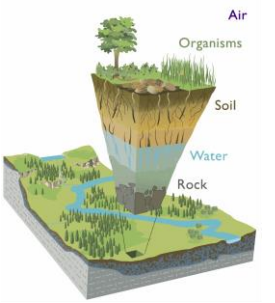
Biogeography Systems

The Geography of Soils

The Critical Zone And Soil

- Critical zone science is the study of where rock meets life
- The critical zone stretches from treetops down to the base of the groundwater system
- Soil is an important component of the critical zone where air, organisms, water. and rock intersect

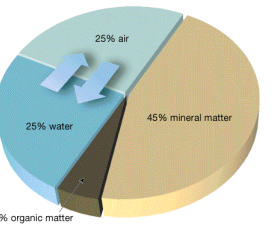


Soil And Earth Systems

- **Soils form through the interaction of all four of Earth's 'spheres':**
  - **Atmosphere supplies oxygen and carbon dioxide for plant photosynthesis and soil chemistry**
  - **Hydrosphere provides soil moisture**
  - **Lithosphere provides minerals that are vital components of soil**
  - **Biosphere is the source of organic material in soil**
- **Mechanical and chemical weathering create soil from bedrock**
- **Soil-forming processes are powered by the Sun**

Soils

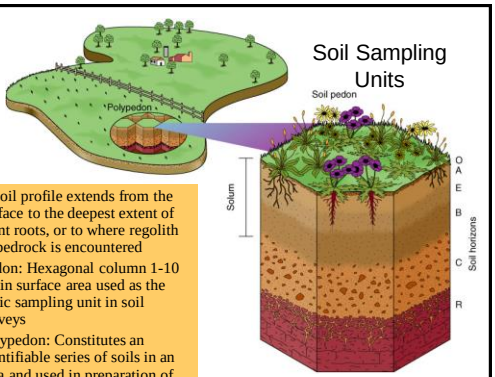
Composition of a good soil



Soils are a combination of minerals, organic matter, water, and air:

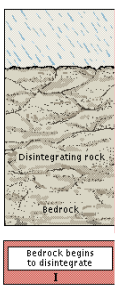
- Rock and mineral fragments are produced by weathering of rocks and support the growth of plants
- Humus (decayed animal and plant remains) is a small, but essential, component

Soil Sampling Units



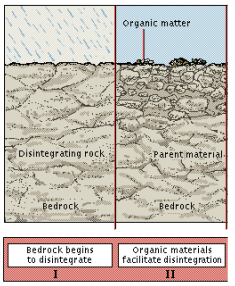
- A soil profile extends from the surface to the deepest extent of plant roots, or to where regolith or bedrock is encountered
- Pedon: Hexagonal column 1-10 m^2 in surface area used as the basic sampling unit in soil surveys
- Polypedon: Constitutes an identifiable series of soils in an area and used in preparation of local soil maps

Formation of Soil



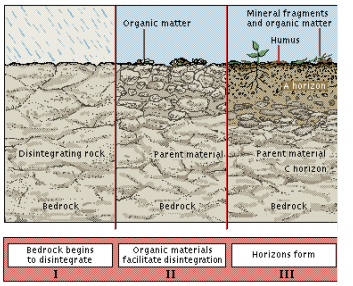
Mechanical and chemical weathering begins to disintegrate bedrock

Formation of Soil



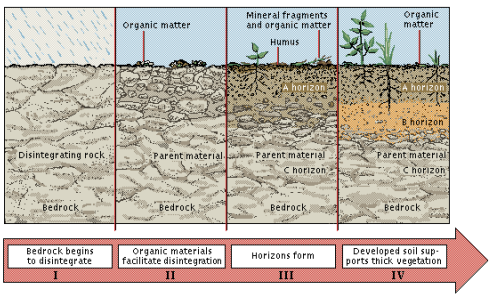
Small organisms and plants begin to occupy loose material; organic acids, burrowing, and plant roots facilitate disintegration

Formation of Soil

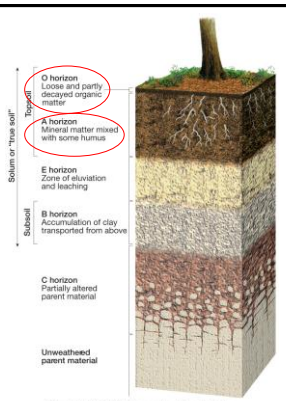


Larger plants with deeper roots follow; soil horizons begin to form from the top down

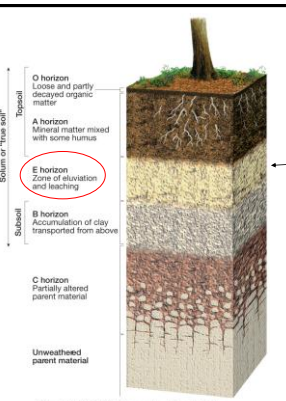
Formation of Soil



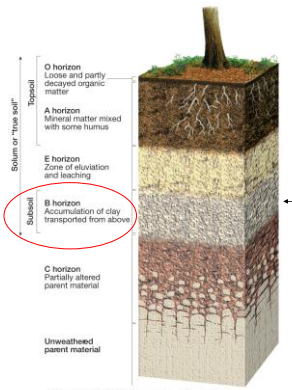
A Soil Profile Consists Of Different Horizons (Layers) Having Distinctive Properties



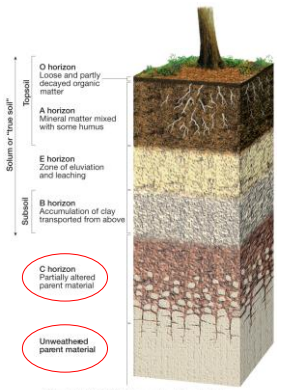
Most organic matter (humus) in the Topsoil



Downward percolating water removes soluble constituents, fine clays and oxides of Al and Fe from this zone



Fine clay, Al and Fe brought down from above accumulate



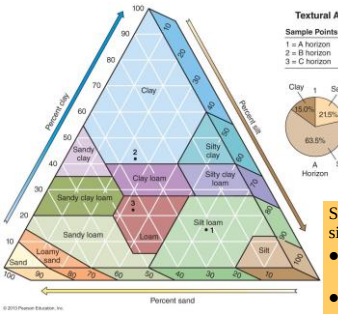
Parent bedrock that was weathered to produce soil above

Soil Color

Munsell Soil Color Chart

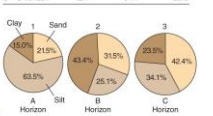
Soil color is a function of composition and chemical makeup:

- Red and yellow: high in Fe-oxide
- Black: Richly organic
- White to pale: Presence of Al-oxides and silicates



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

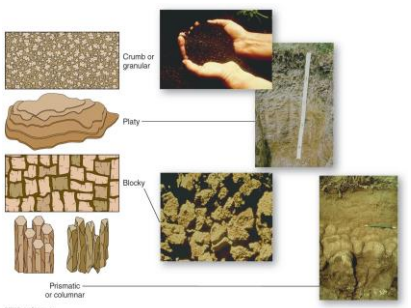


Soil Texture

Soil texture defined by the size of particles:

- Particles range from finest clays up to gravels
- Loam is a balanced mixture of sand, silt and clay beneficial to plant growth

Soil Structure



Soil structure refers to the arrangement of soil particles:

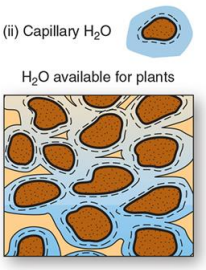
- The term 'ped' describes an individual unit of soil particles
- Peds can be described as blocky, platy, rounded, etc.
- Further described as fine, medium or coarse

Soil Consistence and Porosity

- **Consistency of soil particles:**
  - **Reflects resistance to breaking and manipulation under varying moisture conditions**
  - **Descriptive terms include sticky, plastic, friable, and brittle**
- **Porosity is a measure of the percent pore spaces in a soil**
- **Permeability is a measure of how readily water is transmitted through soil:**
  - **A function of the size of pore spaces and whether or not they are interconnected**

Soil Moisture

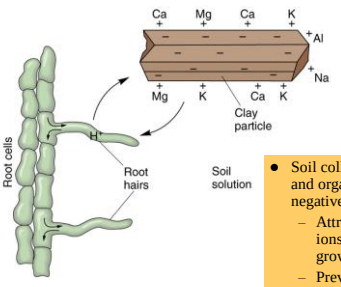
Plants operate most efficiently when soil has the maximum water availability for plant use



Field capacity occurs after excess gravitational water drains from the soil, leaving the remaining water available for plants.

Soil Chemistry And Fertility

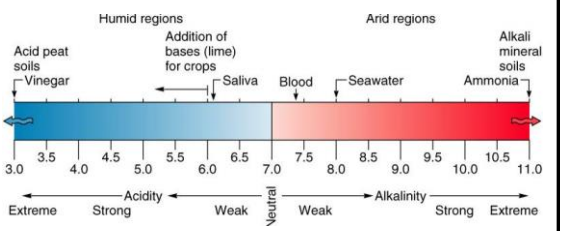
- **Soil chemistry:**
  - **Soil gases mostly nitrogen, oxygen and carbon dioxide**
  - **Soil water is the medium for chemical reactions**
  - **Soil colloids are tiny particles of clay and organic material that retain and exchange important cations with soil solution**
- **Soil fertility is the ability of soil to sustain plants:**
  - **Fertile soil contains organic substances and clay minerals that absorb water and elements needed by plants**



Soil Colloids Retain Mineral Ions For Later Absorption By Root Hairs

- Soil colloids are tiny particles of clay and organic material that carry a negative electrical charge:
  - Attract positive (mainly metallic) ions (cations) critical to plant growth
  - Prevents cations from being leached away
- Cation exchange capacity (CEC) is a measure of how well soil colloids can store and exchange cations:
  - High CEC soil has good fertility

Soil Acidity and Alkalinity

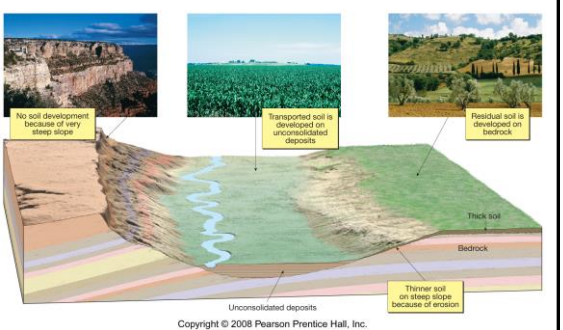


- Acid precipitation is a major contributor to soil acidity
- Humid regions characterized by acidic soils:
  - — Acid soil below pH 6.0 require treatment with lime
- Arid regions are more likely to have alkaline soils

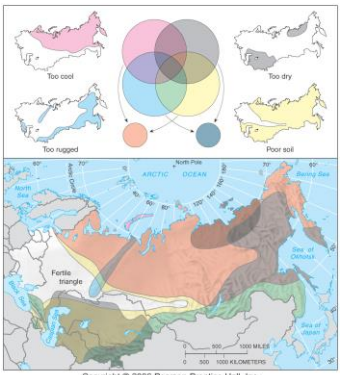
Factors Affecting Soil Formation

- **Climate:**
  - **Most influential control of soil formation**
  - **Warm temperatures and abundant precipitation accelerate chemical weathering and soil formation**
  - **Cold, dry climates less favorable for good soils**
- **Vegetation, animal, and bacterial activity:**
  - **Influence the soil's physical and chemical properties, particularly pH**
- **Topography:**
  - **Steep slopes often have poorly developed soils**
  - **Optimum terrain is a flat-to-undulating upland surface**

Topographic Effects On Soil Formation



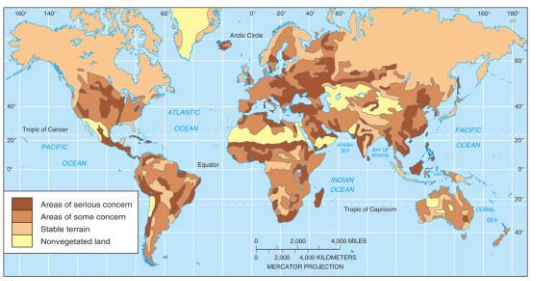
Soil Fertility in Eurasia



Soil Degradation

- A few centimeter's thickness of prime soil require 500 years to mature
- Global soil depletion and loss at record levels:
  - 35% of farmlands are losing soil faster than can form

Soil Degradation



(a)

The Human Factor

- Human intervention is a major impact on soils
- Contributions to soil erosion and depletion:
  - Removal of soil-holding vegetation
  - Land is plowed regardless of topography
  - Flood control structures such as dams and levees block sediments and nutrients from replenishing floodplain soils
  - Exposed soils may be completely leached of needed cations

Dealing With Soil Erosion

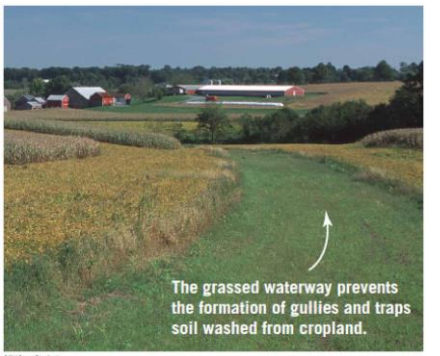
- **Short term solutions:**
  - **Fertilizers**
  - **Increasing irrigation**
  - **Planting higher-yield strains**
- **Still, some 35% of farmlands are losing soil faster than it can form**
- **Addressing soil erosion is a major challenge for the future:**
  - **Growing population will require a larger agricultural system at a time when the amount of fertile soil is declining**

Soil Conservation On Hillsides

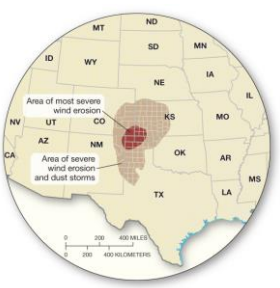
Terraced Farming On Loess Deposits

(b) Terraced farming near the Yellow River on the Loess Plateau in northern China.

Soil Conservation

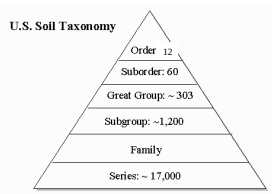


Wind Erosion During Dust Bowl (1935-1938)



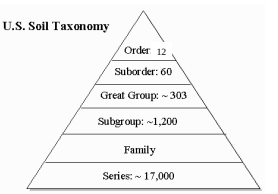
Reducing Wind Erosion

Classifying Soils



- Variations in soil formation over time and distances has led to a variety of recognized soil types
- Groups have been established using common characteristics
- In the United States, a system is used called Soil Taxonomy:
  - Emphasis is placed on the physical and chemical properties of soils

Classifying Soils

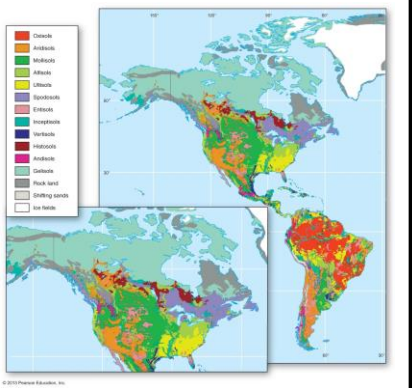


- U.S. Soil Taxonomy:
  - Six hierarchical categories have been established, ranging from Order (the broadest category) to Series (most specific)
  - 12 basic soil orders are recognized
  - Descriptive names are derived from Latin and Greek

TABLE 14.1 Soil Taxonomy Soil Orders

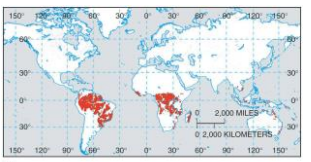
Order	General Location and Climate	Description
Oxisols	Tropical soils; hot, humid areas	Maximum weathering of Fe and Al and eluviation, continuous plinthite layer
Aridisols	Desert soils; hot, dry areas	Limited alteration of parent material, low climate activity, light color, low humus content, subsurface illuviation of carbonates
Mollisols	Grassland soils; subhumid, semiarid lands	Noticeably dark with organic material; humus rich; base saturation; high, friable surface with well-structured horizons
Alfisols	Moderately weathered forest soils; humid temperate forests	B horizon high in clays, moderate to high degree of base saturation, illuviated clay accumulation, no pronounced color change with depth
Ultisols	Highly weathered forest soils; subtropical forests	Similar to Alfisols, B horizon high in clays, generally low amount of base saturation, strong weathering in subsurface horizons, redder than Alfisols
Spodosols	Northern conifer forest soils; cool, humid forests	Illuvial B horizon of Fe/Al clays, humus accumulation, without structure, partially cemented, highly leached, strongly acid, coarse texture of low bases
Entisols	Recent soils; profile undeveloped, all climates	Limited development, inherited properties from parent material, pale color, low humus, few specific properties, hard and massive when dry
Inceptisols	Weakly developed soils; humid regions	Intermediate development; embryonic soils, but few diagnostic features; further weathering possible in altered or changed subsurface horizons
Gelisols	Cold and frozen soils; high latitudes in Northern Hemisphere, southern limits near tree line	Permafrost within 100 cm of the soil surface, evidence of cryoturbation (frost churning) and/or an active layer, patterned ground
Andisols	Volcanic soils; areas affected by frequent volcanic activity (formerly within Inceptisols and Entisols)	Volcanic parent materials, particularly ash and volcanic glass; weathering and mineral transformation important; high CEC and organic content, generally fertile
Vertisols	Expandable clay soils; subtropics, tropics; sufficient dry period	Forms large cracks on drying, self-mixing action, contains >30% in swelling clays, light color, low humus content
Histosols	Organic soils; wet places	Peat or bog, >20% organic matter, much with clay >40 cm thick, surface organic layers, no diagnostic horizons

Soil Regions



Oxisols

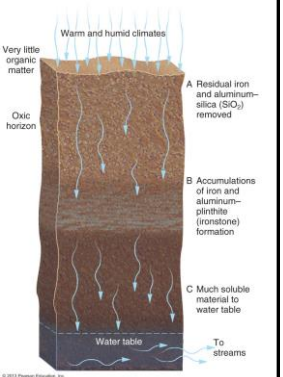
- Oxisols are soils generally found in the tropics and subtropical regions
- The warm, wet climate extensively weathers and leaches the soil via a process called 'laterization'



(b)

Laterization

- Laterization is a leaching process in warm and humid climates
- Heavy precipitation leaches soluble minerals and silica from the A horizon:
  - Removes basic cations and colloidal material
  - Oxisols therefore have a low cation-exchange capacity
- Iron and aluminum accumulate in the B horizon:
  - Soil typically reddish and yellowish due to high iron and aluminum content
- Most soluble material lost to the underlying groundwater system

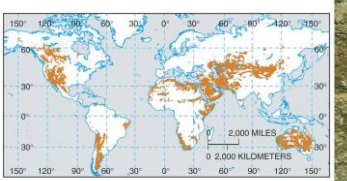


Oxisols

- Oxisols are therefore poor soils for sustaining vegetation:
  - Forest relies on recycling of nutrients from dead vegetation on the forest floor
  - Can only support crops for a few years
  - Slash-and-burn cultivation is destroying rain forests

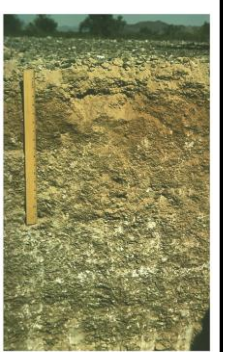
(a)

Aridisols



(b)

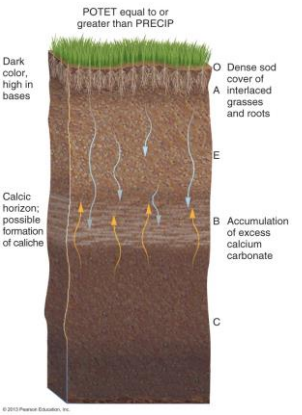
- Aridisols are soils that develop in dry places such as deserts
- Low organic content
- Agricultural use requires large investments in water, drainage and fertilizers



(a)

Aridisols And Calcification

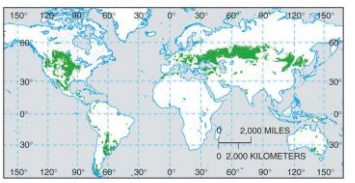
- Aridisols are products of calcification
- Insufficient water to remove soluble minerals
- Accumulation of calcium and magnesium carbonates in the B and C horizons:
  - Forms a hardened layer called caliche



Mollisols

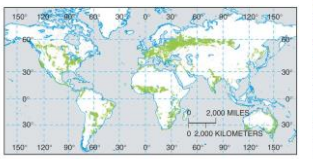
- Dark, soft mollisols have excellent soil fertility
- Humus-rich surface horizon is rich in calcium and magnesium
- The generally dry climate, however, only supports grassy vegetation

Mollisols



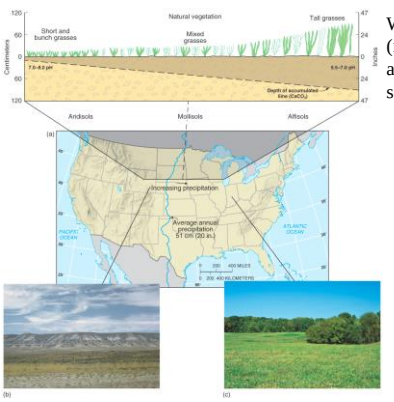
- Mollisols are found in prairies
- Also found in hardwood forests with significant earthworm activity
- Climate ranges from boreal or alpine to tropical:
  - Dry seasons are normal

Alfisols



- Alfisols are moderately weathered, fertile soils that form under boreal forests or broadleaf deciduous forests
- Rich in iron and aluminum
- Clay particles accumulate in the subsurface layer in response to leaching

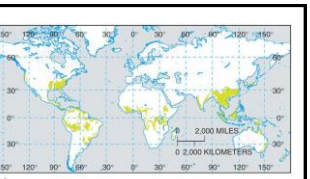
Wyoming (dry) alkaline soils



Wisconsin (moist) acidic soils

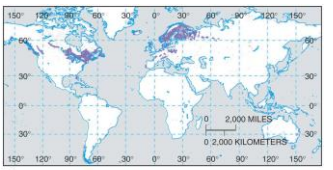
Ultisols

- Ultisols are products of long periods of weathering
- Restricted to humid climates in temperate regions and tropics where growing season is long
- Abundant water contributes to extensive leaching:
  - Water percolating through soils concentrates clay particles in the lower horizons
- Poor soil quality



Spodosols

- Spodosols are soils found only in humid regions with sandy material
- Common in northern coniferous forests and cool, humid forests
- Spodosols are products of podzolization

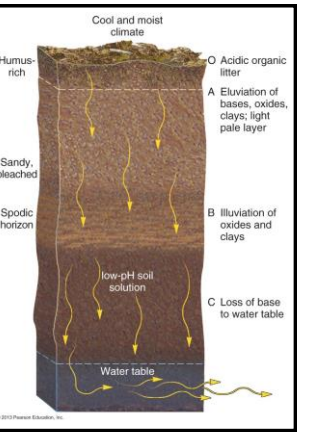


(b)


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

Podzolization

- Podzolization is a process of soil acidification associated with needleleaf forest in cool climates:
  - Surface horizon consists of organic litter from base-poor, acid-rich evergreen trees
  - Acidic solution percolates through underlying A horizon, removing clays, iron and aluminum
  - Dissolved constituents accumulate in B horizon
- Any leached bases are transported downward and lost to the groundwater system below



Spodosols

- Spodosol profile:
  - The O horizon mostly acidic forest litter
  - The A horizon includes a layer that is sandy and light-colored, lacking humus and clay
  - The B horizon consists of accumulated organic matter along with iron and aluminum oxides
- Low base-cation content requires the addition of nitrogen, phosphate, and potash (potassium carbonate) for agricultural use


(a)

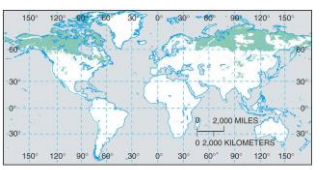
Entisols


Anza-Borrego Desert, California

- Young soils having limited development and exhibiting properties of the parent material
- Productivity varies:
  - Very high for those formed on recent river deposits
  - Very low for those forming on shifting sand or rocky slopes

Gelisols

- Gelisols occur in regions with permafrost
- Low temperatures and frozen conditions for much of the year
- Slow soil-forming processes:
  - Cold temperatures inhibit chemical weathering
- Supports tundra vegetation such as lichens, mosses, and other plants adapted to the harsh cold



(a)


(b)

- Gelisols are affected by cryoturbation, which involves frost churning and mixing of soil in the freeze-thaw cycle:
  - Disrupts soil horizons
  - Organic-rich topsoil is drawn down to lower layers
  - Rocky C-horizon material lifted to the surface
  - Results in little profile development
- Patterned-ground common

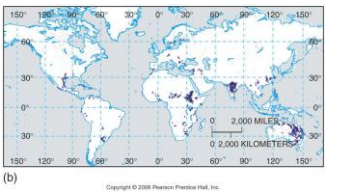
Andisols

(b) Grape vines, Cape Verde Islands

(a) Cultivation of Andisols in Hawai'i

- Andisols are young soils where the parent material is volcanic ash and cinders deposited by recent volcanic activity
- High cation-exchange capacity
- Moderate fertility (Supports sugar cane, pineapple and other cash crops in Hawaii)

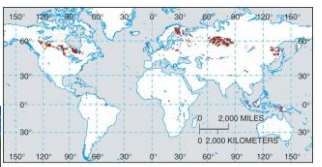
Vertisols



(b)

- Vertisols are found in subhumid to arid climates
- Contain large amounts of clay that shrink upon drying and swell when wet
- Soil expansion and contraction exert stresses on human structures

Histosols



(b)

(a)

- Histosols are organic soils with little or no climatic implications
- Found in any climate where organic debris can accumulate to form a bog soil
- Dark, partially decomposed organic material commonly referred to as peat

Histosol Profile North Of Scotland

Inset photo: Drying blocks of peat