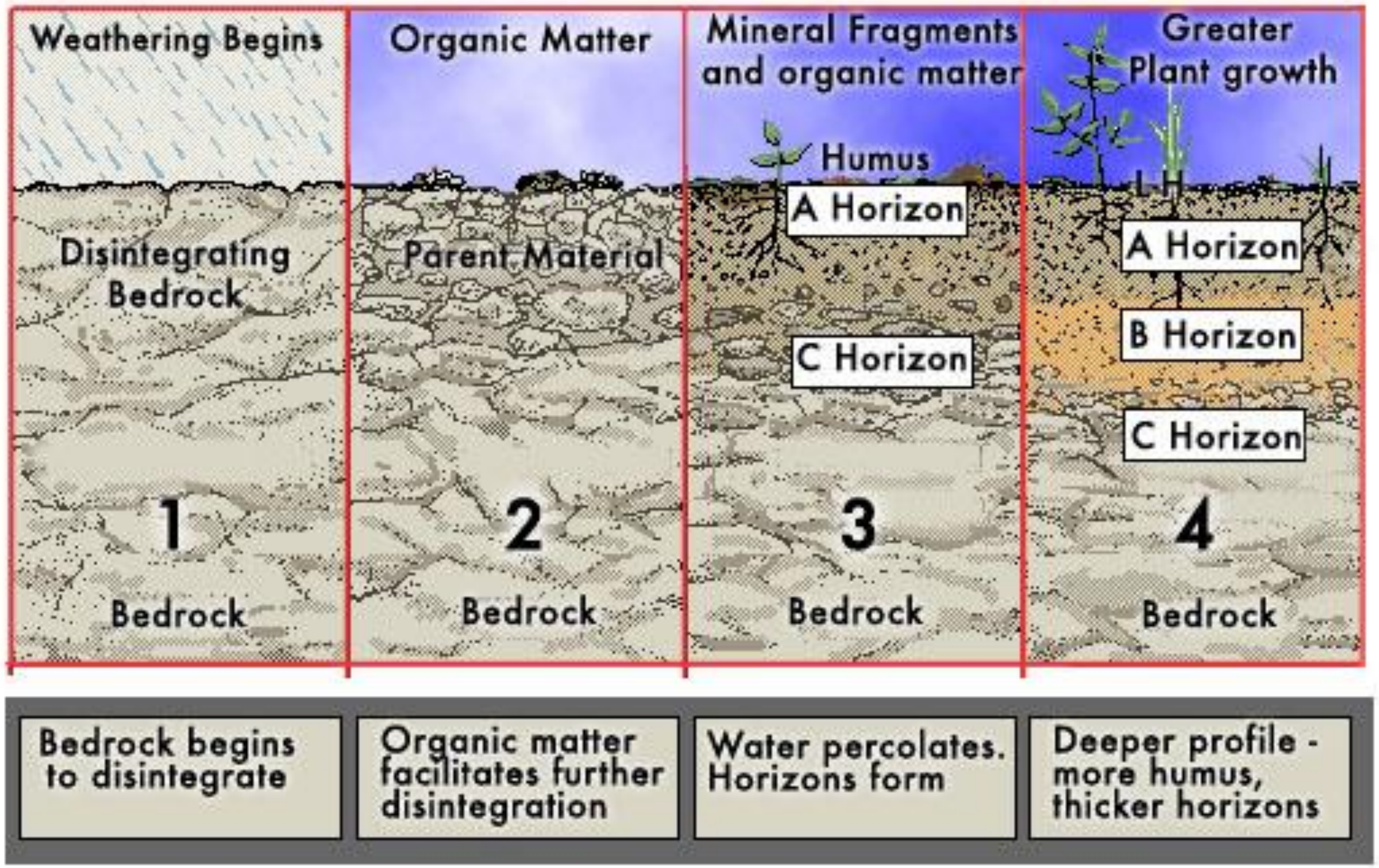


FIGURE 4.1 Silicate minerals are divided into two classes, the ferromagnesian series and the felsic series, based on the presence of Mg or Al in the crystal structure. Among the ferromagnesian series, minerals that exist as isolated crystal units (e.g., olivine) are most susceptible to weathering, while those showing linkage of crystal units and a lower ratio of oxygen to silicon are more resistant. Among the felsic series, Ca-feldspar (plagioclase) is more susceptible to weathering than Na-feldspar (albite) and K-feldspar (orthoclase). Quartz is the most resistant of all. This weathering series is the reverse of the order in which these minerals are precipitated during the cooling of magma.

Soil Formation



Soil-forming processes

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Chemical Weathering

The dominant form of chemical weathering is the carbonation reaction, driven by the formation of carbonic acid, H_2CO_3, in the soil solution:

$$H_2O + CO_2 \leftrightarrow H^+ + HCO_3^- \leftrightarrow H_2CO_3. \tag{4.2}$$

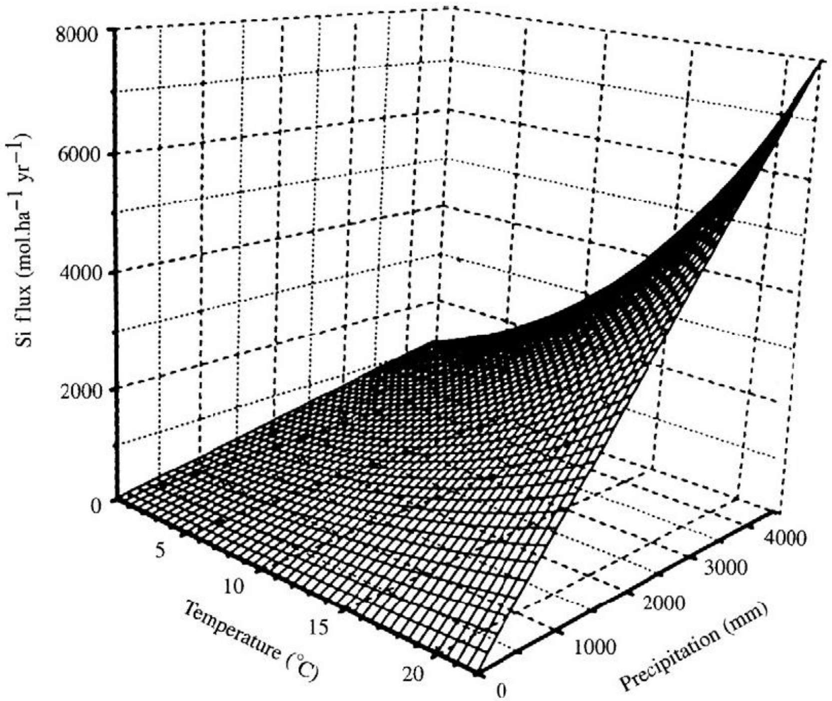


FIGURE 4.2 Loss of silicon (SiO_2) in runoff as a function of mean annual temperature and precipitation in various areas of the world. *Source: Modified from White and Blum (1995).*

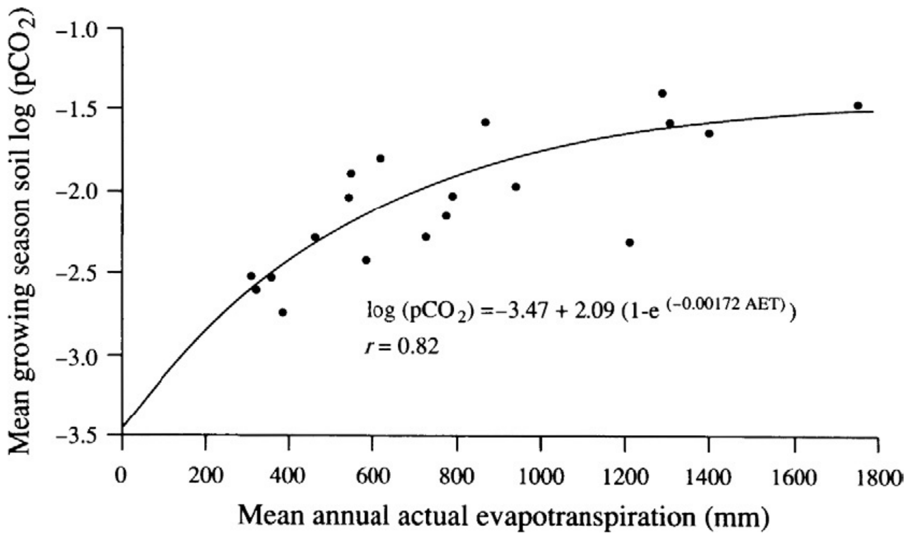
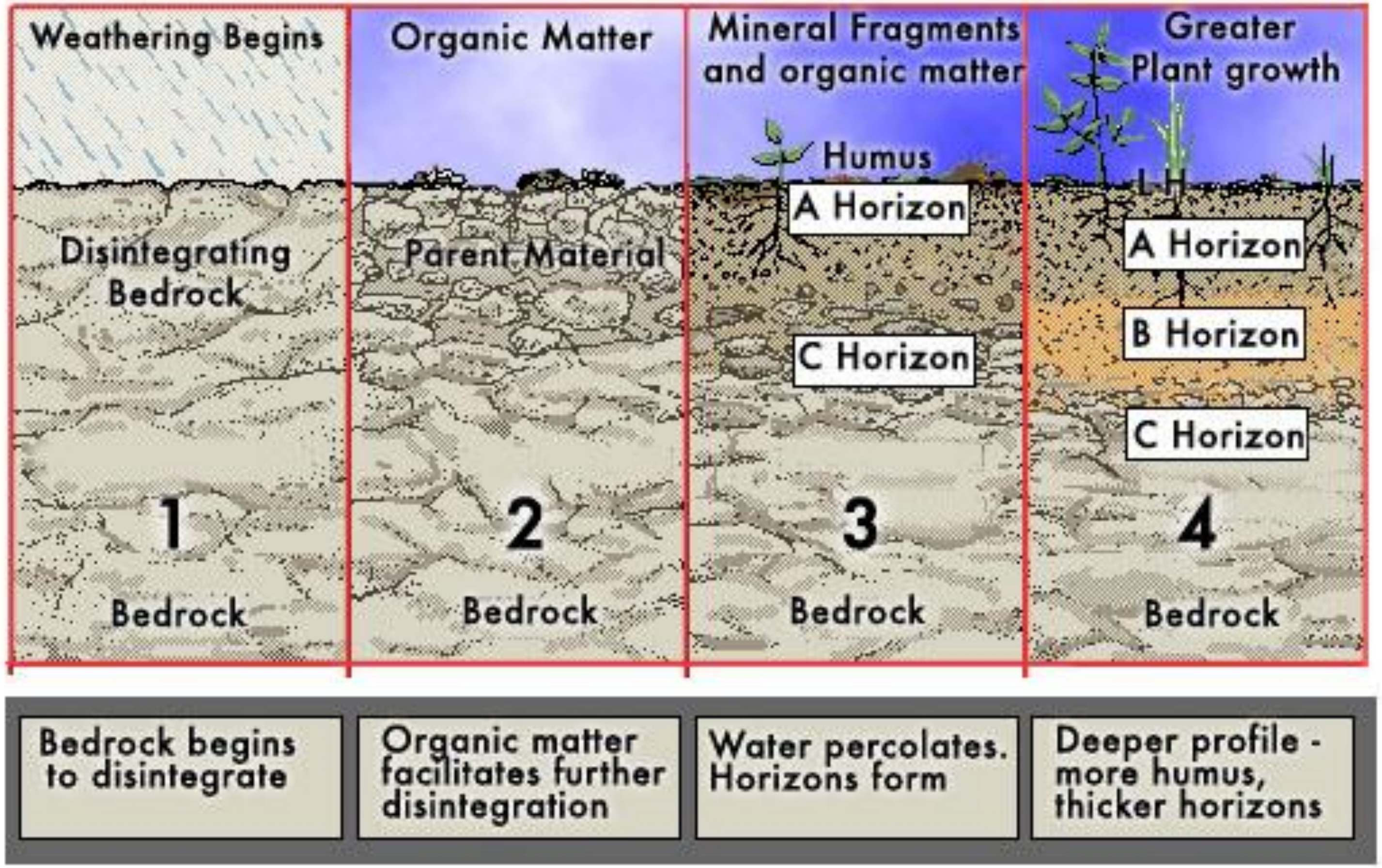


FIGURE 4.3 The relationship between the mean concentration of CO_2 in the soil pore space and the actual evapotranspiration of the site for various ecosystems of the world. *Source: From Brook et al. (1983).*

Soil Formation



Soil-forming processes

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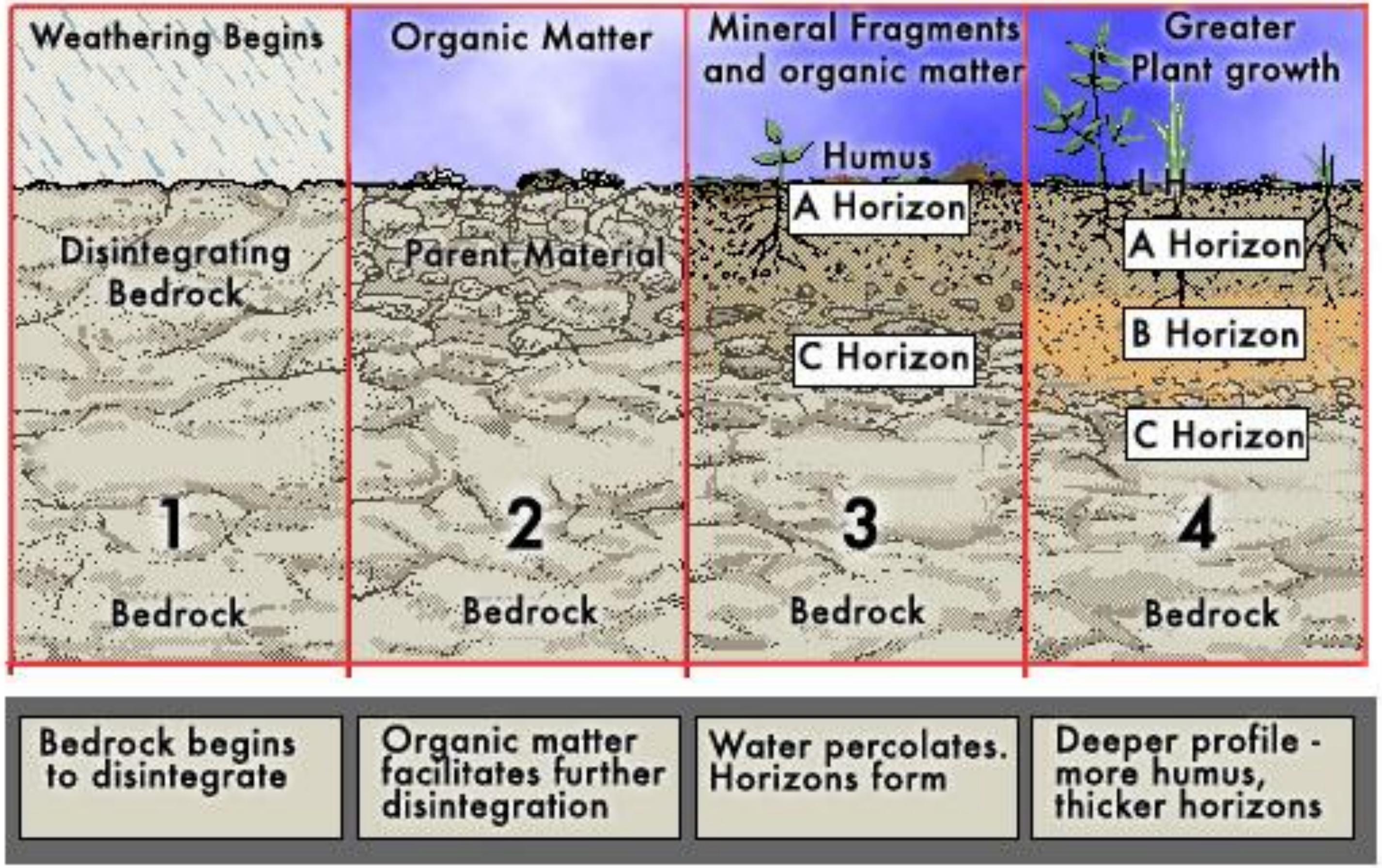
Soil Formation



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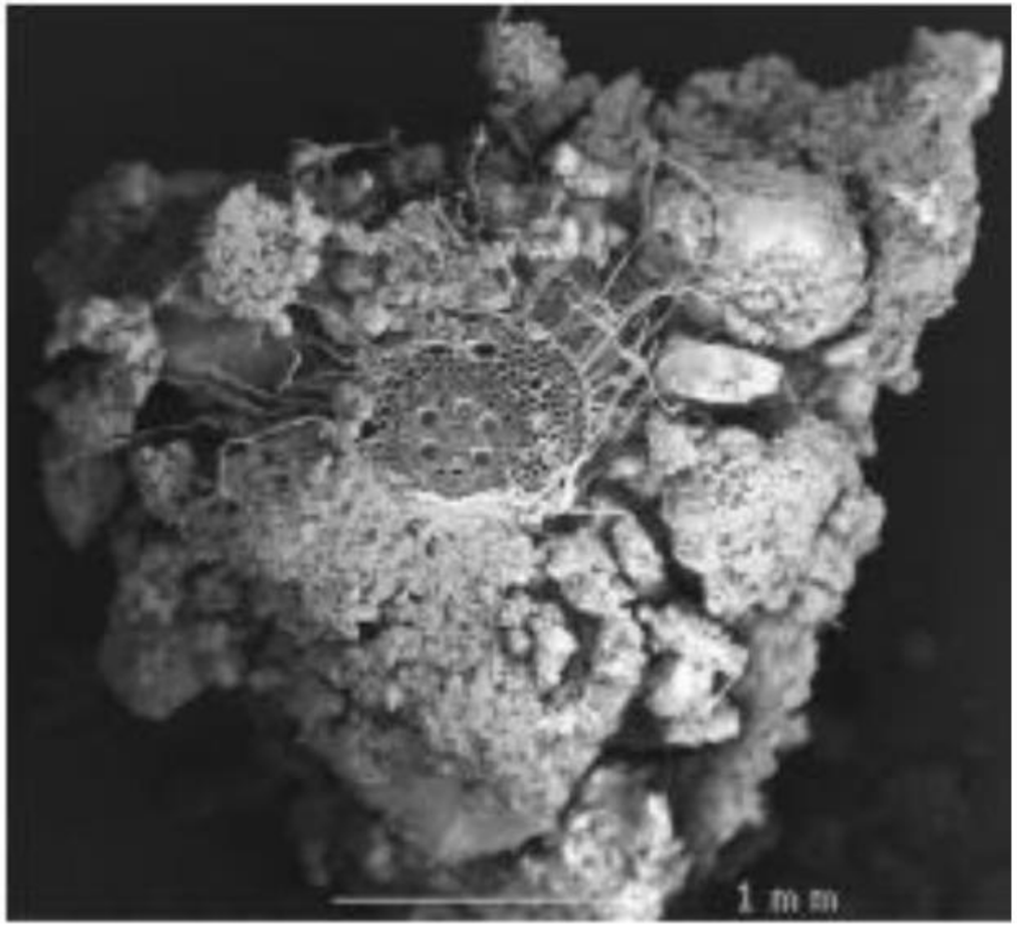
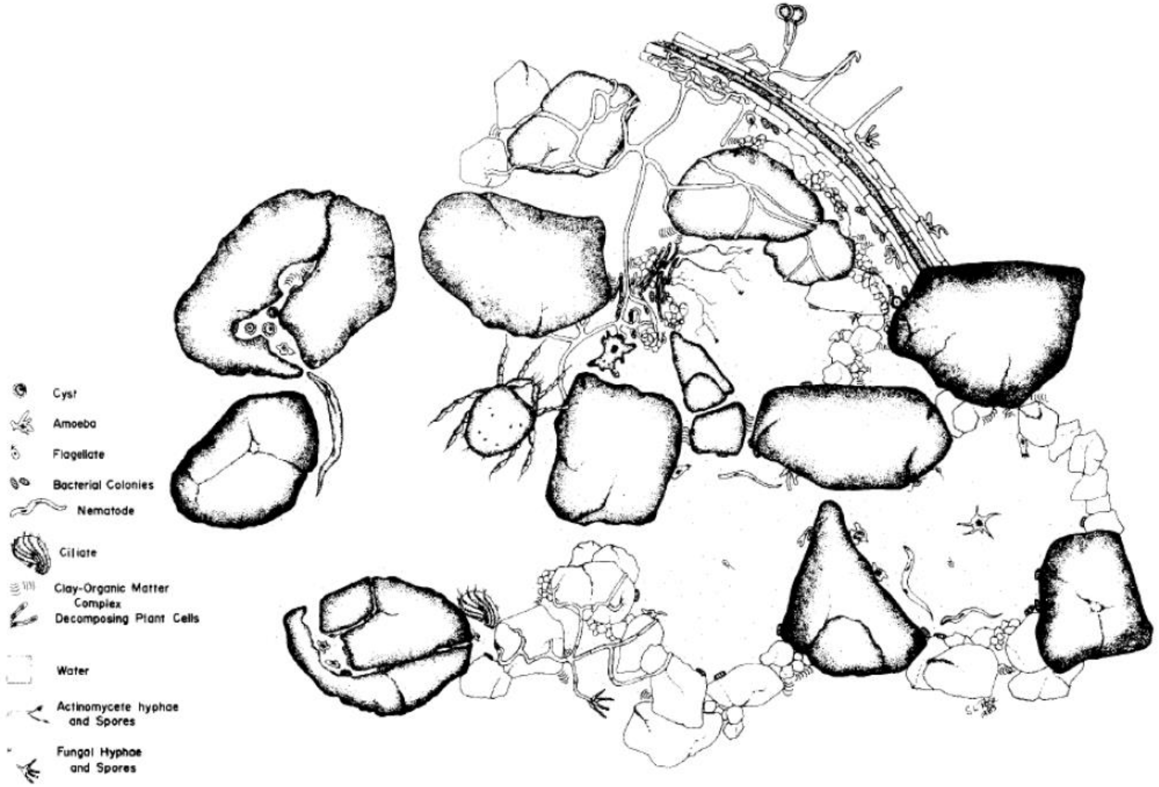
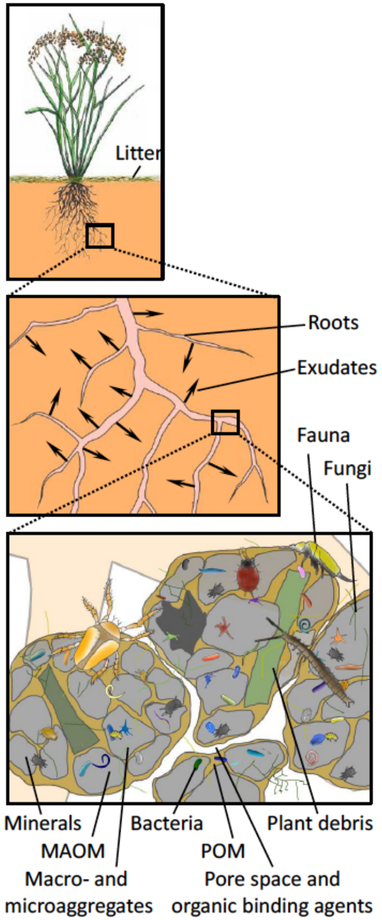
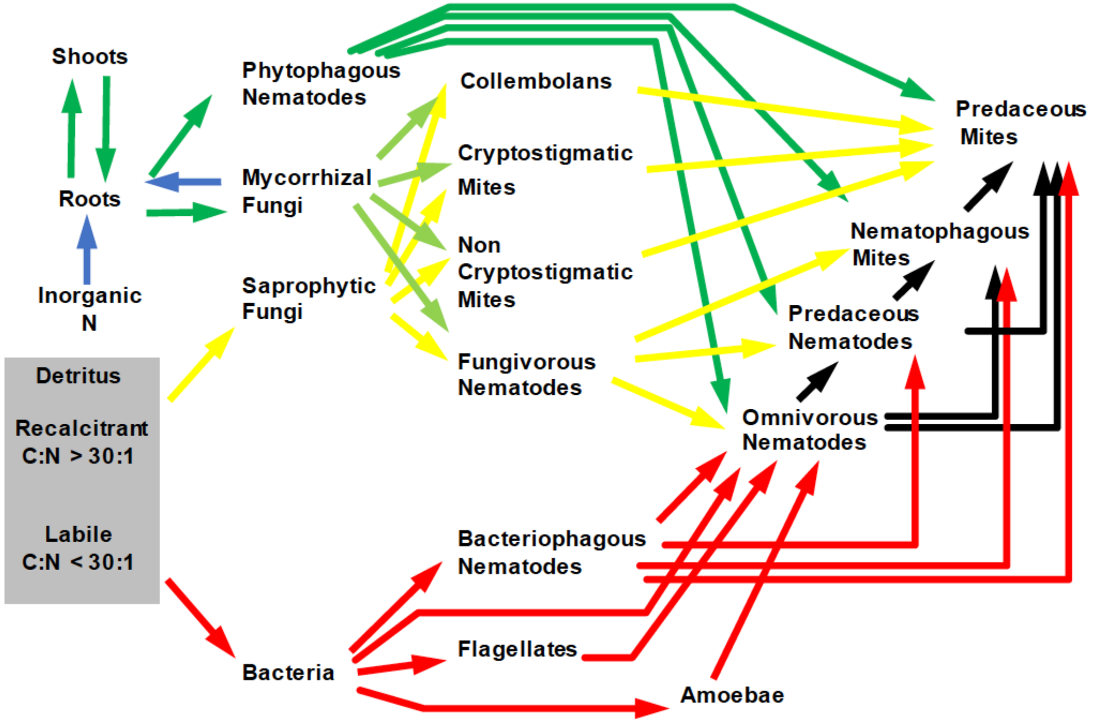
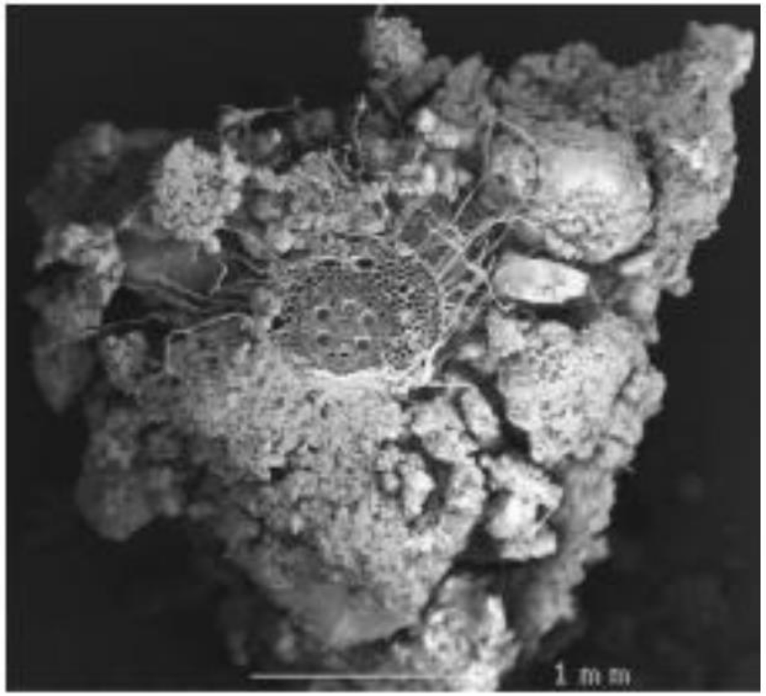




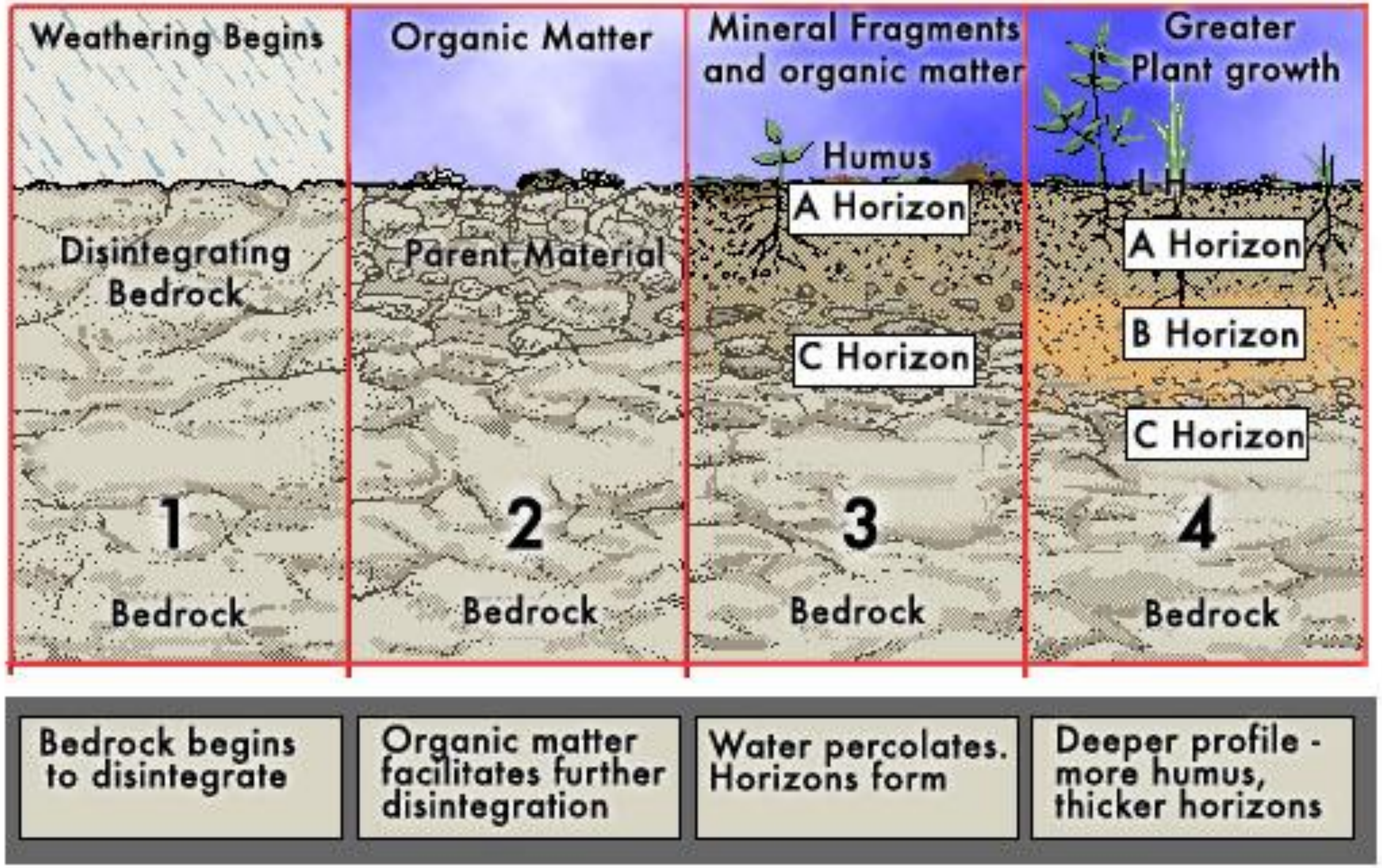
Biological Activity







Soil Formation



Soil-forming processes

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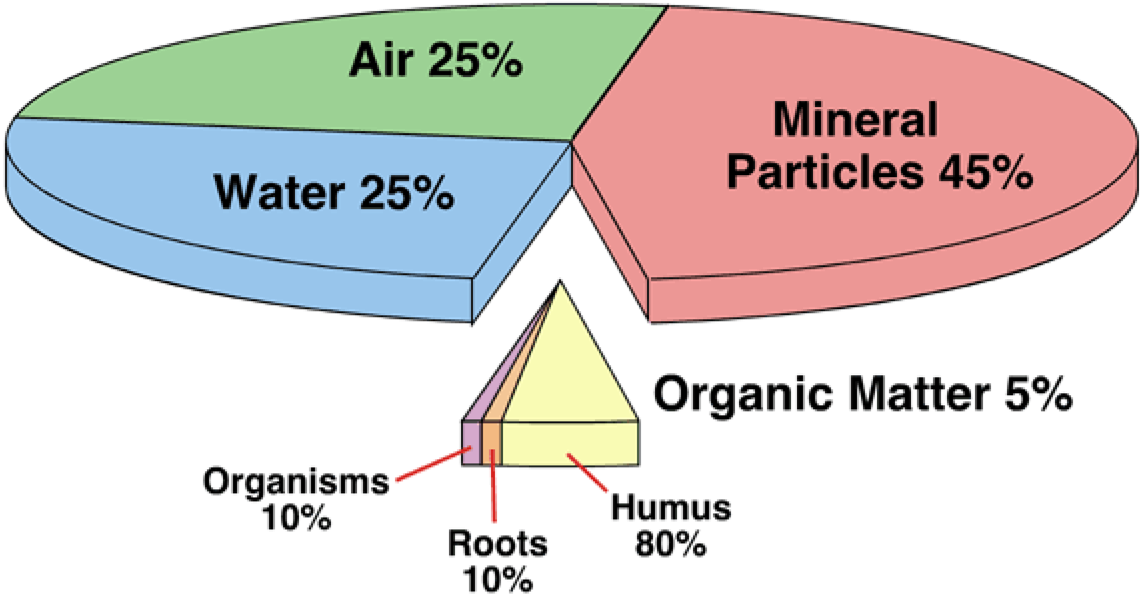
The Composition of Fertile Soil

Components of Soil

- Soil contains:
  - Mineral matter from rock material
  - Organic matter

  Humus: finely divided, partially decomposed organic matter in soils
  - Air
  - Water



Most soils contain four basic components: mineral particles, water, air, and organic matter. Organic matter can be further sub-divided into humus, roots, and living organisms. The values given above are for an average soil.

Soil Formation

$s = f(cl, o, r, p, t, \ldots)$ Jenny (1941)

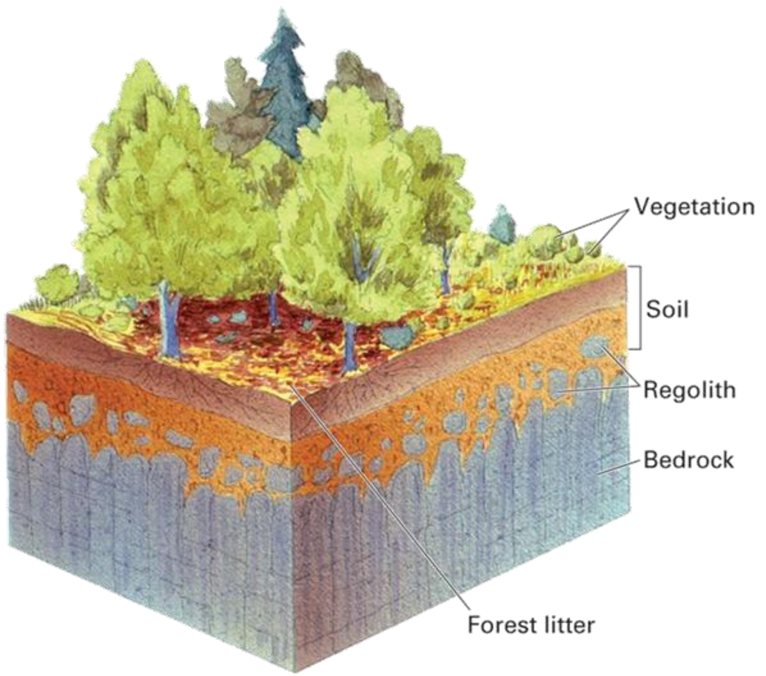
Weathering products hang around and continue to interact with weathering agents and parent material. The result is soil.

Soil

A natural terrestrial surface layer containing living matter and supporting, or capable of supporting plants.

Regolith [Greek: Rhegos - "blanket" + Lithos - "rock"]: The blanket of unconsolidated particulate material lying on top of bedrock. Regolith need not necessarily contain any organic content.

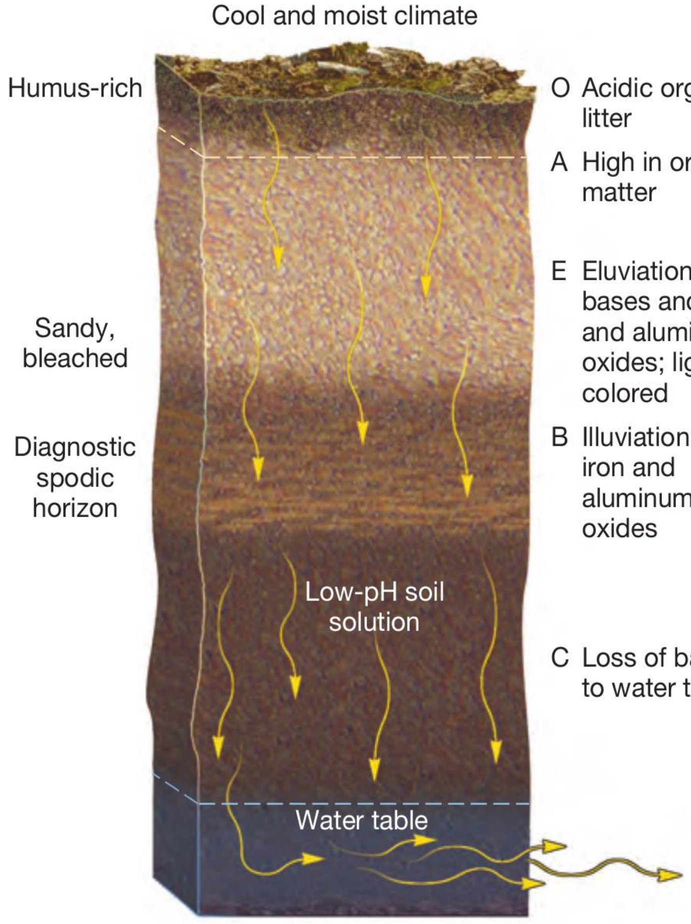
Parent material: The inorganic material base from which soil is formed.



Soil Development and Soil Profiles

s = f(cl, o, r, p, t, ...)   Jenny (1941)

- **C**limate
- **O**rganisms
- **R**elief and topography
- **P**arent material - the underlying geologic material
- **T**ime



Soil Texture

Soil texture

Soil texture is a descriptive property of the mineral portion of soil based on varying proportions of sand, silt and clay.

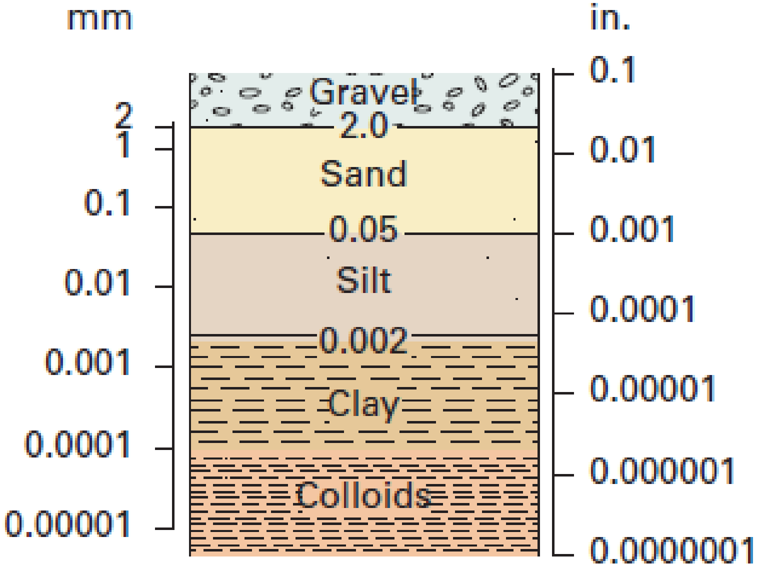
Soil texture determines water holding ability:

•Coarse-textured (sandy) soils allow water to pass through
•Fine-textured soils hold water

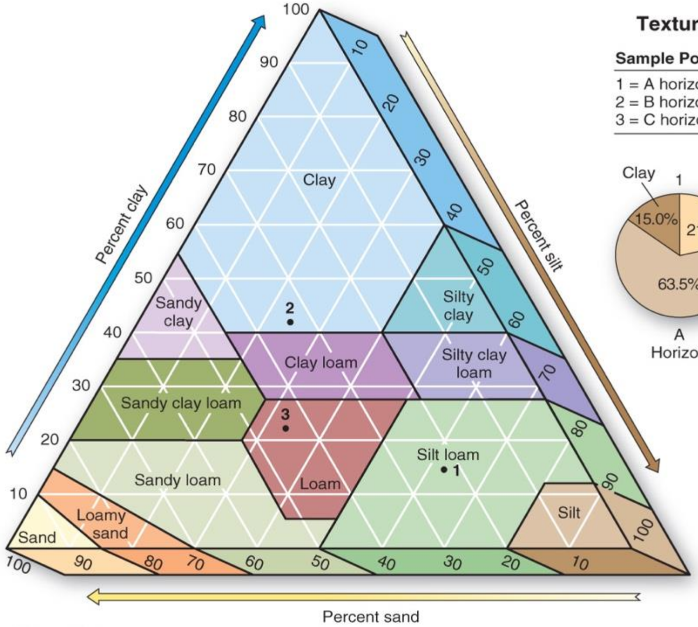
Soil porosity refers to the amount of pore, or open space between soil particles.

Permeability is the degree of connectivity between soil pores. A highly permeable soil is one in which water runs through it quite readily.

Mineral particle sizes

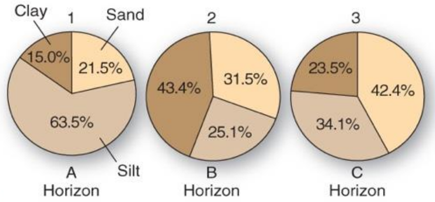


Soil Texture Classification



Textural Analysis of Miami Silt Loam

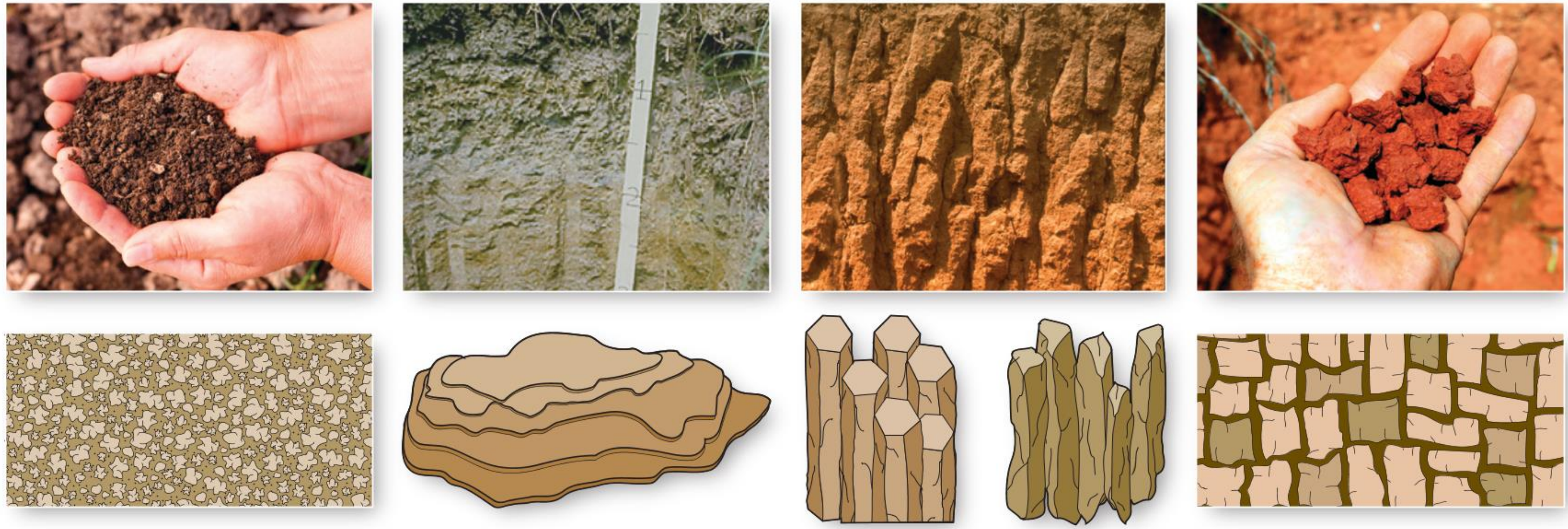
Sample Points	% Sand	% Silt	% Clay
1 = A horizon	21.5	63.5	15.0
2 = B horizon	31.5	25.1	43.4
3 = C horizon	42.4	34.1	23.5



Loam: soil with substantial proportion of each of the three size classes

Types of Soil Structure

- Soil texture describes the size of soil particles.
- Soil structure refers to their arrangement
- The smallest natural lump or cluster of particles is a ped.
- The shape of soil peds determines which of the structure types the soil exhibits: crumb or granular, platy, block, prismatic, or columnar.
- Terms used to describe soil structure include fine, medium, or coarse.



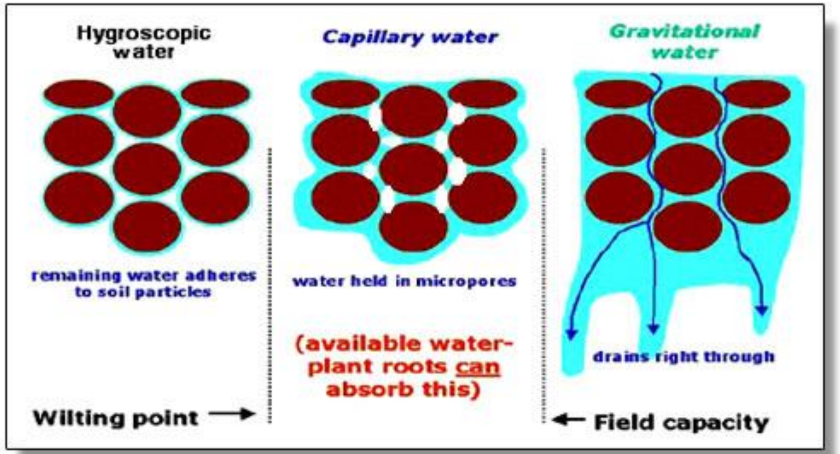
(a) Crumb or granular (b) Platy (c) Prismatic or columnar (d) Blocky

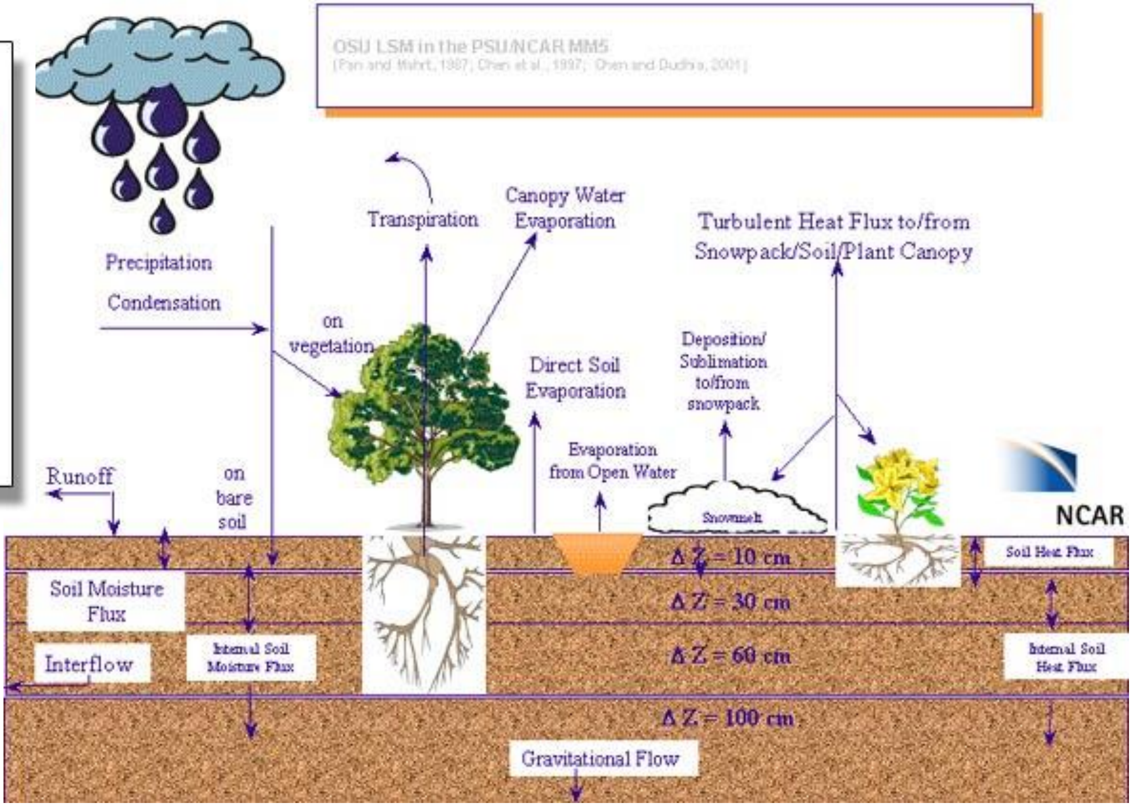
Figure 15.7

Soil Moisture

Soil moisture

The soil layer is also a reservoir of moisture for plants. Soil moisture is a key factor in determining how the soils of a region support vegetation and crops.





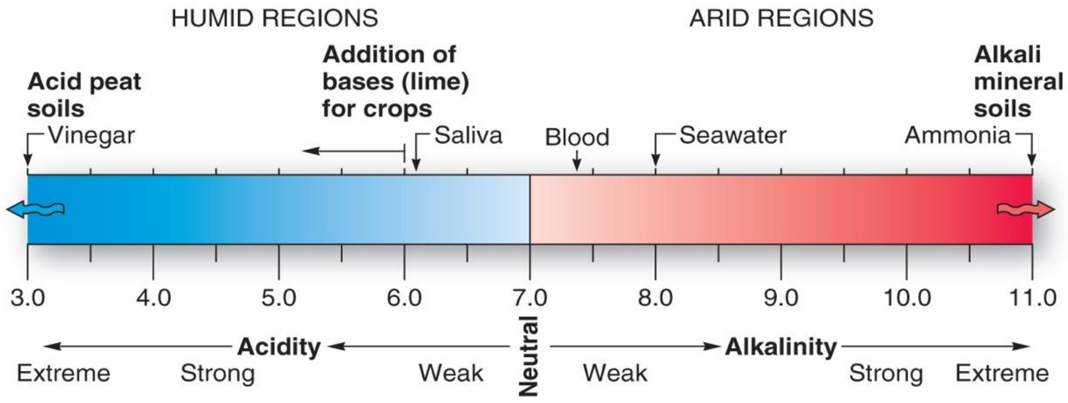
Water from precipitation may:

- Run off
- Evaporate/transpire
- Move down to ground water
- Be retained in soil

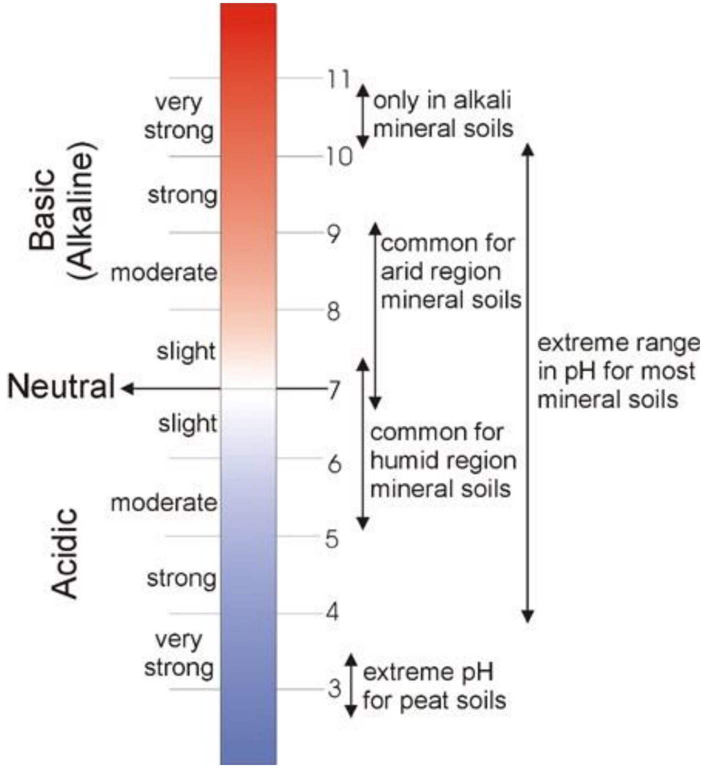
- Water is held in soil by ***capillary tension***
- Storage capacity of soil: amount of water left in soil after soil is saturated and water has drained
- ***Wilting point***: storage level below which plants will wilt
- ***Water capacity***: difference between storage capacity and wilting point. Water capacity is greatest in loam soils

Soil Chemistry

- Water in soil pores is the soil solution.
- A soil rich in hydrogen ions (cations) is an acid soil.
- A soil high in base cations (calcium, sodium) is a basic or alkaline soil.
- Tiny particles of clay or organic material are soil colloids.
- Soil colloids are crucial to soil fertility.



Soil Acidity and Alkalinity

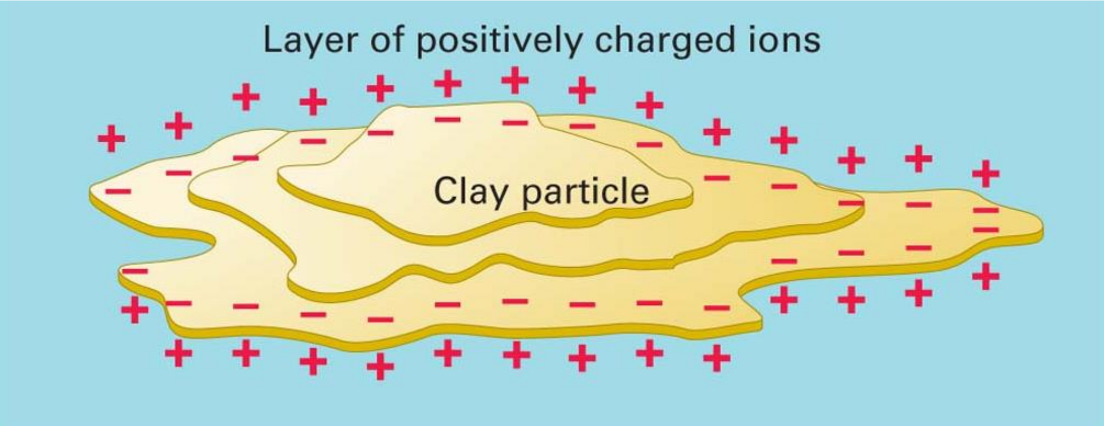


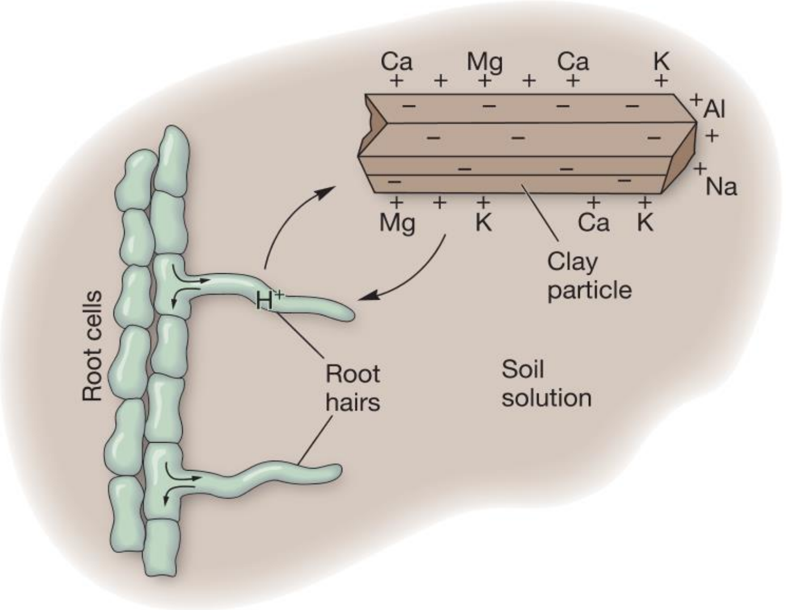
Hydrogen ion concentration in the soil is measured in terms of the pH scale. Soil pH ranges from 3 to 10. Pure water has a pH of 7 which is considered neutral, pH values greater than seven are considered basic or alkaline, below seven acidic. Most good agricultural soils have a pH between 5 and 7. Though acidic soils pose a problem for agriculture due to their lack of nutrients, alkaline soils can pose a problem as well. Alkaline soils may contain appreciable amounts of sodium that exceed the tolerances of plants, contribute to high bulk density and poor soil structure. Alkaline soils are common in semiarid regions.

Soil Colloids and CEC

Soil colloids
Extremely small mineral or organic particles that can remain suspended in water indefinitely.
Positively charged plant nutrient ions, such as calcium, magnesium, potassium and sodium, are called ***bases***.
Soil colloids attract and retain base soil nutrients

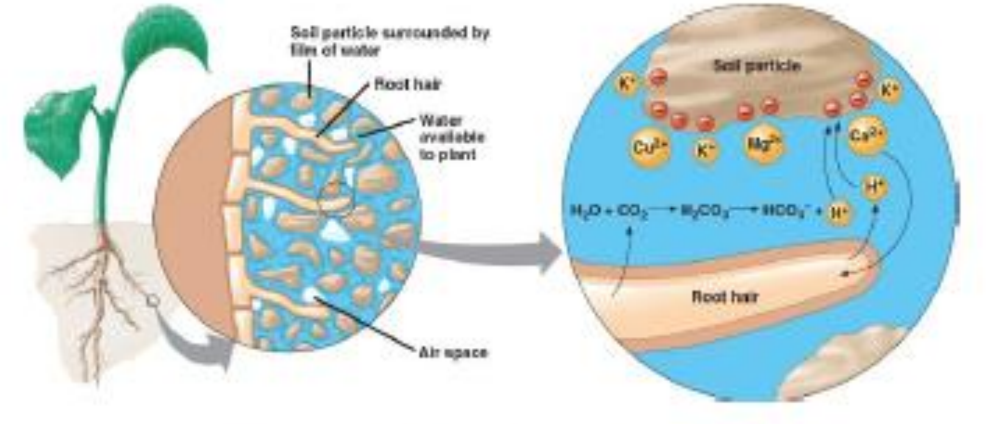
Cation-Exchange Capacity
the amount of positive charge that can be exchanged per mass of soil, usually measured in cmolc/kg.





Effects of Acid Rain on Soil Acidity and Alkalinity

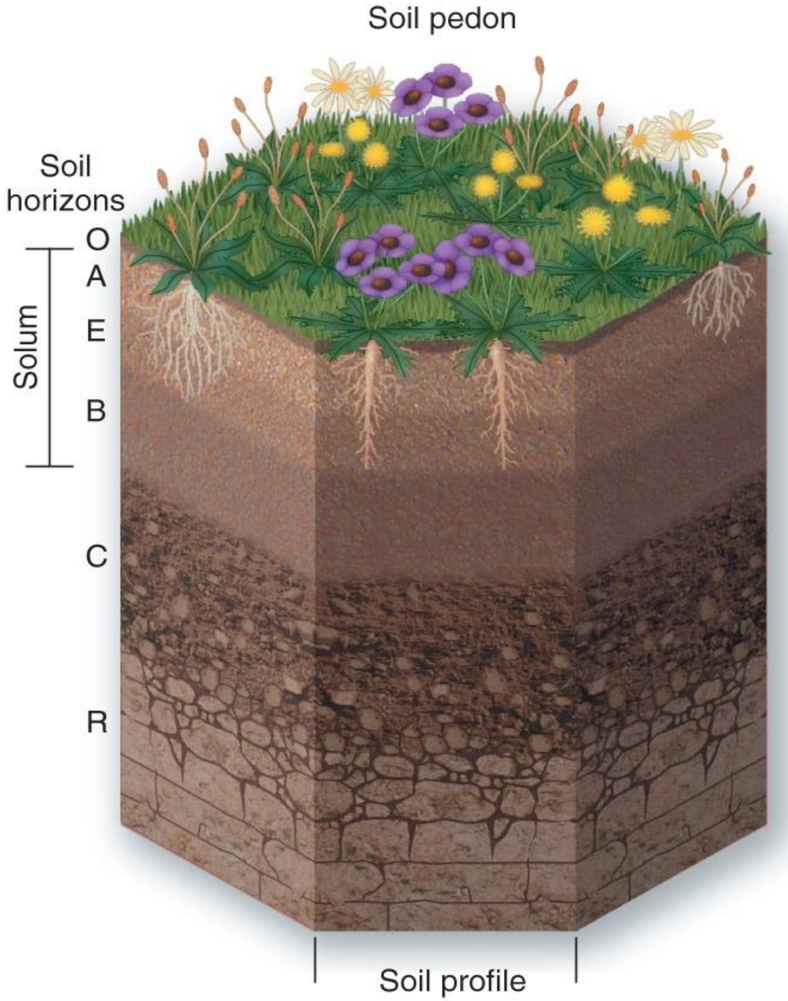
- Acid precipitation is the major contributor to soil acidity.
- Some measurements have shown that acid rain pH is below 2.0.
- High soil acidity can accelerate the chemical weathering of mineral nutrients and increase their depletion rates.
- If soil pH is below 6.0, soil treatment is needed, such as adding alkaline minerals (e.g., calcium carbonate).



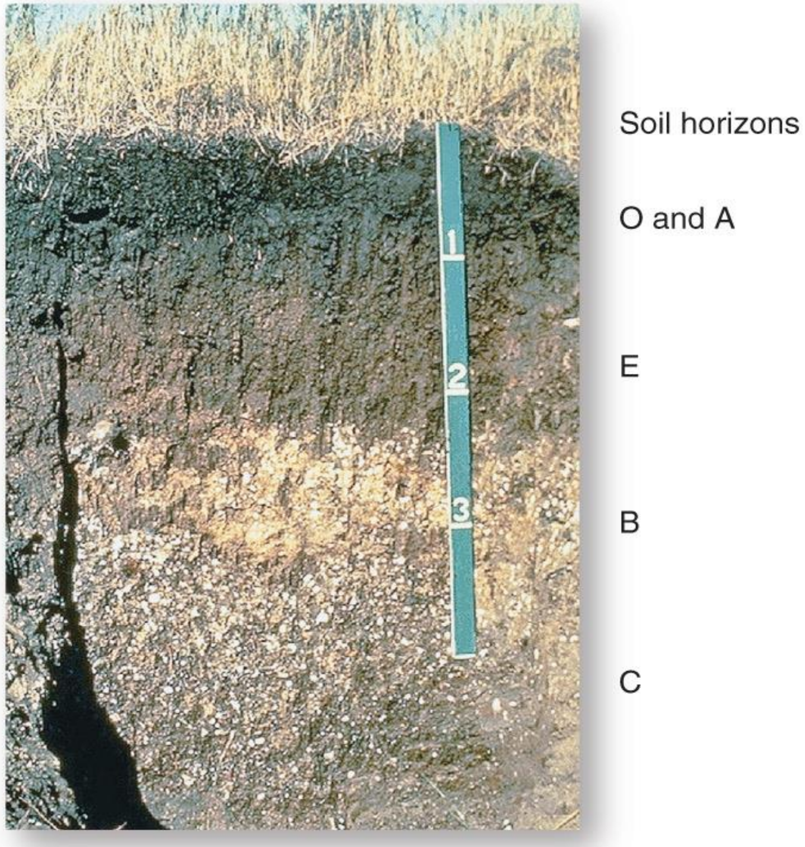
Cation Exchange Capacity Illustration. Photo Source

Soil Horizons

Most soils have a distinct profile or sequence of horizontal layers. Generally, these horizons result from the processes of chemical weathering, eluviation, illuviation, and organic decomposition. Up to five layers can be present in a typical soil: **O**, **A**, **B**, **C**, and **R horizons**



(a) An idealized soil profile within a pedon.



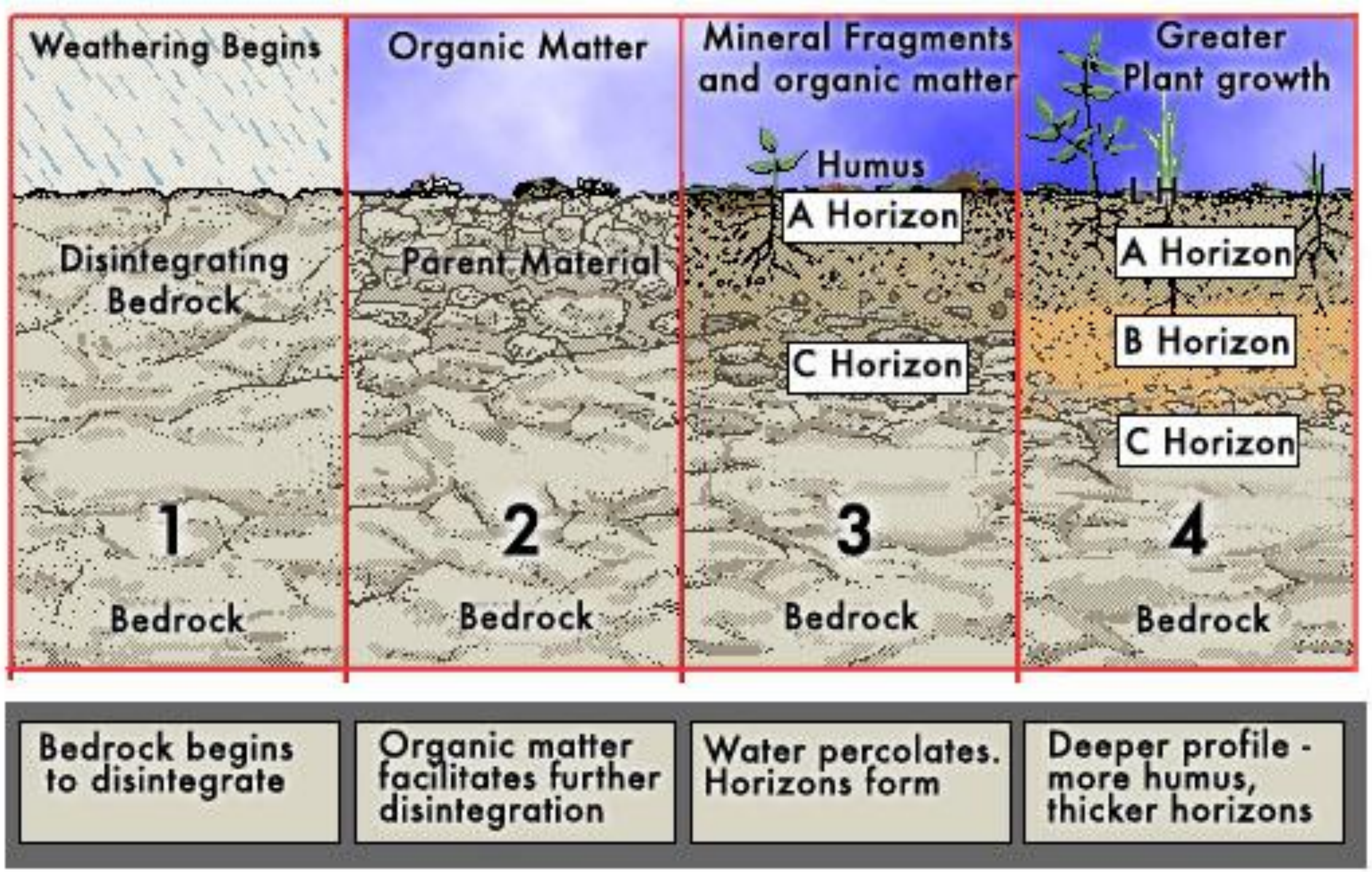
(b) Profile of a well-drained soil with till as parental material (a Mollisol) in southeastern South Dakota. Carbonate nodules are visible in the lower B and upper C horizons.

Figure 15.5

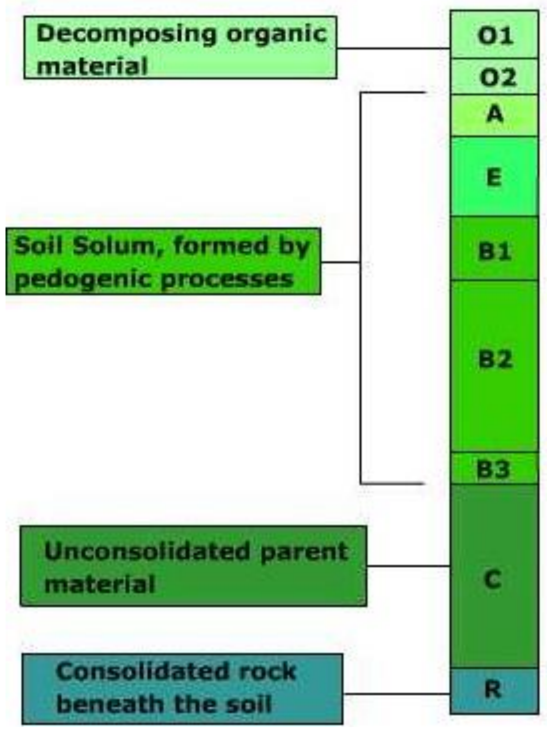
Soil Formation

Soil-forming processes

1. Soil enrichment
2. Removal
3. Translocation
4. Transformation



Soil Horizons

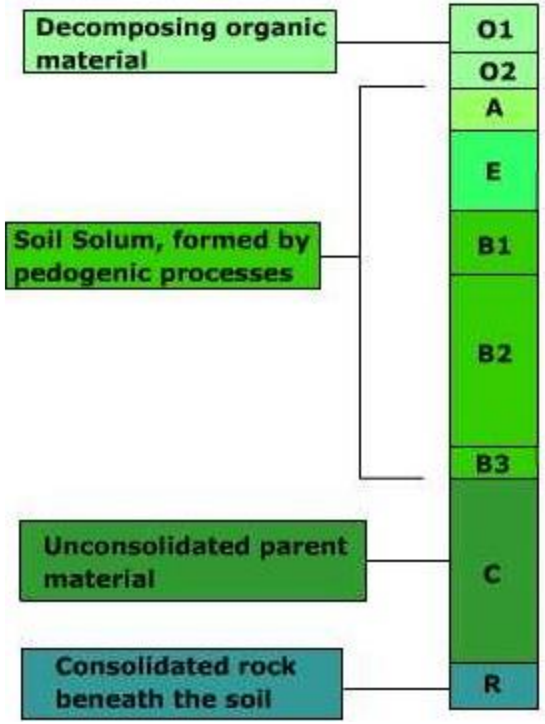


A Typical Soil Profile

O Horizon

At the top of the profile is the O horizon. The O horizon is primarily composed of organic matter. Fresh litter is found at the surface, while at depth all signs of vegetation structure has been destroyed by decomposition. The decomposed organic matter, or humus, enriches the soil with nutrients (nitrogen, potassium, etc.), aids soil structure (acts to bind particles), and enhances soil moisture retention.

Soil Horizons



A Typical Soil Profile

A Horizon

Beneath the O horizon is the A horizon. The A horizon marks the beginning of the true mineral soil. In this horizon organic material mixes with inorganic products of weathering. The A horizon typically is dark colored horizon due to the presence organic matter. ***Eluviation***, the removal of inorganic and organic substances from a horizon by leaching occurs in the A horizon. Eluviation is driven by the downward movement of soil water.

TABLE 4.2 Chemical Composition of Precipitation, Soil Solutions, and Groundwater in a 175-year-old *Abies amabilis* Stand in Northern Washington

			Soluble ions (mg/liter)			Total (mg/liter)	
Solution	**pH**	**Total cations (mEq/liter)**	**Fe**	**Si**	**Al**	**N**	**P**
Precipitation							
Above canopy	5.8	0.03	<0.01	0.09	0.03	0.60	0.01
Below canopy	5.0	0.10	0.02	0.09	0.06	0.40	0.05
Forest floor	4.7	0.14	0.04	3.50	0.79	0.54	0.04
Soil							
15 cm E	4.6	0.12	0.04	3.55	0.50	0.41	0.02
30 cm B_s	5.0	0.08	0.01	3.87	0.27	0.20	0.02
60 cm B3	5.6	0.25	0.02	2.90	0.58	0.37	0.03
Groundwater	6.2	0.26	0.01	4.29	0.02	0.14	0.01

Source: Data from Ugolini et al. (1977), Soil Science ***124****: 291–302. Copyright (1977) Williams and Wilkins.*

Soil Formation

Soil-forming processes

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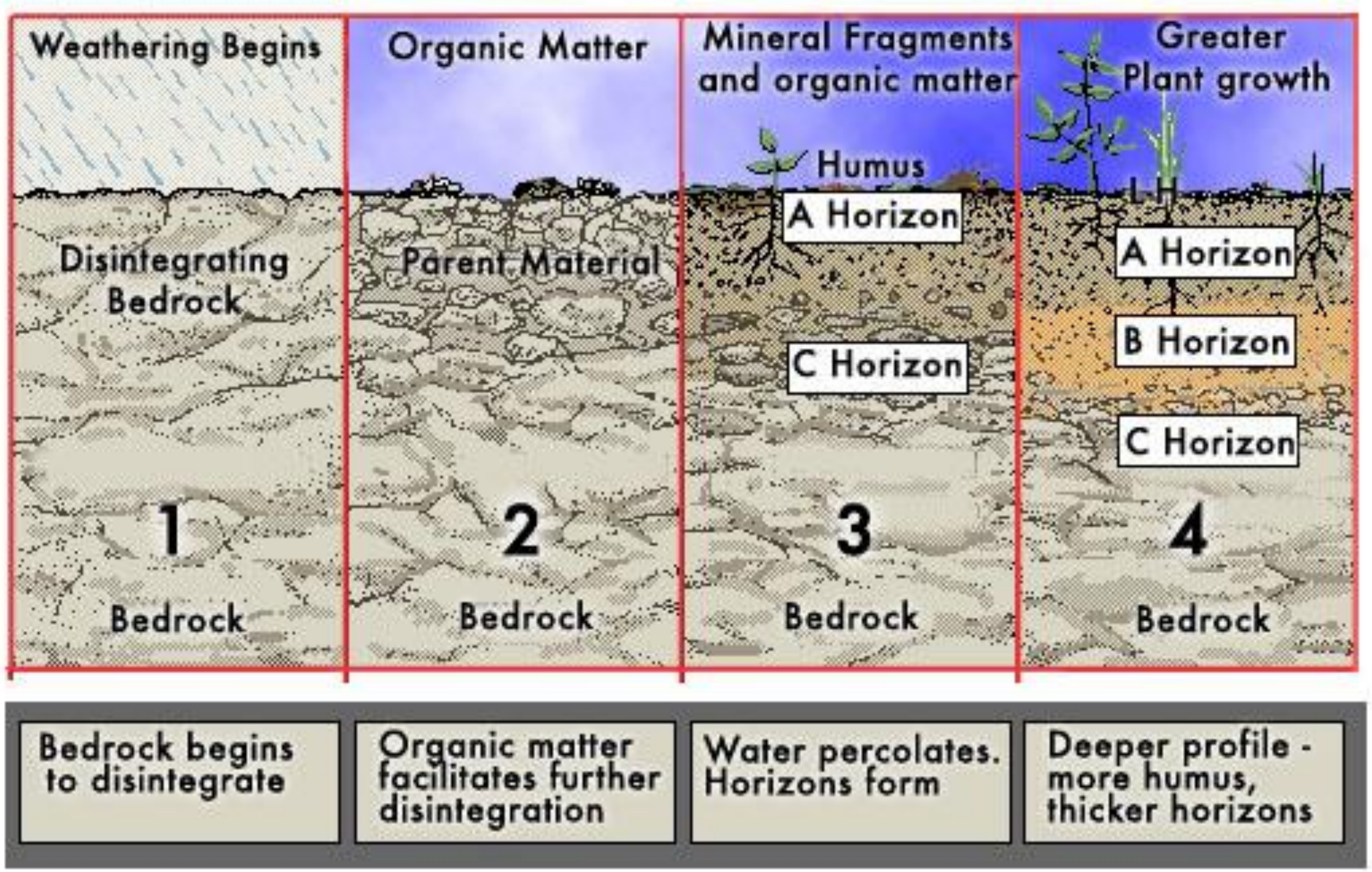
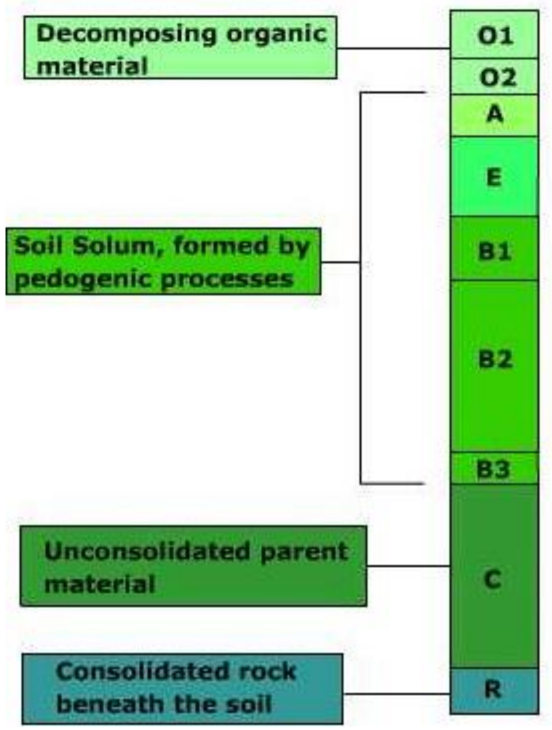


Soil Horizons

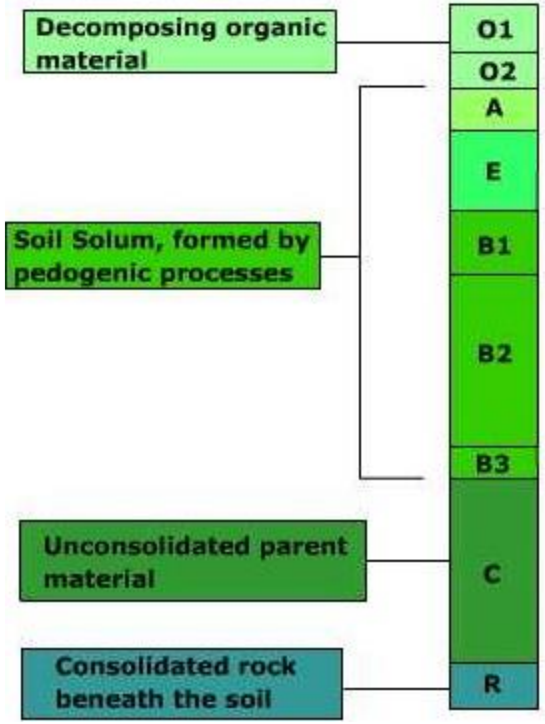


A Typical Soil Profile

E Horizon

The E horizon generally is a light-colored horizon with eluviation being the dominant process. Leaching, or the removal of clay particles, organic matter, and/or oxides of iron and aluminum is active in this horizon. Under coniferous forests, the E horizon often has a high concentration of quartz giving the horizon an ashy-gray appearance.

Soil Horizons

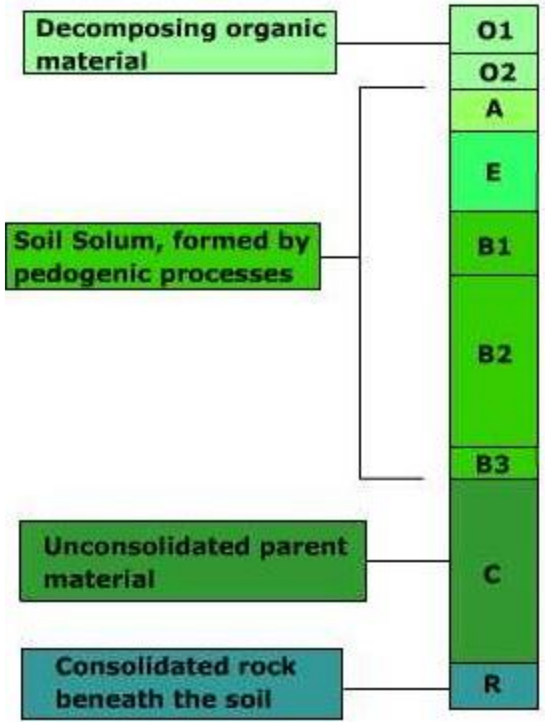


A Typical Soil Profile

B Horizon

Beneath the E horizon lies the B horizon. The B horizon is a zone of ***illuviation*** where downward moving, especially fine material, is accumulated. The accumulation of fine material leads to the creation of a dense layer in the soil. In some soils the B horizon is enriched with calcium carbonate in the form of nodules or as a layer. This occurs when the carbonate precipitates out of downward moving soil water or from capillary action. The diagram below illustrates the effect of climate on eluviation and illuviation. Eluviation is significant in humid climates where ample precipitation exists and a surplus in the water balance occurs. Illuvial layers are found low in the soil profile. Illuvial zones are found closer to the surface in semiarid and arid climates where precipitation is scarce. Capillary action brings cations like calcium and sodium dissolved in soil water upwards where they precipitate from the water.

Soil Horizons



A Typical Soil Profile

C Horizon

The C horizon represents the soil parent material, either created in situ or transported into its present location. Beneath the C horizon lies bedrock.

Soil Formation

Soil-forming processes

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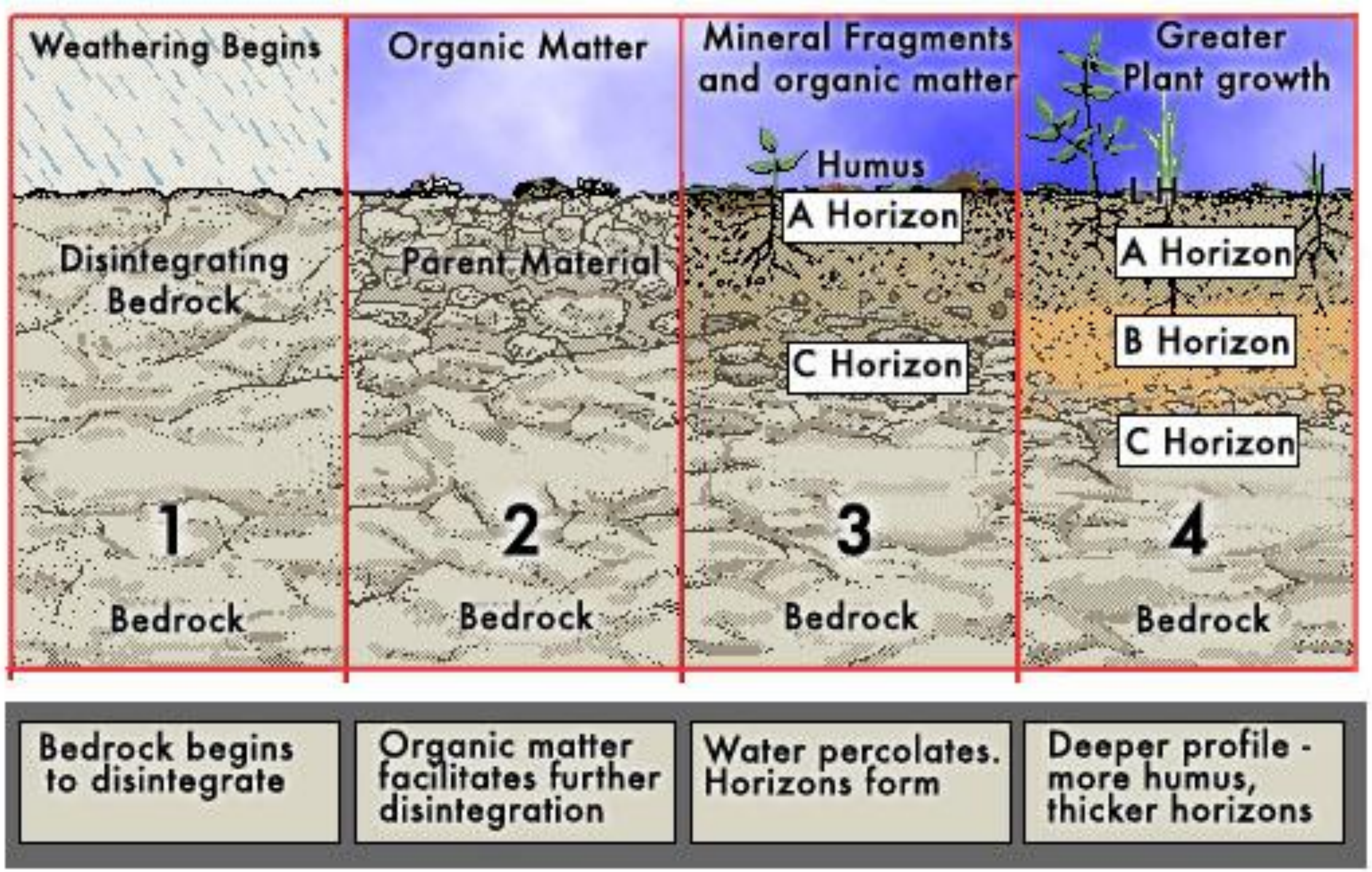
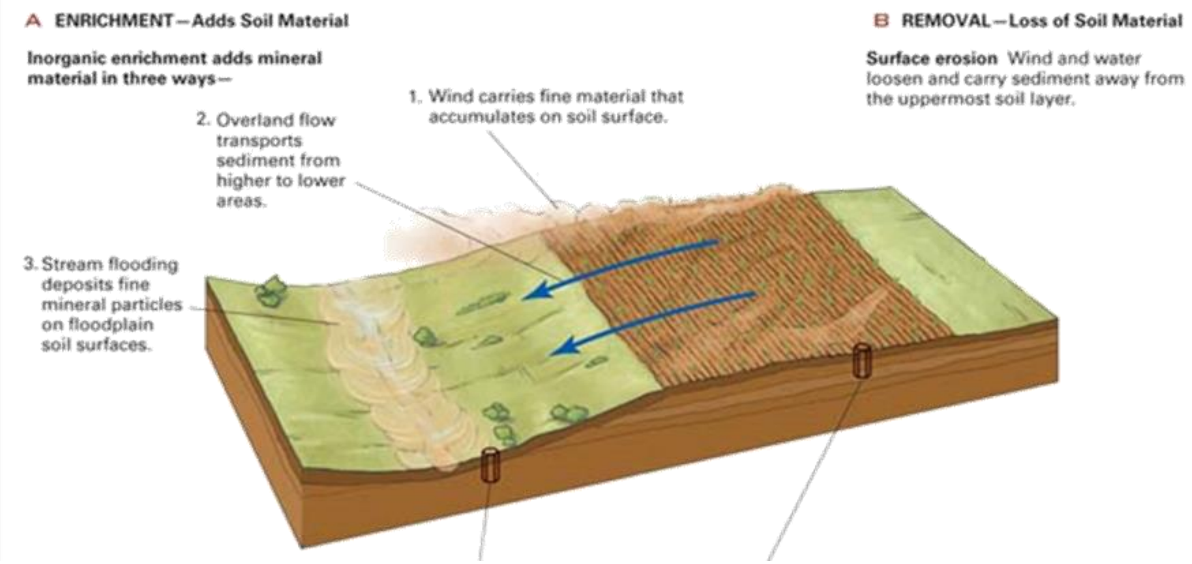


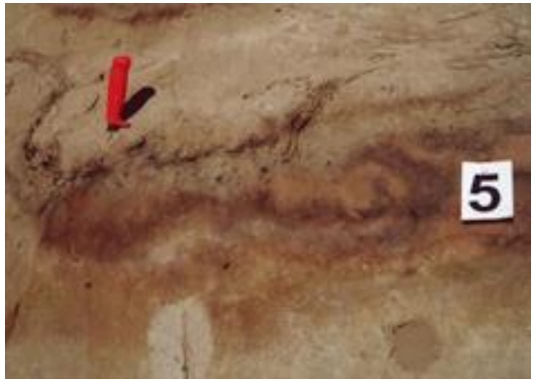
Soil Formation

Enrichment and removal



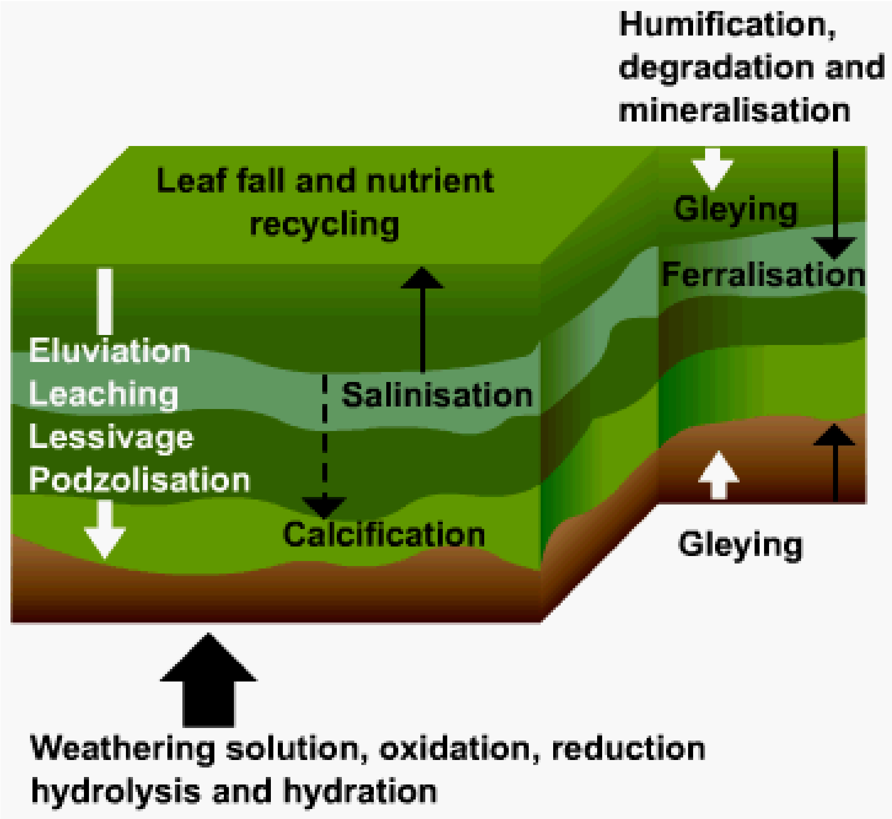
Enrichment is the addition of organic and mineral material to the soil by sedimentation and biological activity.
Removal takes place by **leaching**, as dissolved material is carried away in percolating soil water, and by erosion.
Removal of soil forming materials means that they are completely removed from the soil profile. Easily dissolved elements like calcium carbonate can be removed from the soil profile under rainy climates.

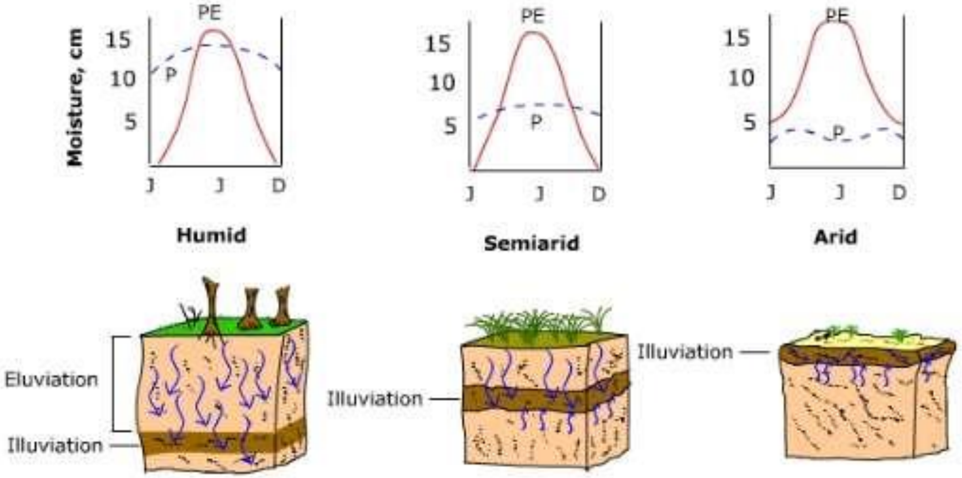
Soil Formation



Translocation

In translocation process, **eluviation** describes the downward movement of material, while **illuviation** is the accumulation of that material in lower layers





Translocation process

Soil Formation

Translocation

In dry climates, calcium carbonate is leached and carried down to the *B* horizon, where it is deposited in crystalline form, a process called ***calcification***.

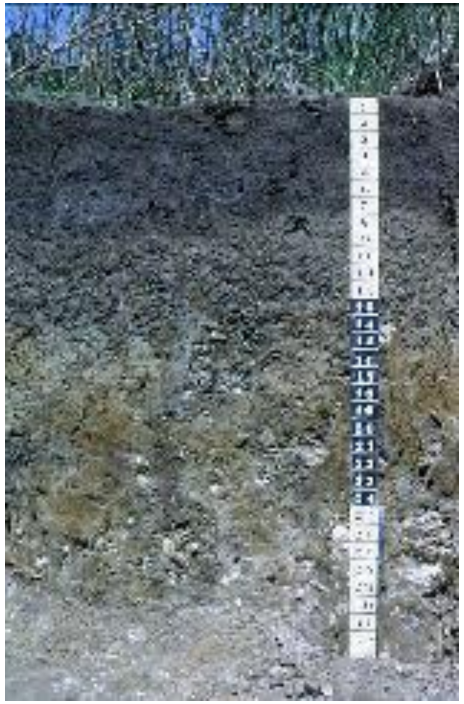
Calcification occurs in warm, semi-arid environments, usually under grassland vegetation. Soil tends to be rich in organic matter and high in soluble bases. The B horizon of the soil is enriched with calcium carbonate precipitated from water moving downward through the soil, or upward by capillary action of water from below.

Mollisol soil enriched with calcium carbonate

Translocation

Gleyzation

Gleyzation occurs in regions of high rainfall and low-lying areas that may be naturally waterlogged. Bacterial activity is slowed in the constantly wet environment thus inhibiting the decomposition of dead vegetation allowing it to accumulate in thick layers. Peat is found in the upper portion of the soil. Decaying plant matter releases organic acids that react with iron in the soil. The iron is reduced rather than oxidized giving the soil a black to bluish - gray color.



Cultivated gley soil in southern Canada

Translocation

Soil Formation

Podzolization

Podzolization occurs in cool and moist climates under pine forests. They are typical of the colder portions of the humid continental and subarctic climates. The E horizon is heavily leached and basically composed a of light colored layer of sand. The upper portion of the B horizon is stained reddish color from the accumulation of sesquioxides. The profile gets lighter in color as depth increases. Podzolization of sandy soils in the southern United States has been the result of planting pine plantations.

TABLE 4.3 Silicon/Sesquioxide ($Al_2O_3 + Fe_2O_3$) Ratios for the A- and B-Horizons of Some Soils in Different Climatic Regions

		Mean Si/sesquioxide ratio		
Region	Number of sites	A-horizon	B-horizon	References
Boreal	1	12.0	8.1	Wright et al. (1959)
Boreal	1	9.3	6.7	Leahey (1947)
Cool-temperate	4	4.07	2.28	Mackney (1961)
Warm-temperate	6	3.77	3.15	Tan and Troth (1982)
Tropical	5	1.47	1.61	Tan and Troth (1982)

Note that the removal of Al and Fe results in high values in boreal and cool temperate soils, especially in the A-horizon. Lower values characterize tropical soils, where there is little differentiation between horizons as a result of the removal of Si from the entire profile in long periods of weathering.

Typical ashy, gray layer left from leaching of sesquioxides is apparent in this podzolized soil.

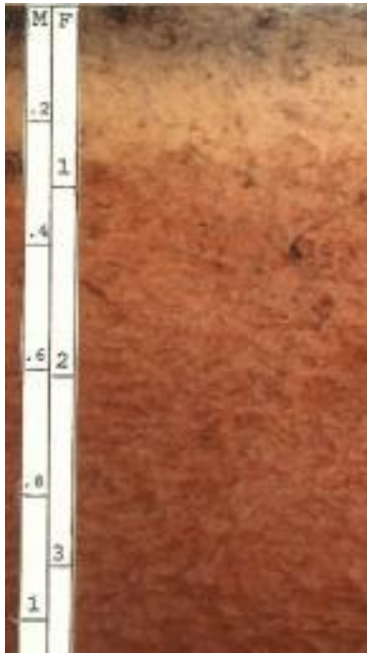
Soil Formation

Translocation

In moist climates, a large amount of surplus soil water moves downward to the ground-water zone. This water movement leaches calcium carbonate from the entire soil in a process called ***decalcification***.

Laterization

The deep red to bright orange-red soils of the tropics are a product of laterization. Laterization occurs in the hot, rainy tropics where chemical weathering proceeds at a rapid rate. Soils subject to laterization tend toward the acidic and lack much organic matter as decomposition and leaching is extreme. Exposure of the soil to the hot tropic sun by deforestation bakes the soil dry, reducing infiltration, increasing runoff, and reducing fertility.



This ultisol displays the typical features of a soil having undergone laterization

Soil Formation

Translocation

In some low areas, a layer of ground water lies close to the surface, producing a flat, poorly drained area. As water at or near the soil surface evaporates, ground water is drawn to replace it by capillary tension, much like a cotton wick draws oil upward in an oil lamp. This ground water is often rich in dissolved salts. When this salt-rich water evaporates, the salts are deposited and build up. This process is called ***salinization***.

Salinization occurs in warm and dry locations where soluble salts precipitate from water and accumulate in the soil. Saline soils are common in desert and steppe climates. Salt may also accumulate in soils from sea spray. The rapid evaporation of salt-rich irrigation water has devastated thousands of acres of land world-wide.

Accumulation of salts is easily seen in this salinized soil.

Laterization

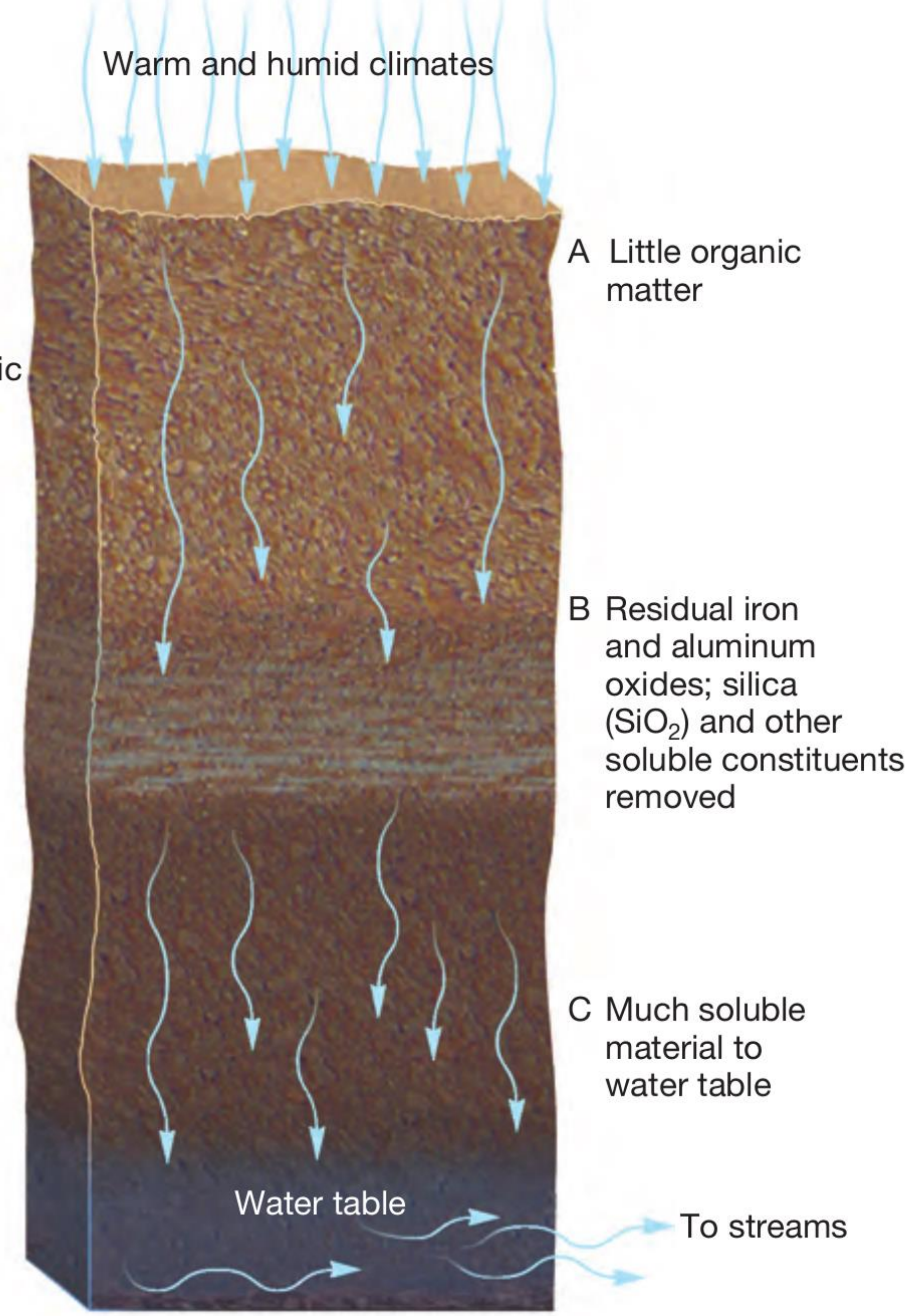


Figure 15.18

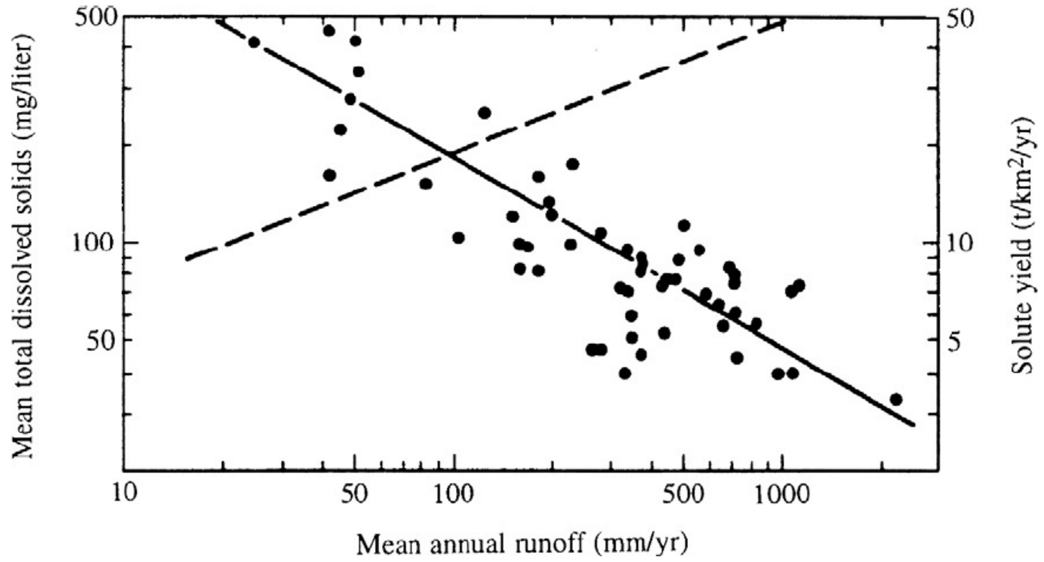


FIGURE 4.18 Variation in the concentration of total dissolved solids (*solid line*) and the total annual transport of dissolved substances (*dashed line*, shown without data) for various streams in Kenya as a function of mean annual runoff. *Source: From Dunne and Leopold (1978). Used with permission of Springer-Verlag.*

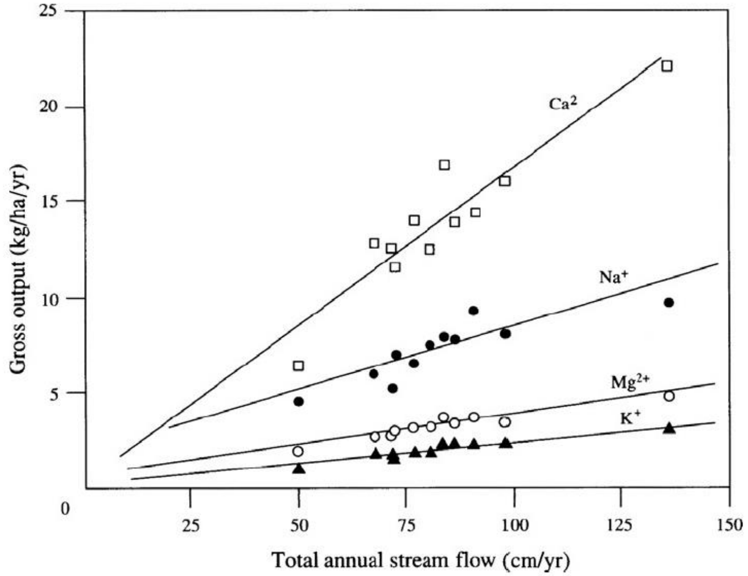
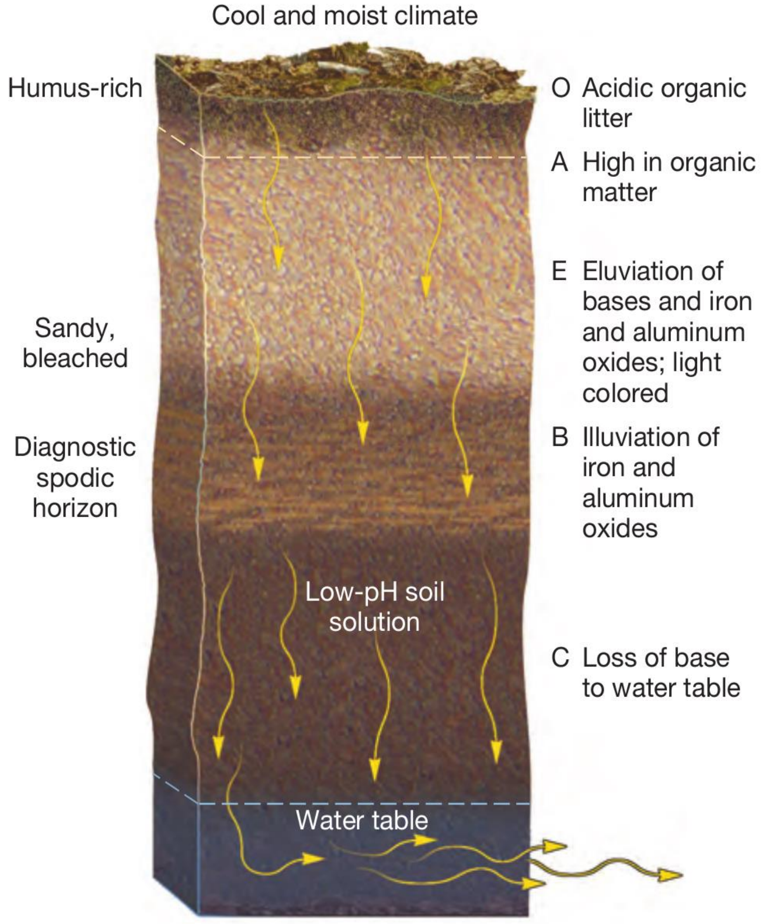


FIGURE 4.17 Annual stream water loss of major cations as a function of the stream discharge in different years in the Hubbard Brook Experimental Forest in New Hampshire. *Source: From Likens and Bormann 1995a).*

Soil Development and Soil Profiles

s = f(cl, o, r, p, t, …) Jenny (1941)

- **C**limate
- **O**rganisms
- **R**elief and topography
- **P**arent material - the underlying geologic material
- **T**ime

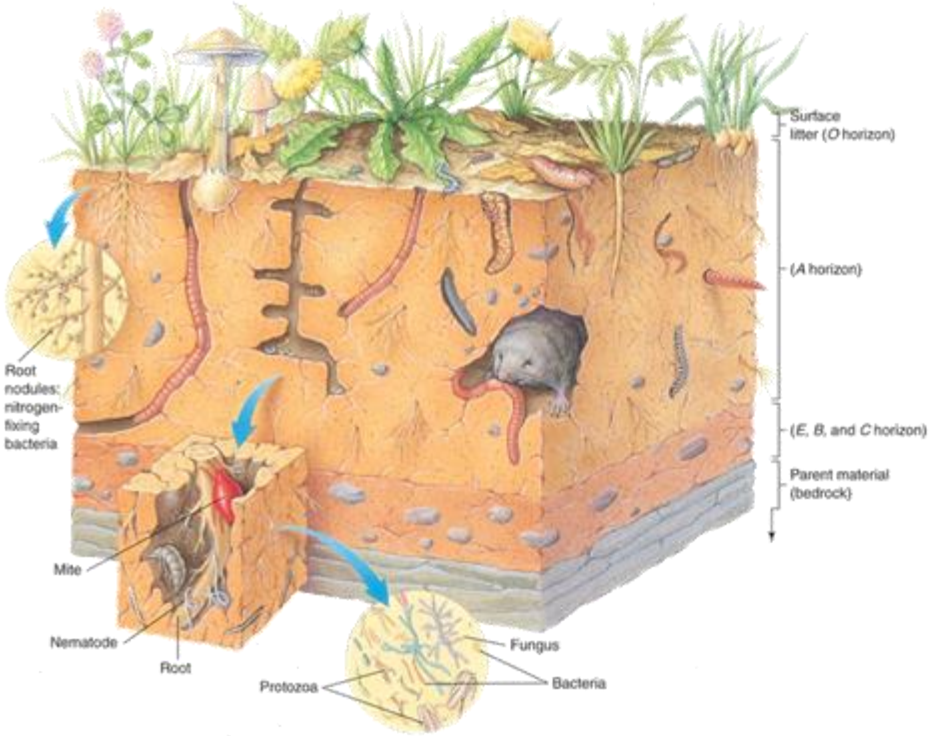


Factors in Soil Formation

Soil research has shown that soil profiles are influenced by five separate, yet interacting, factors: parent material, climate, topography, organisms, and time. Soil scientists call these the ***factors of soil formation***. These factors give soil profiles their distinctive character.

Organisms

Biological organism, both plant and animal, play an important role in the development and composition of soil. Organisms add organic matter, aid decomposition, weathering and nutrient cycling. The richness and diversity of soil organisms and plant life that grows on the surface is, of course, also tied to climate.



Soil organisms

Factors in Soil Formation

Climate

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.

Factors in Soil Formation

Climate

Soil temperature also helps to determine the chemical development of soils and the formation of horizons.

Below 10° C (50° F), biological activity is slowed, and at or below the freezing point (0° C, 32° F), biological activity stops and chemical processes affecting minerals are inactive. The root growth of most plants and germination of their seeds require soil temperatures above 5° C (41° F). Plants in the warm, wet low-latitude climates may need temperatures of at least 24° C (75° F) for their seeds to germinate.

The temperature of the uppermost soil layer and the soil surface also strongly affects the rate at which organic matter is decomposed by microorganisms. In cold climates, decomposition is slow, and so organic matter accumulates to form a thick *O* horizon. This material becomes humus, which is carried downward to enrich the *A* horizon. But in warm, moist climates of low latitudes, bacteria rapidly decompose plant material, so you won't find an *O* horizon layer, and the entire soil profile will contain very little organic matter.

Factors in Soil Formation

Climate

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.

Climate, interacting with vegetation, also affects soil chemistry. Pine forests tend to dominate cool, humid climates. Decomposing pine needles in the presence of water creates a weak acid that strips soluble bases from the soil leaving it in an acidic state. Additionally, pine trees have low nutrient demands so few soil nutrients are taken back up by the trees to be later recycled by decaying needle litter. Broadleaf deciduous trees like oak and maple have higher nutrient demand and thus continually recycle soil nutrients keeping soils high in soluble bases.

Factors in Soil Formation

Time

As time passes, the weathering processes continue to act on soil parent material to break it down and decompose it. Horizon development processes continue to differentiate layers in the soil profile by their physical and chemical properties. As a result, older more mature soils have well-developed sequence of horizons, though some may undergo so much weathering and leaching that visually distinct layers may be hard to see. This is a notable characteristic of oxisols. Some geological processes keep soils from developing by constantly altering the surface and thus not allowing parent material to weather over a significant period of time. For instance, erosion of hillsides constantly removes material thus impeding soil development. Along the channels of rivers, new sediment is frequently deposited as the river spills out onto its floodplain during floods. The constant addition of new material restarts the soil development process.

Climate interacts with time during the soil development process. Soil development proceeds much more rapidly in warm and wet climates thus reaching a mature status sooner. In cold climates, weathering is impeded and soil development takes much longer.

Soil Formation

Factors in Soil Formation

Relief and Topography

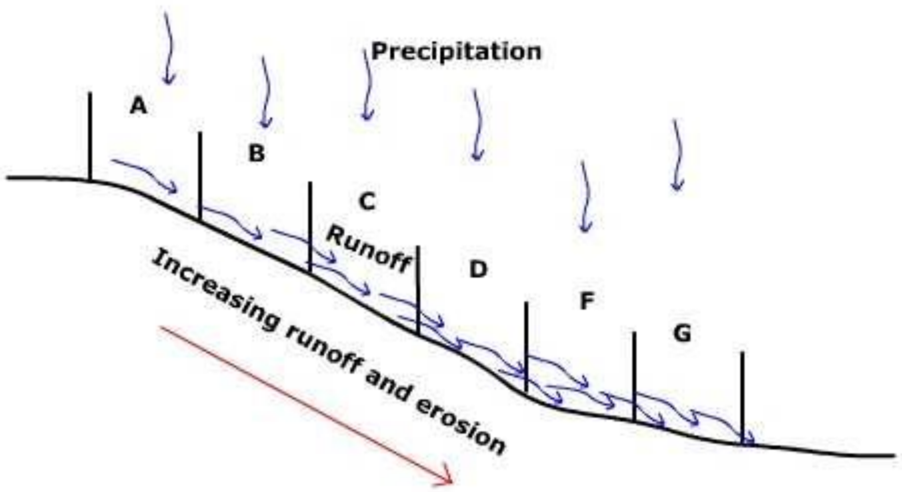
Relief and Topography has a significant impact on soil formation as it determines runoff of water, and its orientation affects microclimate which in turn affects vegetation. For soil to form, the parent material needs to lie relatively undisturbed so soil horizon processes can proceed. Water moving across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

Factors in Soil Formation

Relief and Topography

Effect on soil erosion

Slope angle and length affects runoff generated when rain falls to the surface. Examine the diagram below showing the relationship between hill slope position, runoff, and erosion.



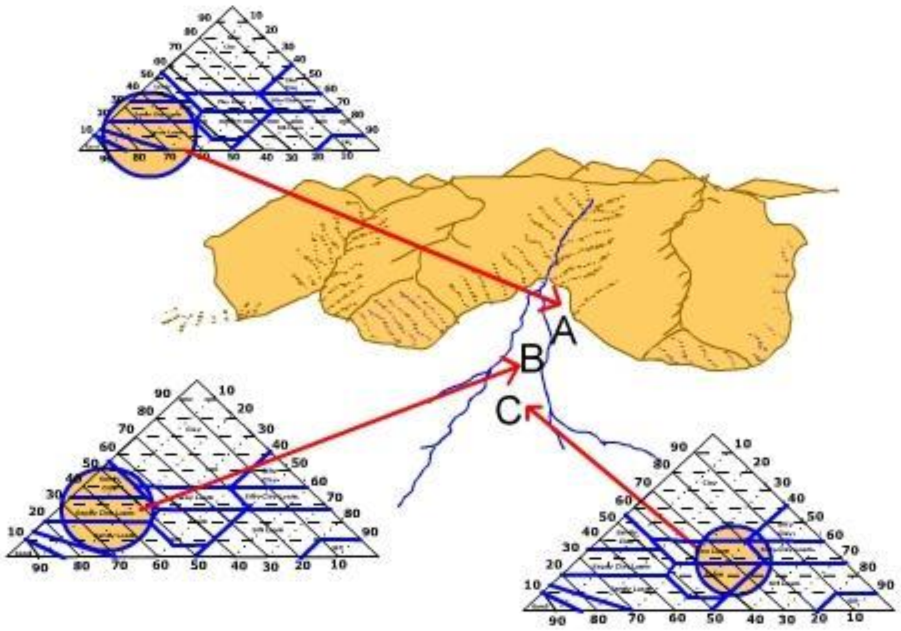
Hill slope position, runoff & erosion

Soil Formation

Factors in Soil Formation

Relief Topography

Effect on deposition and soil texture
Water velocity not only determines the rate of erosion but the deposition of soil material in suspension too. Figure below shows the relationship between location and texture. Sites A, B, and C, are located progressively further from the base of a slope. A soil texture triangle is used to illustrate the variation in soil textures at the three sites.



Location, Deposition and Soil Texture

Factors in Soil Formation

Relief and Topography

Microclimatic effects

Hill slope orientation affects the microclimate of a place. As the slope of the surface increases, so does the local sun angle, up to a point. As the local sun angle increases, the intensity of heating increases, causing warmer surface temperatures and, likely, increased evaporation. Orientation of the hill slope is certainly important too. Those slopes which face into the sun receive more insolation than those facing away. Thus inclined surfaces facing into the sun tend to be warmer and drier, than flatter surfaces facing way from the sun. The microclimate also impact vegetation type.

Soil Formation

Factors in Soil Formation

Parent material

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. The character and chemical composition of the parent material plays an important role in determining soil properties, especially during the early stages of development.

Stabilized dunes are a form of Eolian (wind deposited) parent material

Soil Formation

Factors in Soil Formation

Human activity

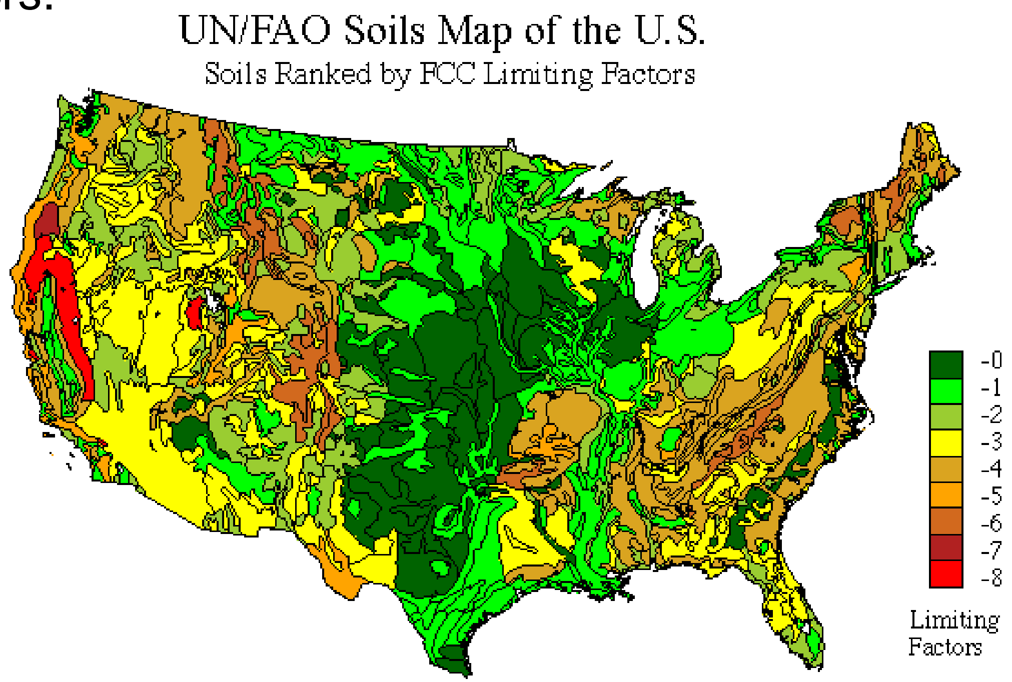
Human activity also influences the physical and chemical nature of the soil. Large areas of agricultural soils have been cultivated for centuries. As a result, both the structure and composition of these agricultural soils have undergone great changes. These altered soils are often recognized as distinct soil classes that are just as important as natural soils.

Soil Formation

Factors in Soil Formation

Human activity

A soils map of the United States created from the United Nations Food and Agriculture Organization digital soils map of the world. Soils are classified by their number of agronomic limiting factors. Soils with a high number of limiting factors are problematic and require remediation for agricultural production. The best soils for agriculture have no or few limiting factors.



Soil Taxonomy

- Soil taxonomy is a soil classification system, which emphasizes the physical and chemical properties of the soil profile.
- Soil taxonomy is a six-fold hierarchy
- Soils are grouped into: (1) orders, (2) suborders, (3) great groups, (4) subgroups, (5) families, and (6) series.
- Soil taxonomy is a basic system of soil classification for making and interpreting soil surveys.

Soil Order

Soils characterized by maturity

- Entisols : Little, if any horizon development
- Inceptisols : Beginning of horizon development
- Alfisols : Deciduous forest soils
- Spodosols : Acidic, coniferous forest soils
- Ultisols : Extensively weathered soils
- Oxisols : Extremely weathered, tropical soils

Soils characterized by climate

- Mollisols : Soft, grassland soils
- Aridisols : Soils located in arid climates
- Gelisols : Soils containing permafrost

Soils characterized by patent material

- Vertisols : Shrinking and swelling clay soils
- Andisols : Soil formed in volcanic material

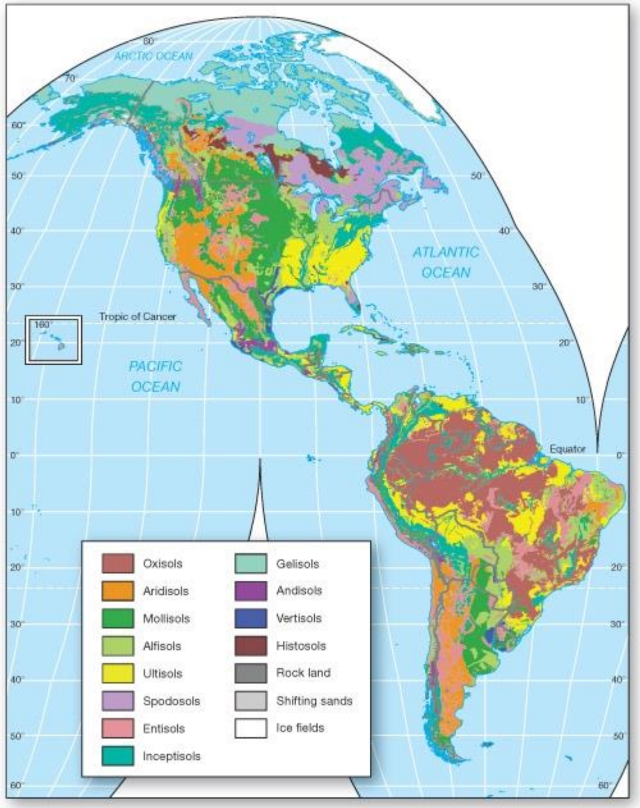
Soils high in organic matter

- Histosols : Soils formed in organic material

Figure 15.1 Soil Orders

Order	Description/Climate/Location	Characteristics
Oxisols	Tropical soils; hot, humid areas	Maximum weathering of Fe and Al and eluviation; no clearly marked horizons.
Aridisols	Desert soils; hot, dry areas	Limited alteration of parent material; light color; low humus content; subsurface illuviation of carbonates.
Mollisols	Grassland soils; subhumid, semiarid lands	Noticeably dark with organic material; humus-rich; surface with well-structured horizons.
Alfisols	Moderately weathered forest soils; humid temperate climate	B horizon high in clays; no pronounced color change with depth.
Ultisols	Highly weathered forest soils; subtropical climate	Similar to Alfisols; B horizon high in clays; strong weathering in subsurface horizons.
Spodosols	Northern conifer forest soils; cool, humid climate	Illuvial B horizon of Fe/Al clays; partially cemented; highly leached; strongly acid.
Entisols	Recent soils; profile undeveloped; all climates	Limited development; inherited properties from parent material; pale color; low humus; hard and massive when dry.
Inceptisols	Weakly developed soils; humid regions	Young soils with few diagnostic features.
Gelisols	Permafrost-affected soils; tundra climate at high latitude and in mountain highlands	Permafrost within 100 cm of the soil surface; evidence of cryoturbation and/or an active layer.
Andisols	Soils formed from volcanic activity; especially common along the Pacific Rim	Volcanic parent materials; weathering and mineral transformation important; generally fertile.
Vertisols	Expandable clay soils; subtropics, tropics; sufficient dry period	Forms large cracks on drying; self-mixing action; contains >30% swelling clays; light color; low humus content.
Histosols	Organic soils; wetlands	Peat or bog; >20% organic matter; surface organic layers; no diagnostic horizons.

Soil Taxonomy



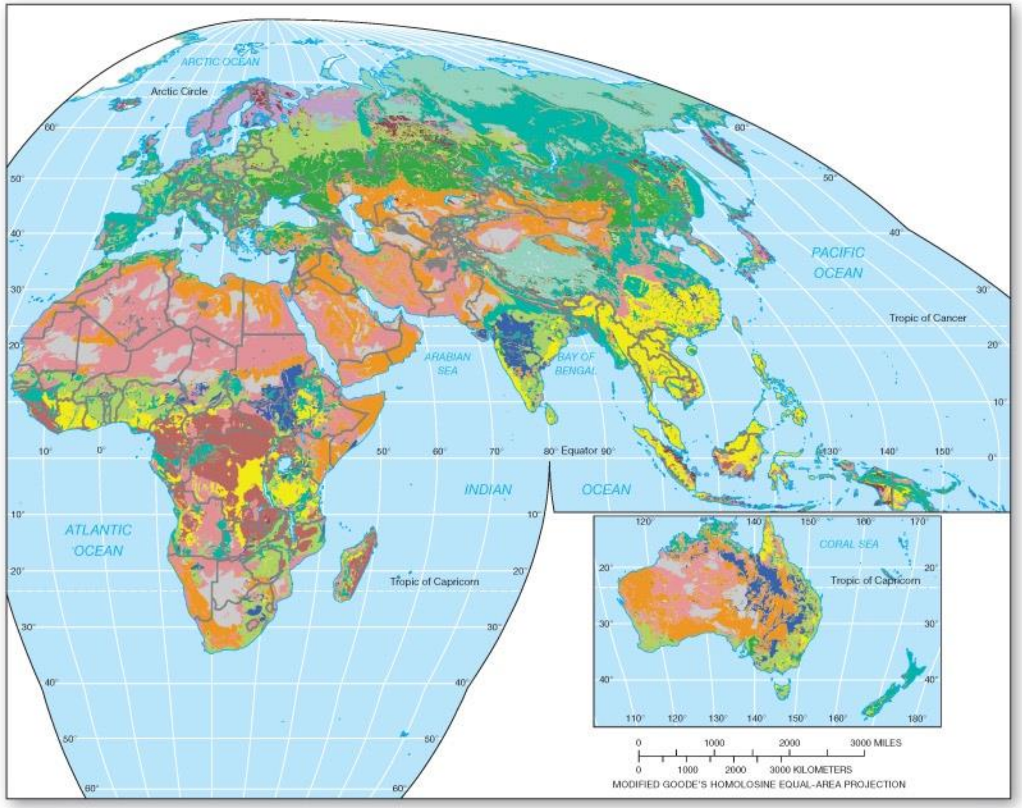


Figure 15.15

Desertification

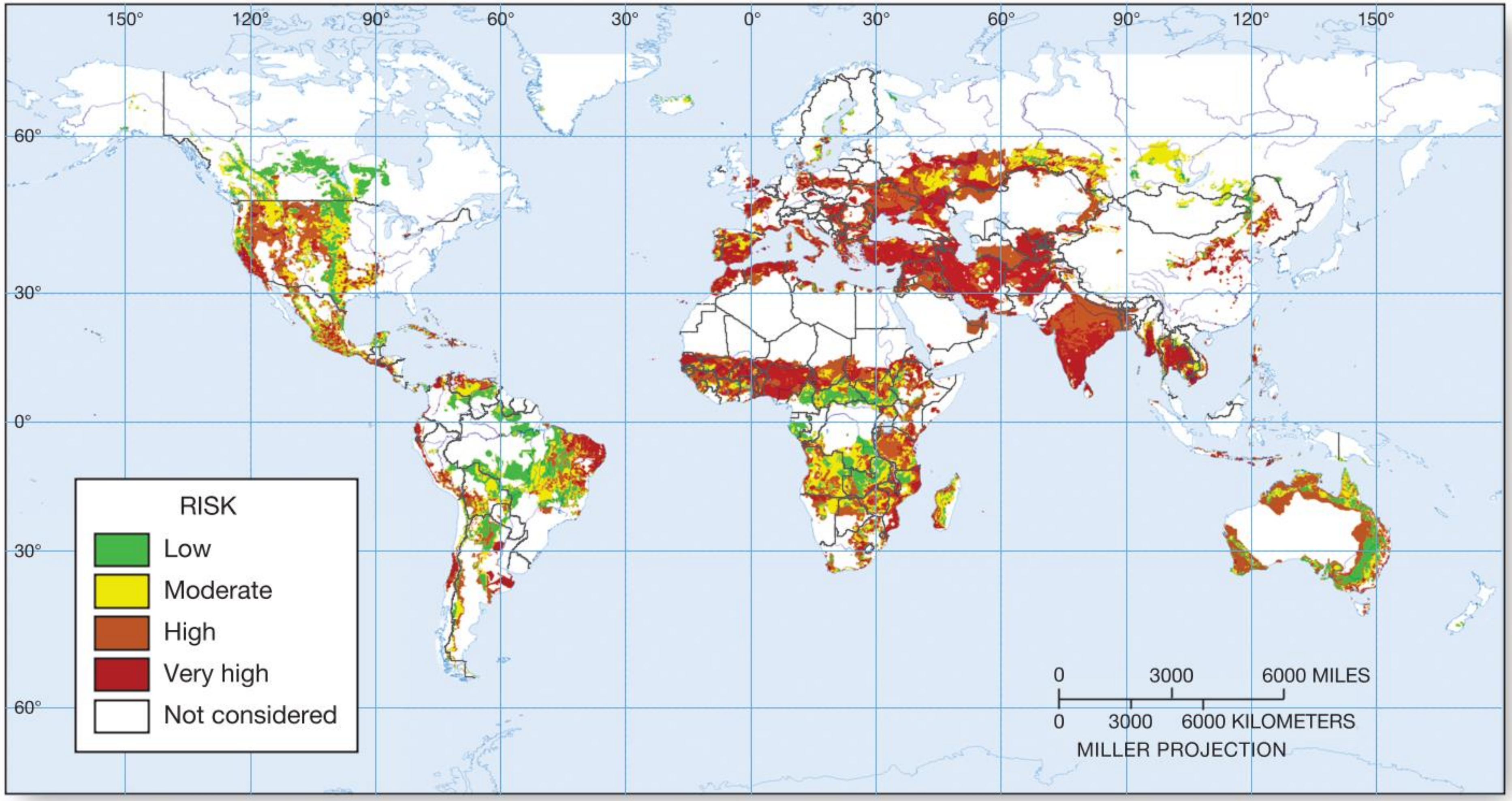


Figure 15.12

Drying Lake Urmia in Iran

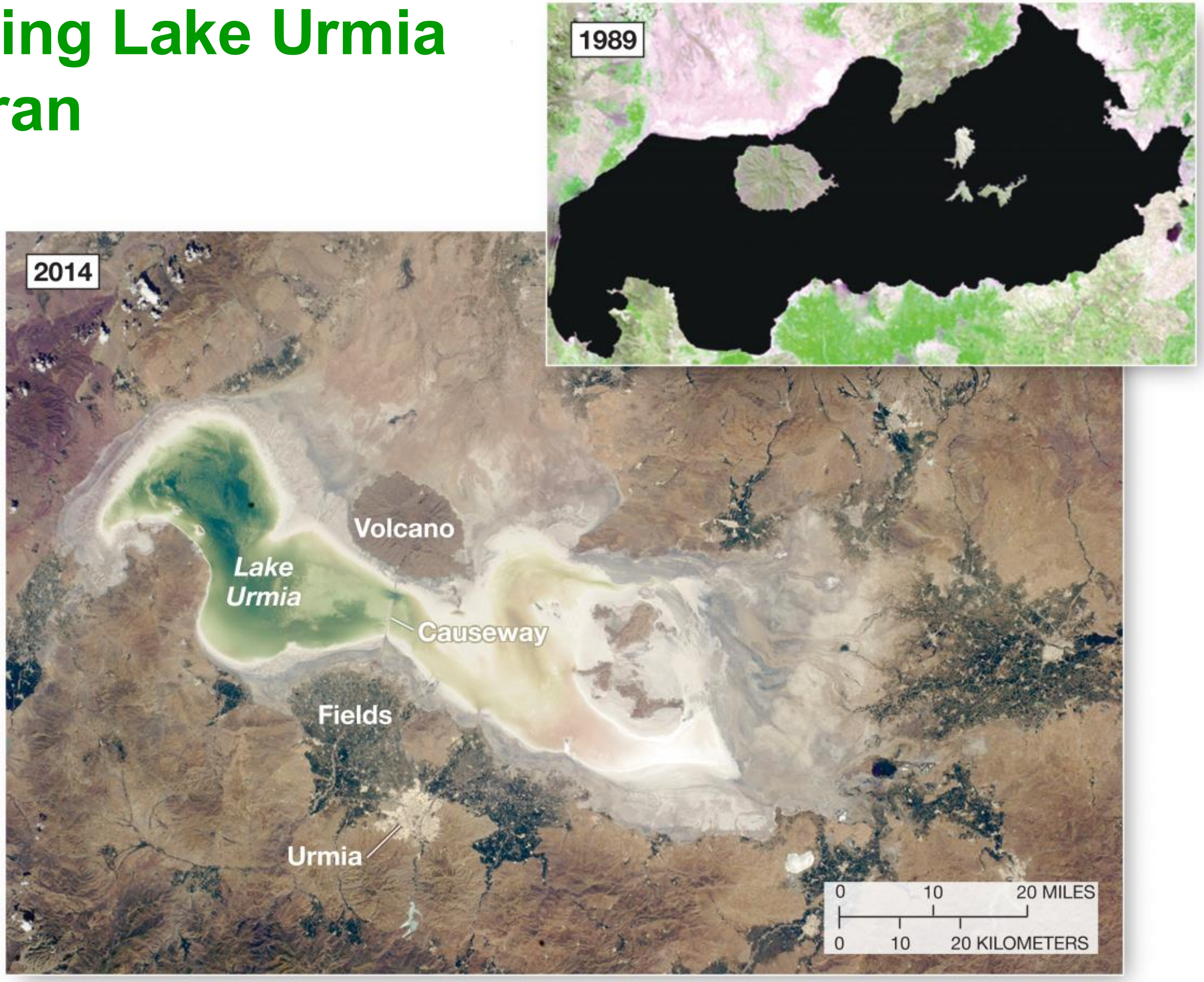
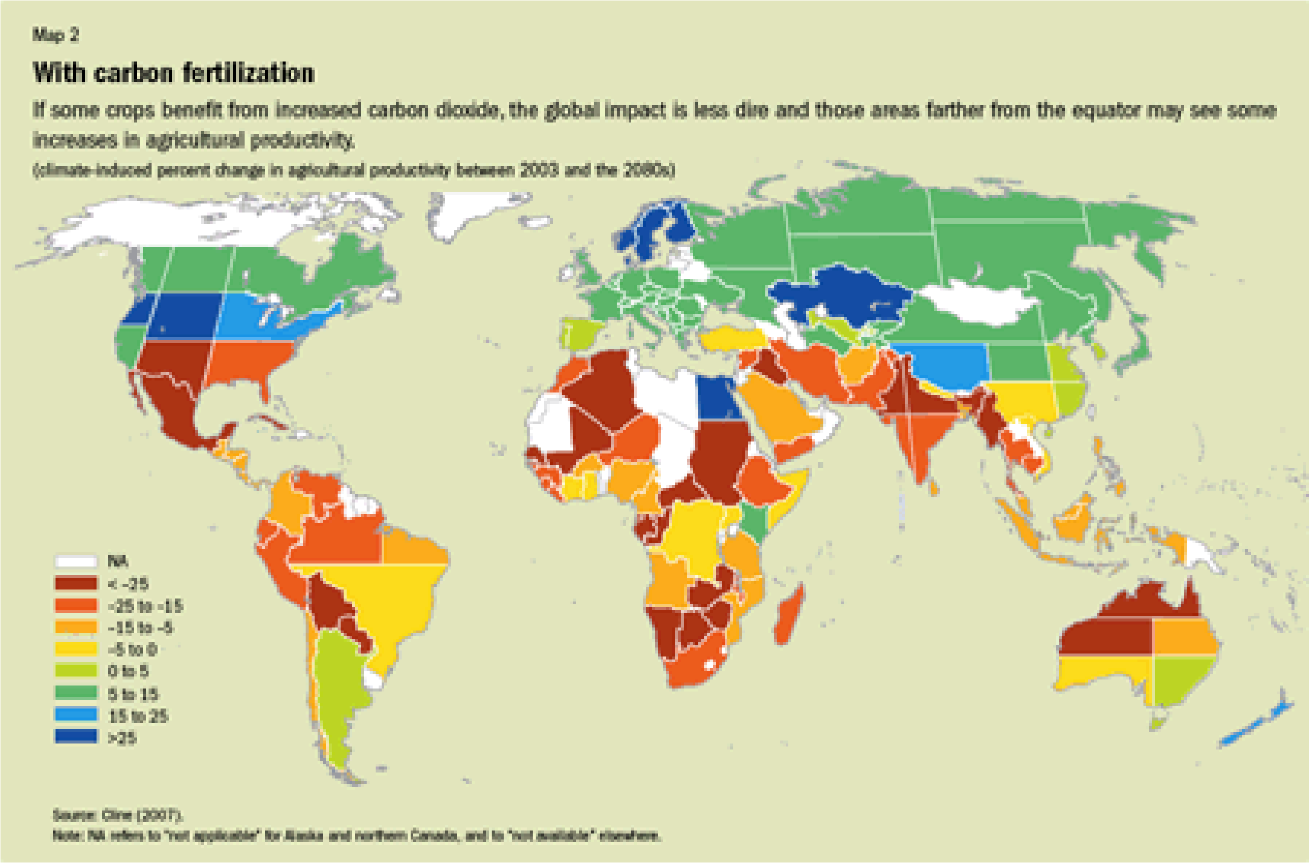


Figure 15.14

Global climate change and agriculture

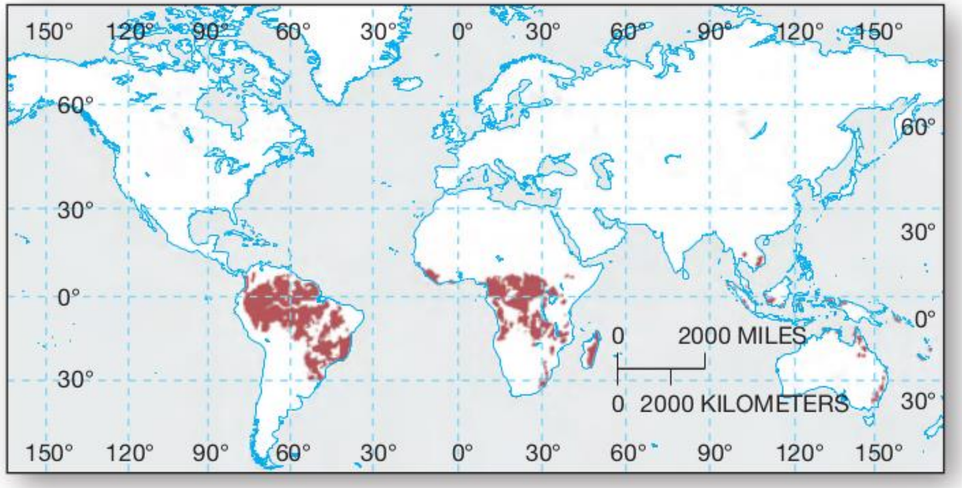
Global climate change is predicted to increase global temperatures and summer droughts, change rainfall pattern, and produce more extreme events.
Scientists think that the immediate impact on crop yields will be positive.

Asymmetric Impact of ***Global Warming*** on ***Agriculture***



Oxisols

(a) Highly weathered Oxisol profile in central Puerto Rico.



(b) Worldwide Oxisol distribution.

[replace with figure 15.16 as shown]

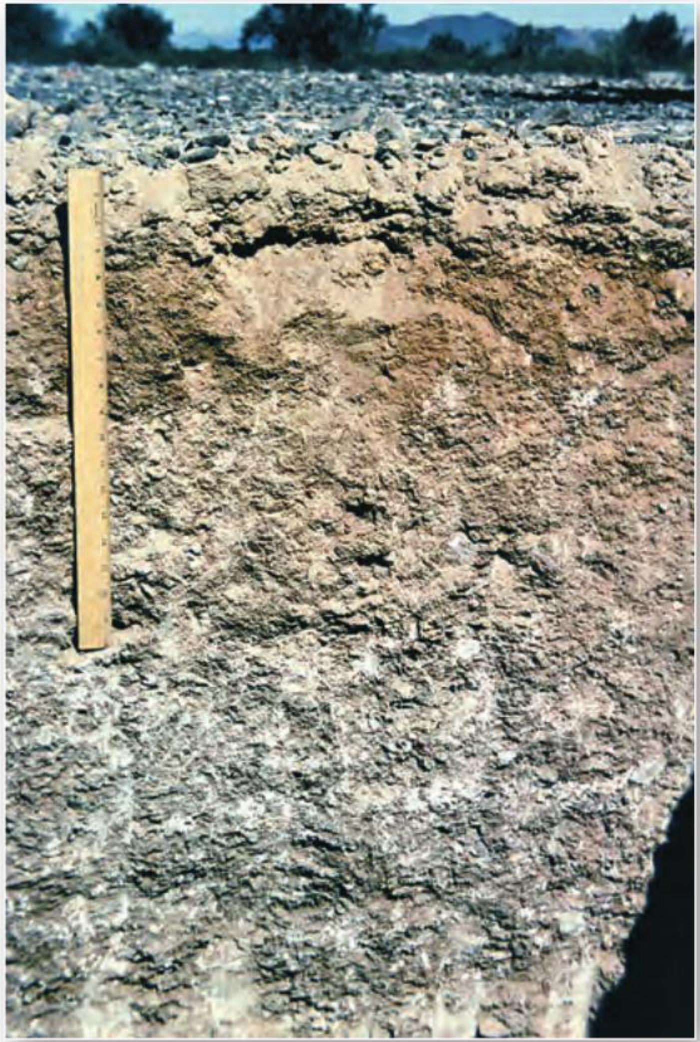
(c) Oxisols underlie the tropical rain forests of South America. Note the lack of distinct soil horizons.

Figure 15.16

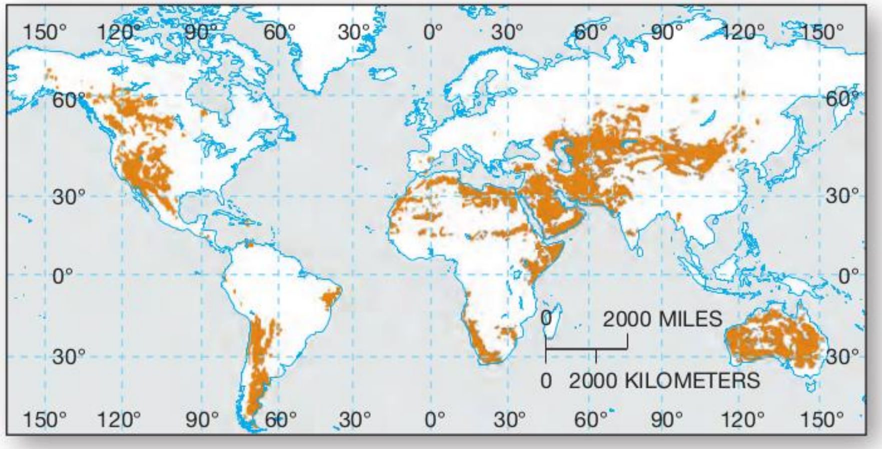
Oxisols

- Oxisols have developed in the moist climates of the equatorial, tropical, and subtropical zones on land surfaces that have been stable over long periods of time.
- Tropical soils
- Formed by intense moisture and high temperatures
- Mature soils found in old landscapes
- Leaching process in well-drained soils in the humid tropics is laterization

Aridisols



(a) Aridisol profile in central Arizona.



(b) Worldwide Aridisol distribution.

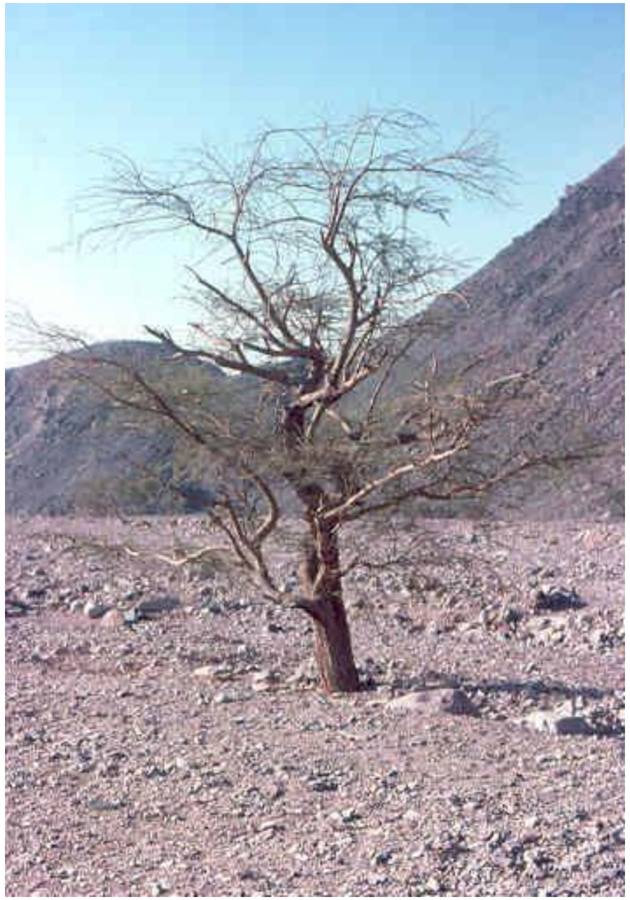
(c) Irrigated cropland and surrounding desert, Imperial Valley, southern California.

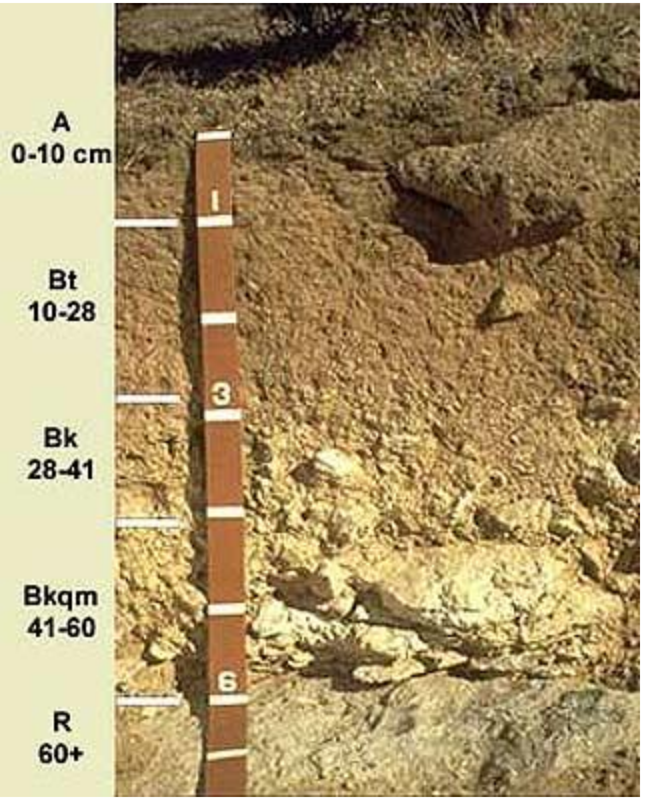
Figure 15.19

Aridisols

Soils characterized by climate
Aridisols

Aridsols characterize the desert climate and are dry for long periods of time. The soils don't contain much humus, and they are pale ranging from gray to red.





Calcification

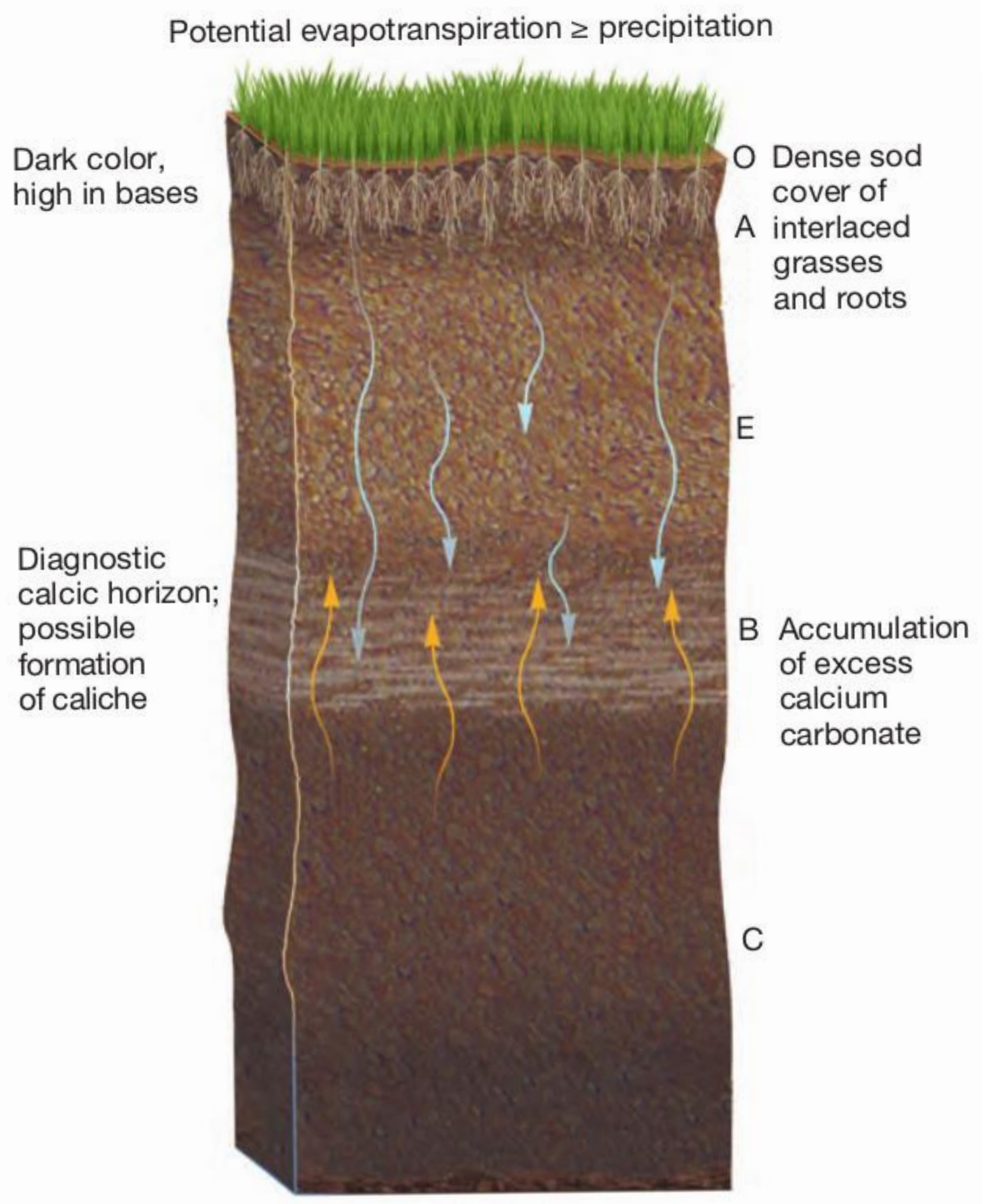
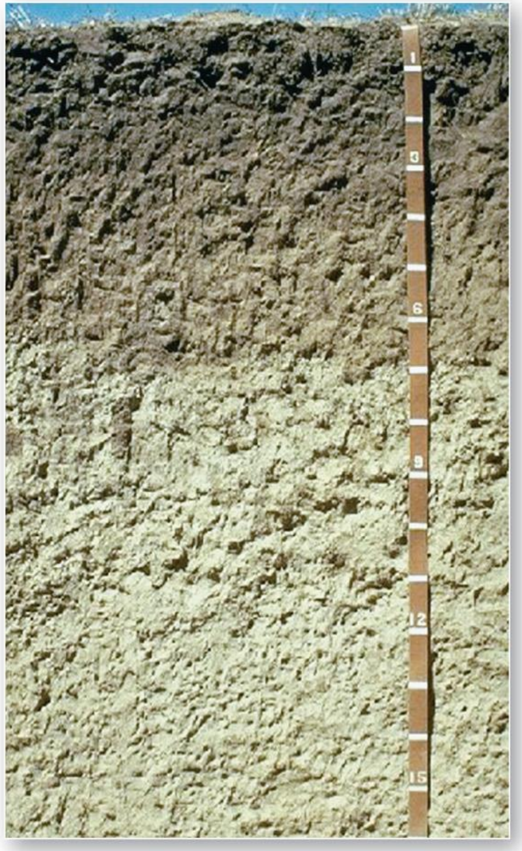


Figure 15.20

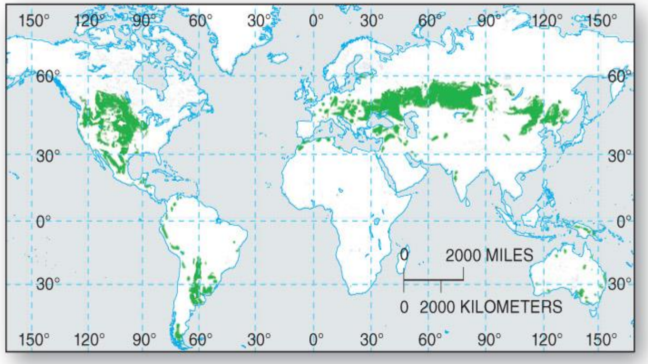
Aridisols

- Desert soils
- Aridisols occupy about 19% of Earth's land surface, the single largest soil order in the world.
- Pale and light soil color
- Shallow soil horizons
- Salinization can occur in arid regions

Mollisols



(a) Mollisol profile in eastern Idaho, from loess that is high in calcium carbonate, related to the soils of the Palouse agricultural region.



(b) Worldwide Mollisol distribution.

(c) Wheat flourishes in the fertile Palouse of eastern Washington.

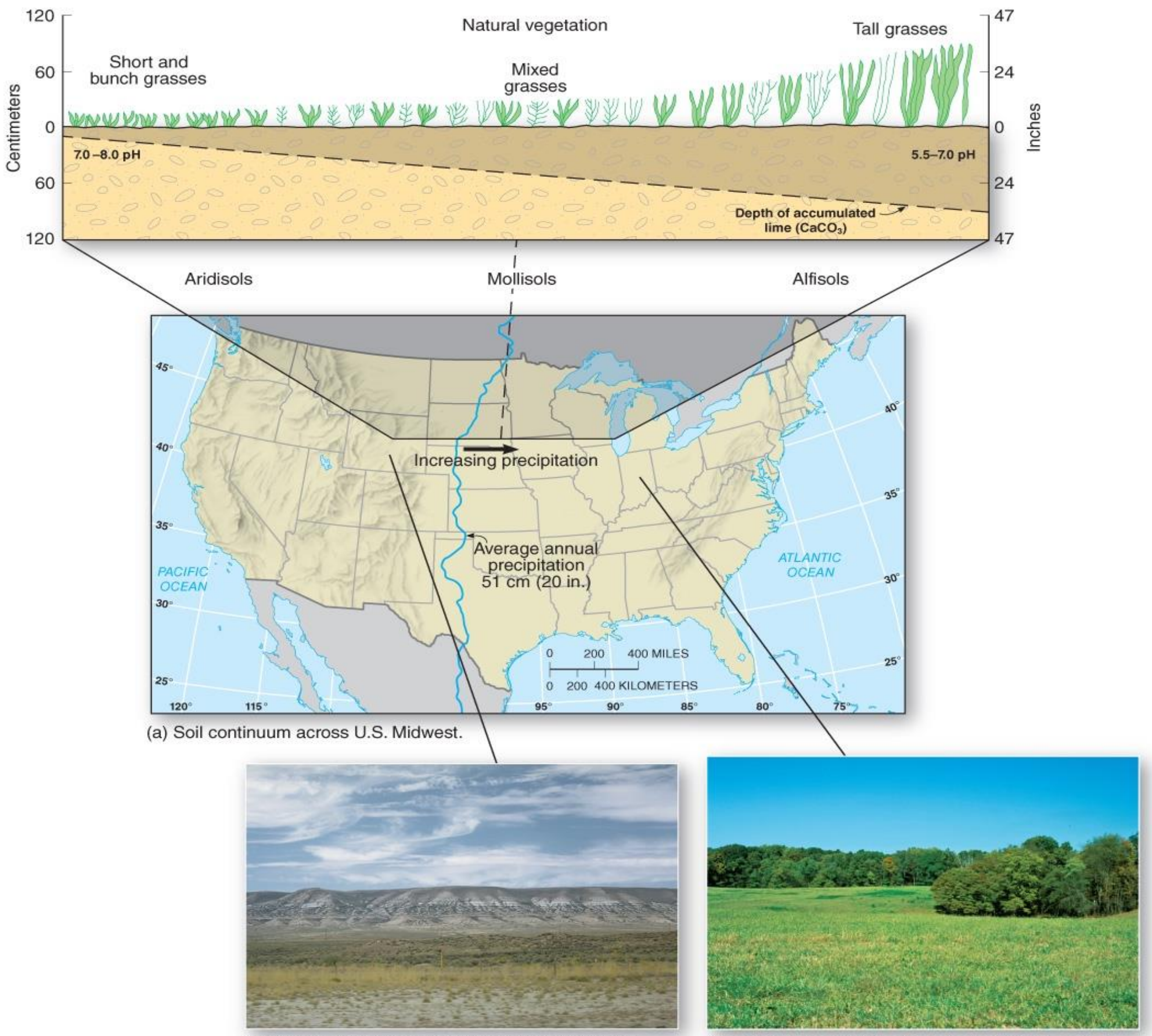
- Mollisols (grassland soils) are soft, even when dry.
- High fertility
- The largest single soil order in the United States
- The U.S. breadbasket region

Figure 15.21

Mollisols

- Grassland soils
- Mollisols are soft, even when dry.
- High fertility makes the one of the most important agricultural soils
- The largest single soil order in the United States
- The U.S. breadbasket region

Soils of the Midwest



(a) Soil continuum across U.S. Midwest.

(b) Bunch grasses and shallow soils of Wyoming.

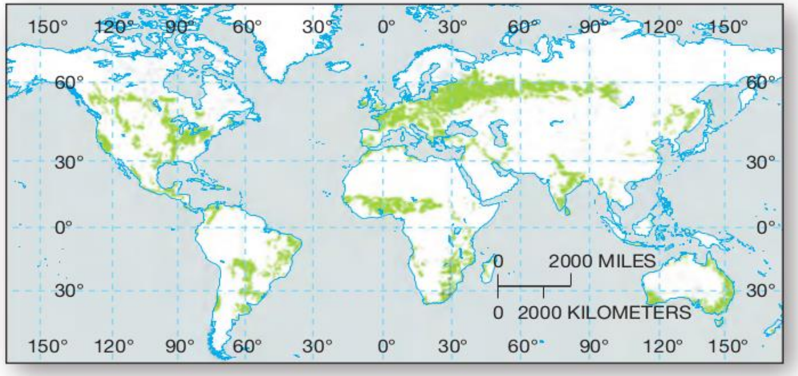
(c) Farmlands and Alfisols south of Bedford, Indiana.

Figure 15.22

Alfisols

The Alfisols are soils characterized by a clay-rich horizon produced by illuviation.

(a) Alfisol profile in northern Idaho loess.



(b) Worldwide Alfisol distribution.

(c) An olive orchard in northern California, where virtually all U.S. olive production occurs.

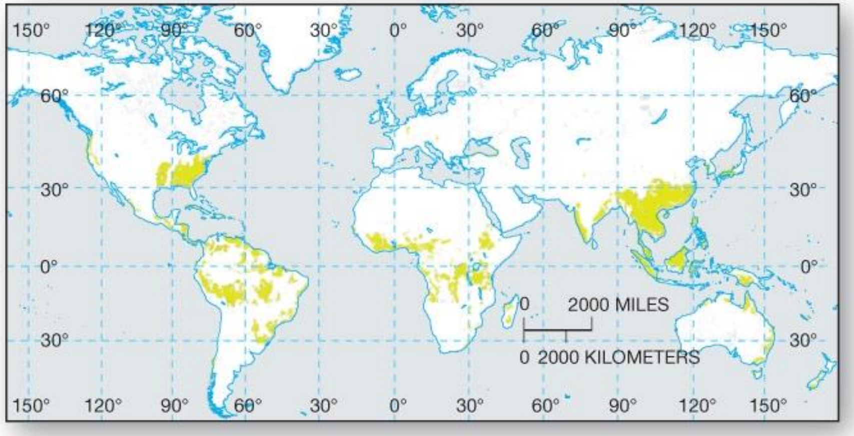
Figure 15.23

Alfisols

- Forest soils
- Alfisols are the most spatially widespread soil orders
- Moderately weathered
- Fertile
- Productivity depends on temperature and moisture

Ultisols

- Highly weathered forest soils
- Can develop from alfisols
- Subtropical forests
- Southeast United States



(a) Worldwide Ultisol distribution.

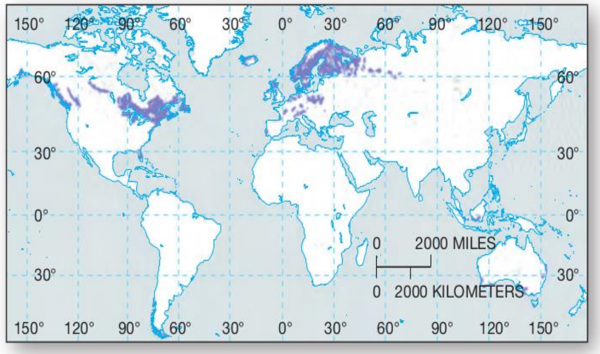
(b) Ultisols planted in rows of peanuts in west-central Georgia have the characteristic reddish color.

Figure 15.24

Spodosols

- In forested areas in the humid continental mild-summer climates of northern America and Europe
- Form from sandy parent materials
- Lack humus and clay in the A horizon
- Acid accumulation in the soil

(a) Spodosol profile from northern New York.



(b) Worldwide Spodosol distribution.

(c) Characteristic temperate forest and Spodosols in the cool, moist climate of central Vancouver Island.

Figure 15.25

Spodosols

- Northern conifer forest soils
- Often found north and east of alfisols
- Form from sandy parent materials
- Acid accumulates in the soil in a process called podzolization

Podzolization

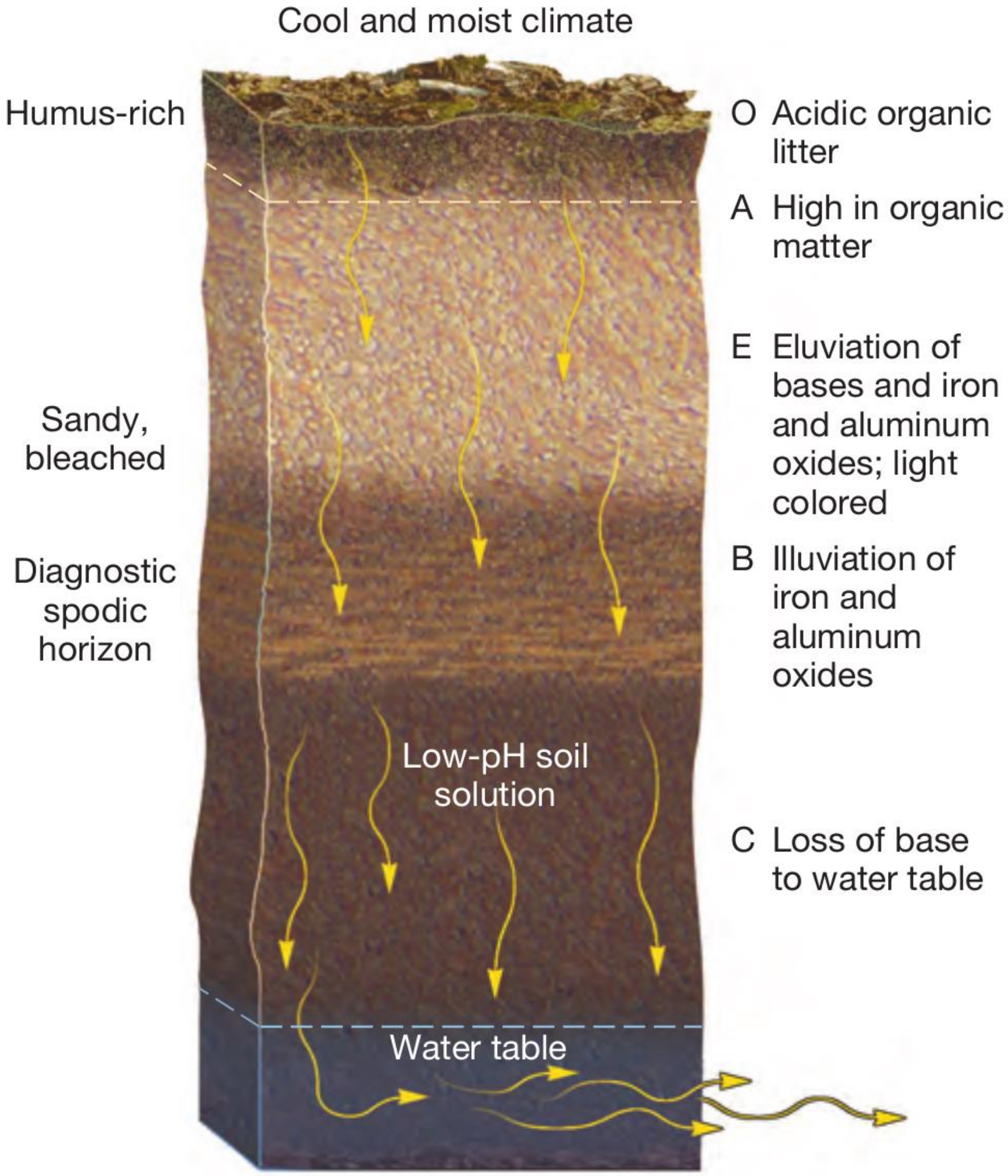


Figure 15.26

Entisols

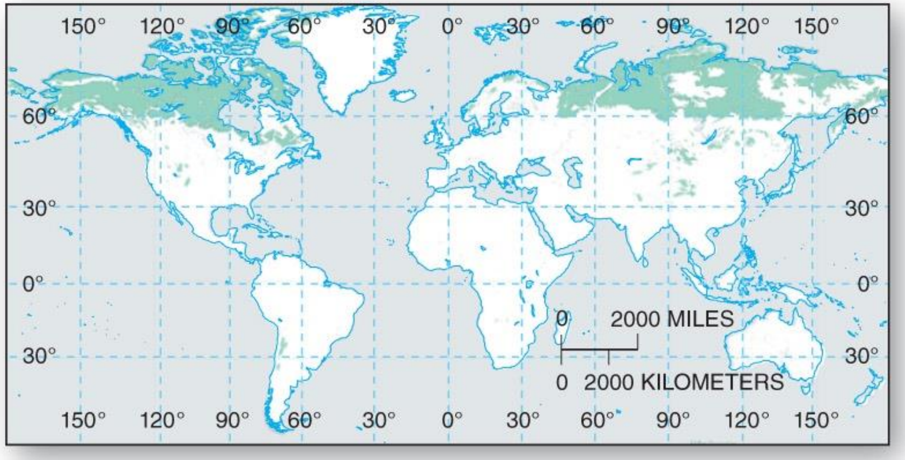
Entisols are mineral soils without distinct horizons. They are soils
in the scene that they support plants, but they may be found in any climate
and under any vegetation.

- *Recent* soils
- They are not not climate-dependent
- Lack vertical development

Figure 15.27

Gelisols

- Cold and frozen soils
- High latitudes
- Permafrost within 2 m of the soil surface
- Store large quantities of organic carbon



(a) Worldwide Gelisol distribution.

(b) The tundra is green in the brief summer season on Spitsbergen Island, as the active layer thaws.

Figure 15.28

Andisols

- Volcanic soils
- Derived from volcanic ash ad glass
- Moderate fertility

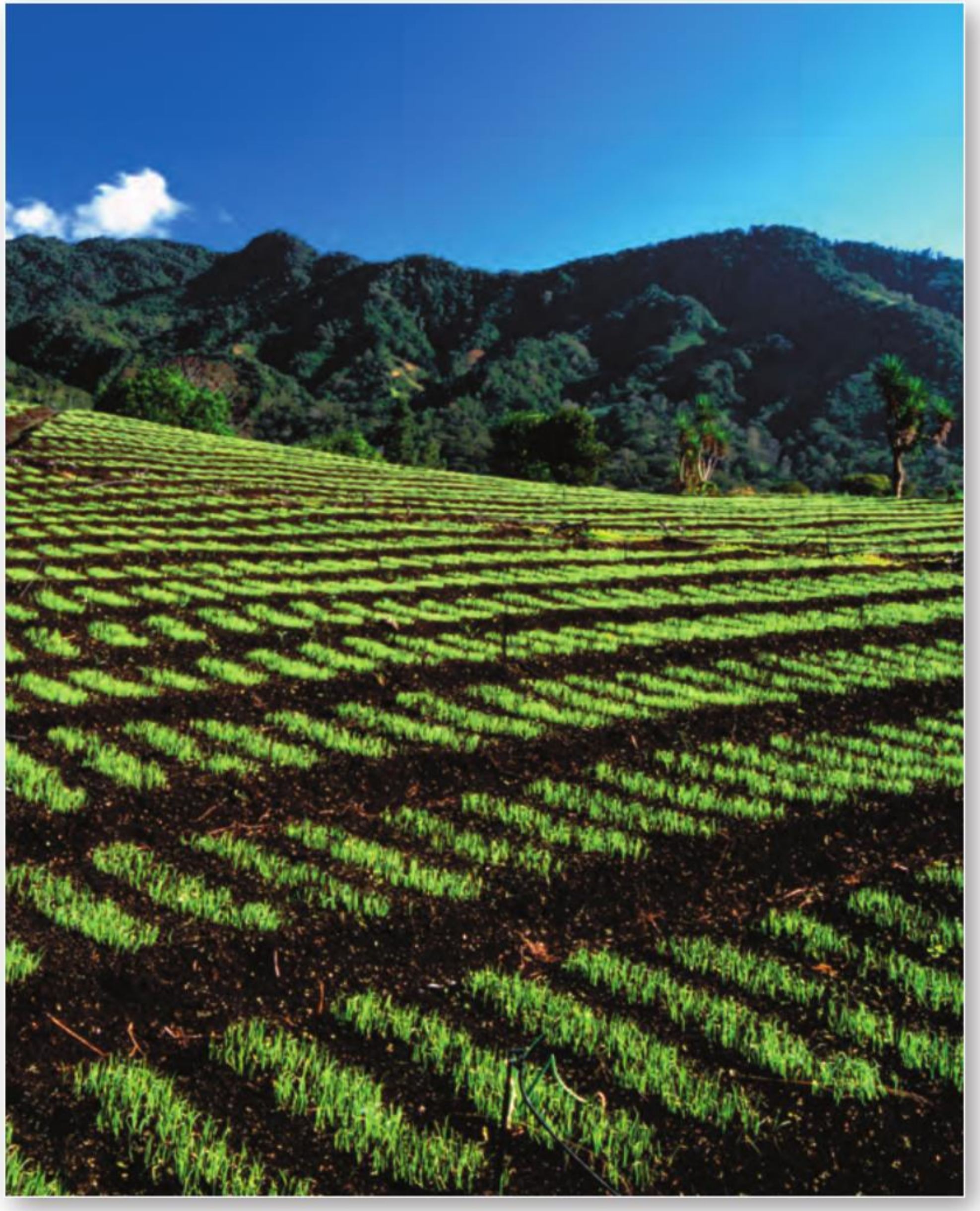
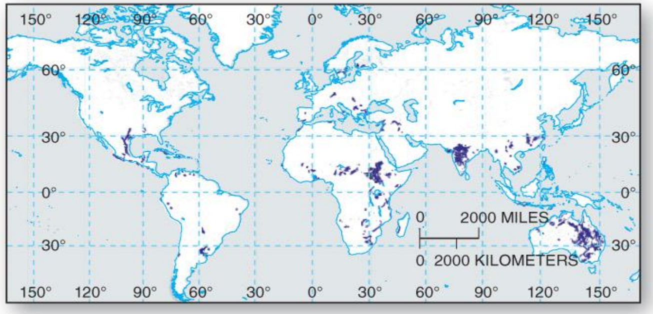


Figure 15.30

Vertisols

- Heavy clay soils
- Contain more than 30% swelling clays
- Swelling clays swell significantly when they absorb water.
- Swell when moistened and shrink when dried, create cracks, destroy foundation.
- Black color is due to specific mineral content, rather than organics.

(a) Vertisol profile in the Lajas Valley of Puerto Rico.



(b) Worldwide Vertisol distribution.

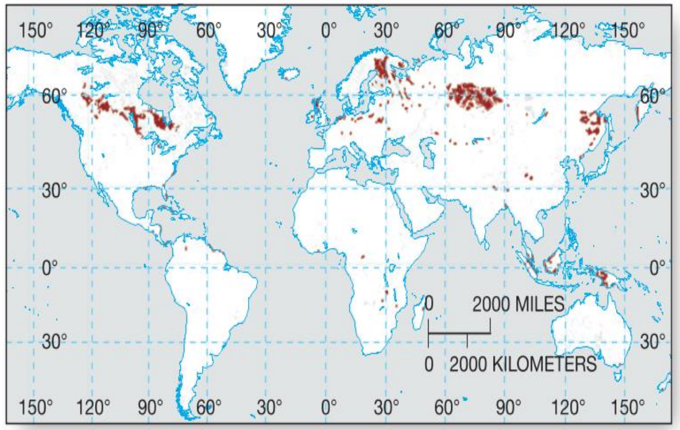
(c) Commercial sorghum crop planted in Vertisols on the Texas coastal plain, northeast of Palacios. Note the characteristic dark soil color.

Figure 15.31

Histosols

- Organic soils (peat, muck, bog)
- Hydric soils – soils are saturated with water or flooded for long periods of time

(a) A Histosol profile on Mainland Island in the Orkneys, north of Scotland. The inset photo shows drying blocks of peat, used as fuel. Note the fibrous texture of the sphagnum moss growing on the surface and the darkening layers with depth in the soil profile as the peat is compressed and chemically altered.



(b) Worldwide Histosol distribution.

(c) A bog in coastal Maine near Acadia National Park.

Figure 15.32