Soil Development

Soils Sustain Life

Right off the Bat!!

- A soil is not a geologic deposit, it is a product of in situ weathering.
- Engineers, archaeologists, and others have learned that anything that is not rock on the Earth’s surface is soil.
- The way a soil is defined depends largely on the way you view it, eg. engineers, archaeologists, agronomists, ect.

Our definition of Soil

- A soil is a natural body consisting of layers (horizons) of mineral and/or organic constituents of variable thickness, which differ from the parent materials in their morphological, physical, chemical, and mineralogical properties and their biological characteristics.

Soil forming factors

- Hans Jenny (1941) Cl, o, r, p, t
- cl, climate
- o, biotic influence
- r, topographic relief
- p, parent material
- t, time

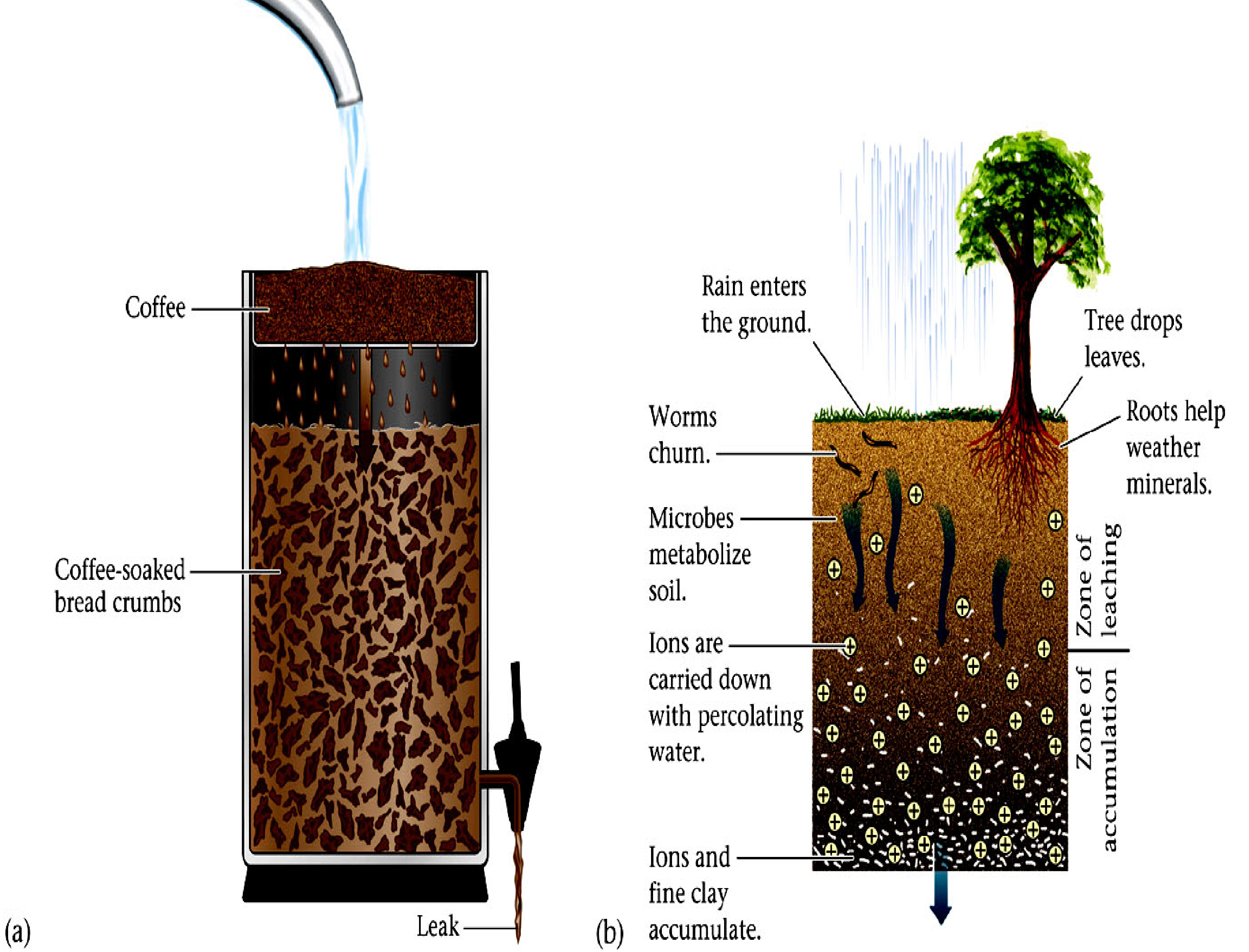
Jenny's individual soil functions

- s or S = f (cl, o, r, p, t)   climofunction
- s or S = f (o, cl, r, p, t)   biofunction
- s or S = f (r, cl, o, p, t)   topofunction
- Lithofunction
- Chronofunction
- To solve each function, the first factor listed (cl) is allowed to vary while the others remain constant. It is then possible to statistically determine the dependancy of one (or more) soil properties on a single factor

Soil characteristics

- Horizons

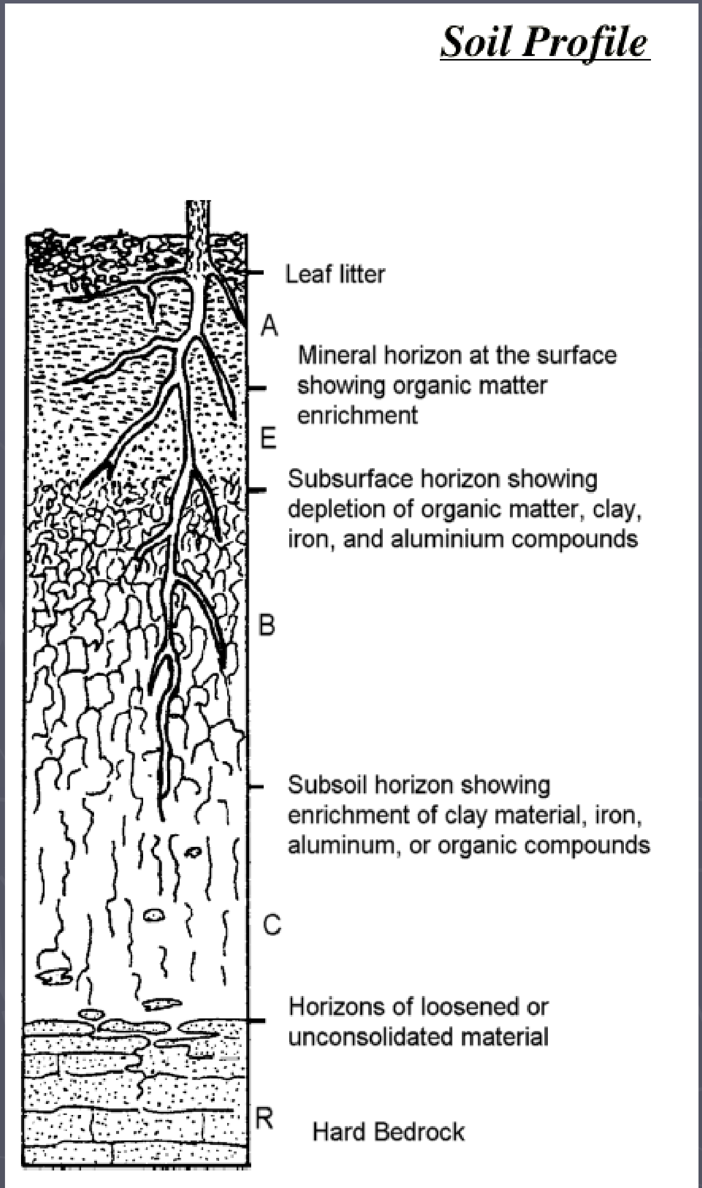
Horizon	Properties
O	Uppermost horizon; fresh to partly decomposed organic matter.
A	Mineral soil mixed with humus; dark colored.
E	Zone of maximum *eluviation* (leaching) of clay, iron, and aluminum, leaving residual minerals such as quartz in sand and silt sizes. Lighter color than A horizon.
B	Zone of *illuviation* (accumulation) of clay, iron, and aluminum compounds from above, with development of distinctive structures such as granular, blocky, or prismatic aggregates. Colors more intense than overlying and underlying horizons.
C	Relatively unweathered unconsolidated mineral matter below the zone of major biologic activity. May be mechanically fractured, stained by oxides, or loosely recemented by calcium carbonate, gypsum, iron oxide, or more soluble salts.


Coffee
Coffee-soaked bread crumbs
Leak
(a)
Rain enters the ground.
Tree drops leaves.
Worms churn.
Roots help weather minerals.
Microbes metabolize soil.
Zone of leaching
Ions are carried down with percolating water.
Zone of accumulation
Ions and fine clay accumulate.
(b)

Horizons

- Distinctive weathered zones that are roughly parallel to the land surface and are the product of weathering processes. The Master horizons are O, A, E, B, C, and R.
- Subhorizons

Horizon examples



Subhorizons

TABLE 2.6 Lowercase Letter Symbols to Designate Subordinate Distinctions Within Master Horizons

Letter	Distinction	Letter	Distinction
a	Organic matter, highly decomposed	n	Accumulation of sodium
b	Buried soil horizon	o	Accumulation of Fe and Al oxides
c	Concretions or nodules	p	Plowing or other disturbance
d	Dense unconsolidated materials	q	Accumulation of silica
e	Organic matter, intermediate decomposition	r	Weathered or soft bedrock
f	Frozen soil	s	Illuvial accumulation of O.M.[a] and Fe and Al oxides
g	Strong gleying (mottling)	ss	Slickensides (shiny clay wedges)
h	Illuvial accumulation of organic matter	t	Accumulation of silicate clays
i	Organic matter, slightly decomposed	v	Plinthite (high iron, red material)
j	Jarosite (yellow sulfur mineral)	w	Distinctive color or structure
jj	Cryoturbation (frost churning)	x	Fragipan (high bulk density, brittle)
k	Accumulation of carbonates	y	Accumulation of gypsum
m	Cementation or induration	z	Accumulation of soluble salts

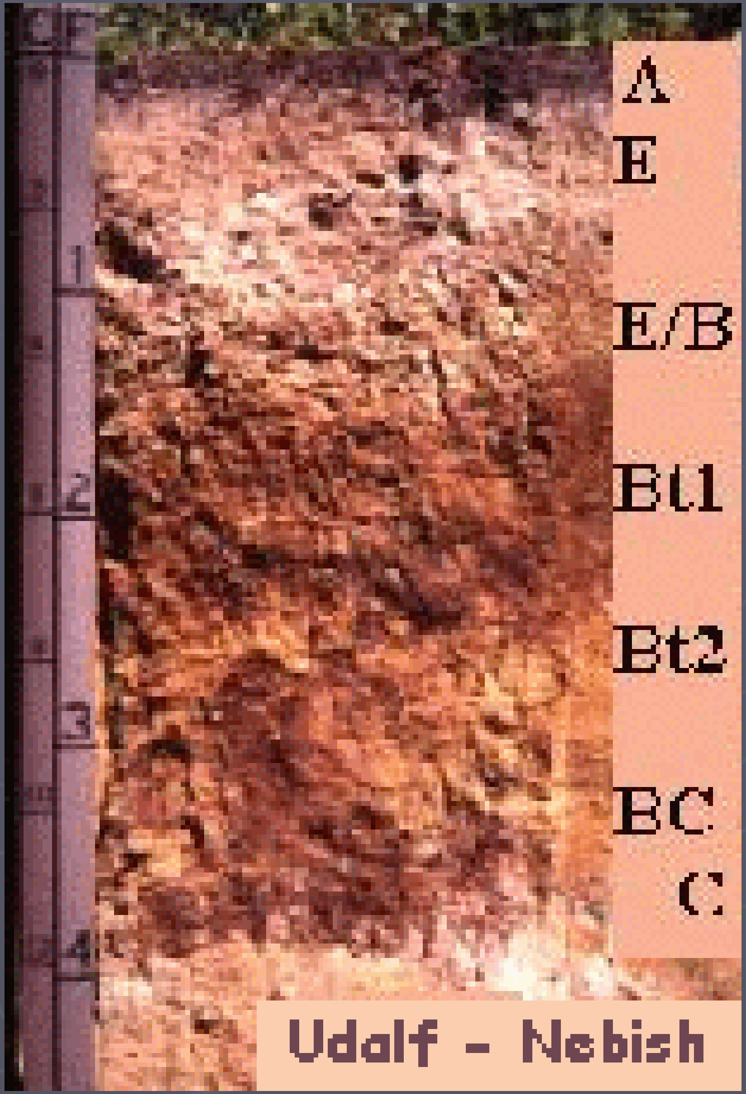
[a] O.M. = organic matter.

Subhorizon characteristics

Surface horizons = epipedons	
Mollic (A)	Thick, dark-colored, high base saturation, strong structure
Umbric (A)	Same as mollic except low base saturation
Ochric (A)	Too light-colored, low organic content or thin to be Mollic; may be hard and massive when dry
Melanic (A)	Thick, black, high in organic matter (>6% organic C), common in volcanic ash soils
Histic (O)	Very high in organic content, wet during some part of year
Anthropic (A)	Human-modified molliclike horizon, high in available P
Plaggen (A)	Human-made sodlike horizon created by years of manuring
Subsurface horizons	
Argillic (Bt)	Silicate clay accumulation
Natric (Btn)	Argillic, high in sodium, columnar or prismatic structure
Spodic (Bh, Bs)	Organic matter, Fe and Al oxides accumulation
Cambic (Bw, Bg)	Changed or altered by physical movement or by chemical reactions, generally nonilluvial
Agric (A or B)	Organic and clay accumulation just below plow layer resulting from cultivation
Oxic (Bo)	Highly weathered, primarily mixture of Fe, Al oxides and non-sticky-type silicate clays
Duripan (Bqm)	Hardpan, strongly cemented by silica
Fragipan (Bx)	Brittle pan, usually loamy textured, dense
Albic (E)	Light-colored, clay and Fe and Al oxides mostly removed
Calcic (Bk)	Accumulation of $CaCO_3$ or $CaCO_3 \cdot MgCO_3$
Gypsic (By)	Accumulation of gypsum
Salic (Bz)	Accumulation of salts
Kandic (Bt)	Accumulation of low-activity clays
Petrocalcic (Ckm)	Cemented calcic horizon
Petrogypsic (Cym)	Cemented gypsic horizon
Placic (Csm)	Thin pan cemented with iron alone or with manganese or organic matter
Sombric (Bh)	Organic matter accumulation
Sulfuric (Cj)	Highly acid with Jarosite mottles

Transitional major horizons

- AB, BA, OE, ect.



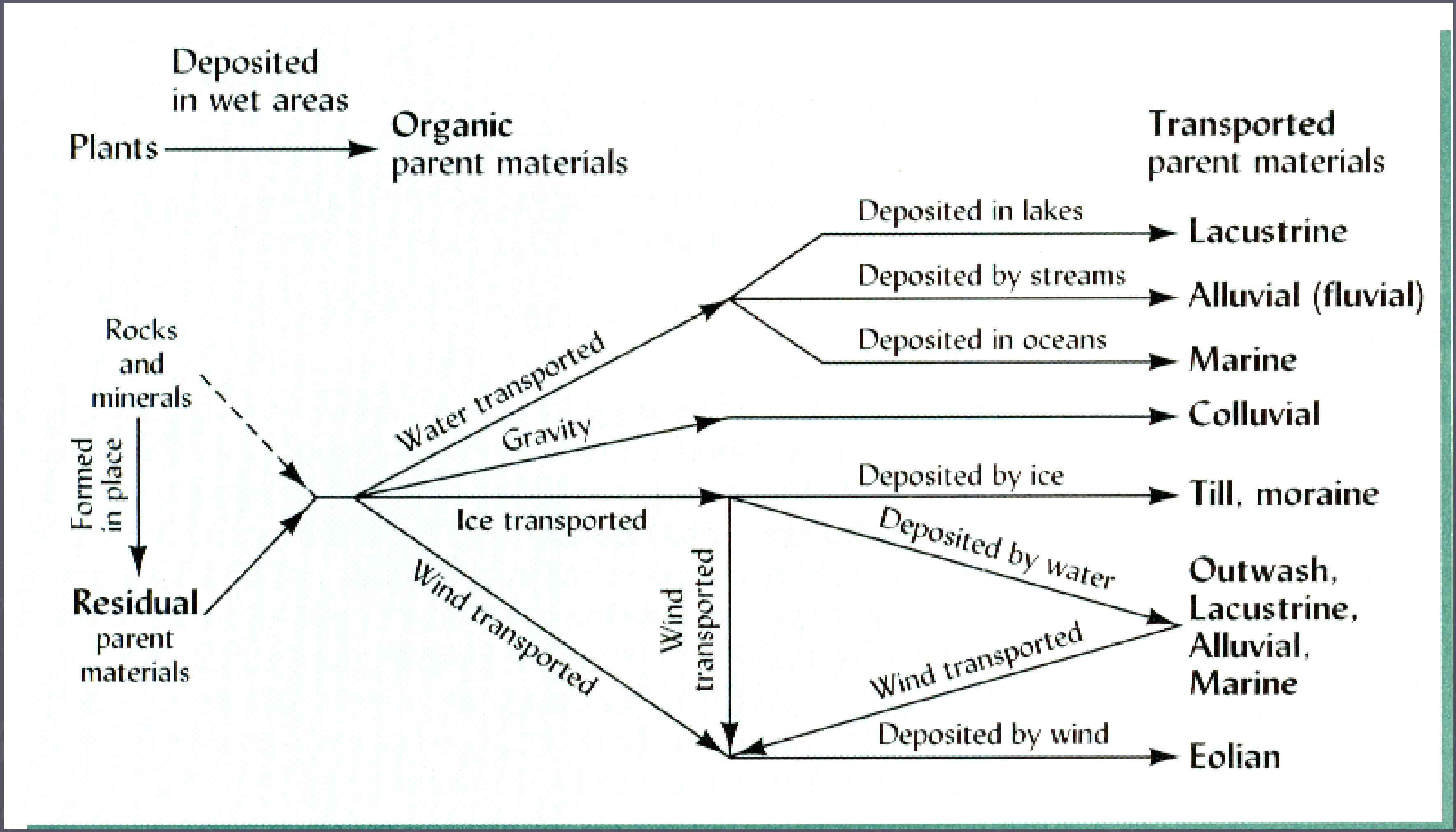
Formational factors considerations

- Each certainly influences the end weathering product (soil)
- Climate, organisms, and topographic relief, are likely to change (evolve) over the duration (2 to 20,000 years) of soil formation.
- In general, Climate (ppt. and temp.) and Parent material are the most controlling factors in regards to soil formation. (complex combinations.

An example of the importance of climate

- Australian buaxite
- Parent material, 90% sandstone, 10% kaolinite
- Climate, Hot monsoons, with approx. 1500mm/yr ppt., plus time produces an abundant source of buaxite from and unlikely parent material.
- The end weathering product (soil profile) has leached the majority, 85% of the quartz to 8 m, the upper 5 m consists of hydrated AlOH (oxides) with iron stains.

Parent Material types

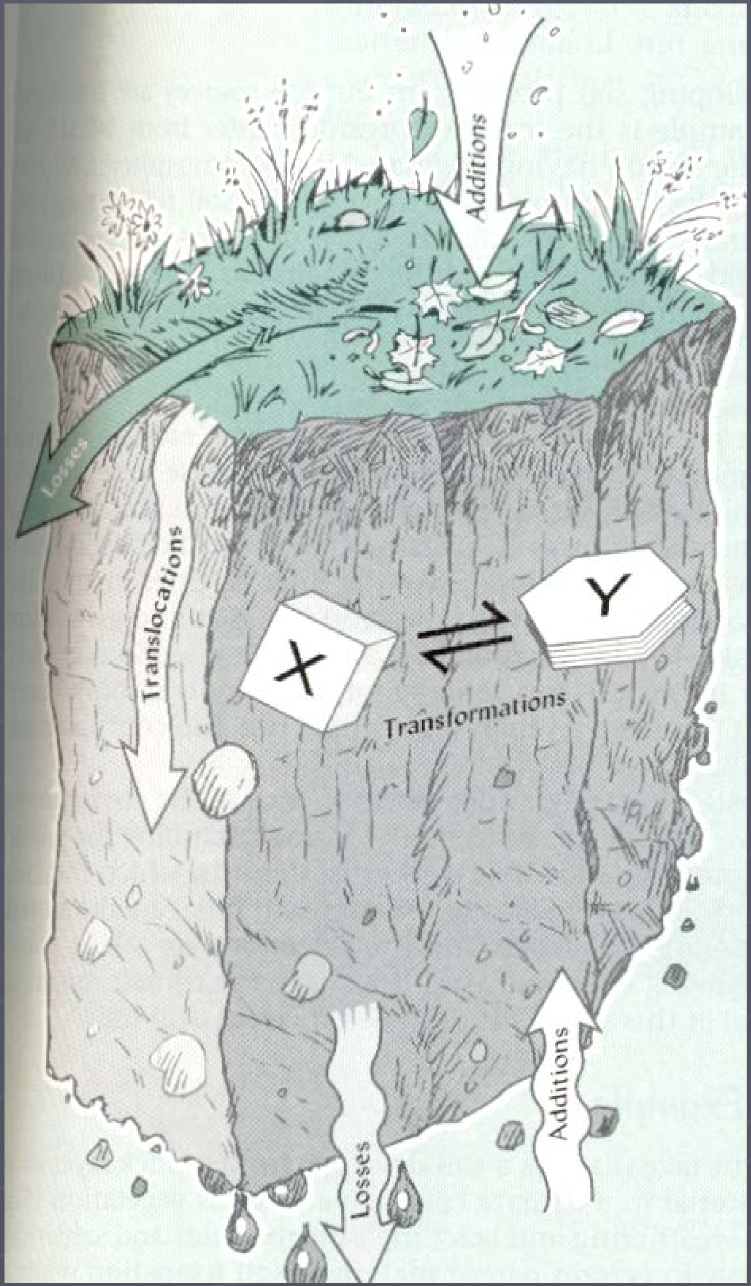


The basic processes of soil formation

- Transformations
- Translocations
- Additions
- Losses

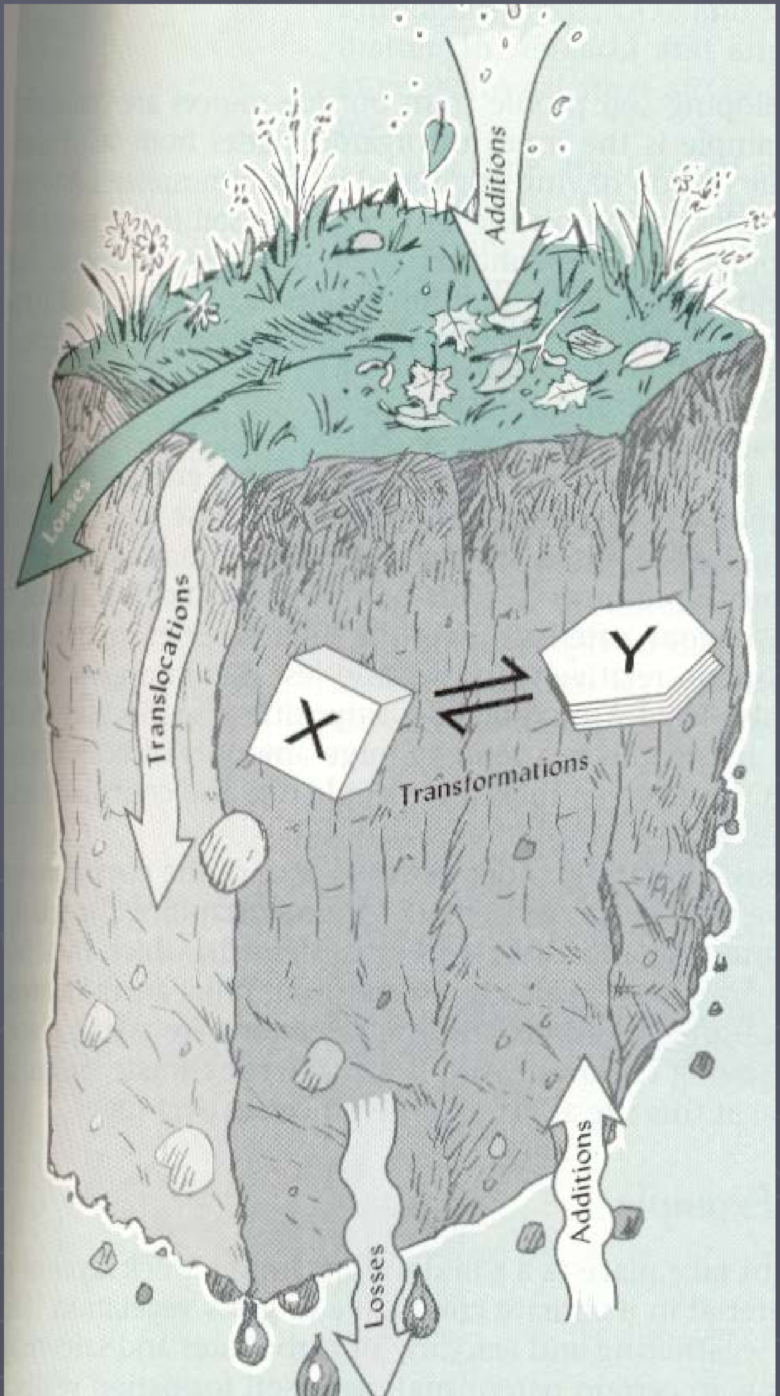
Transformations

- Chemical and mineralogical changes or precipitation
- Hydrolosis
- Neoformation
- Decompostion of organic residue and synthesis of organic acids, humus



Translocations

- The movement (laterally or vertically) of inorganic or organic materials within a soil profile



Translocation terms

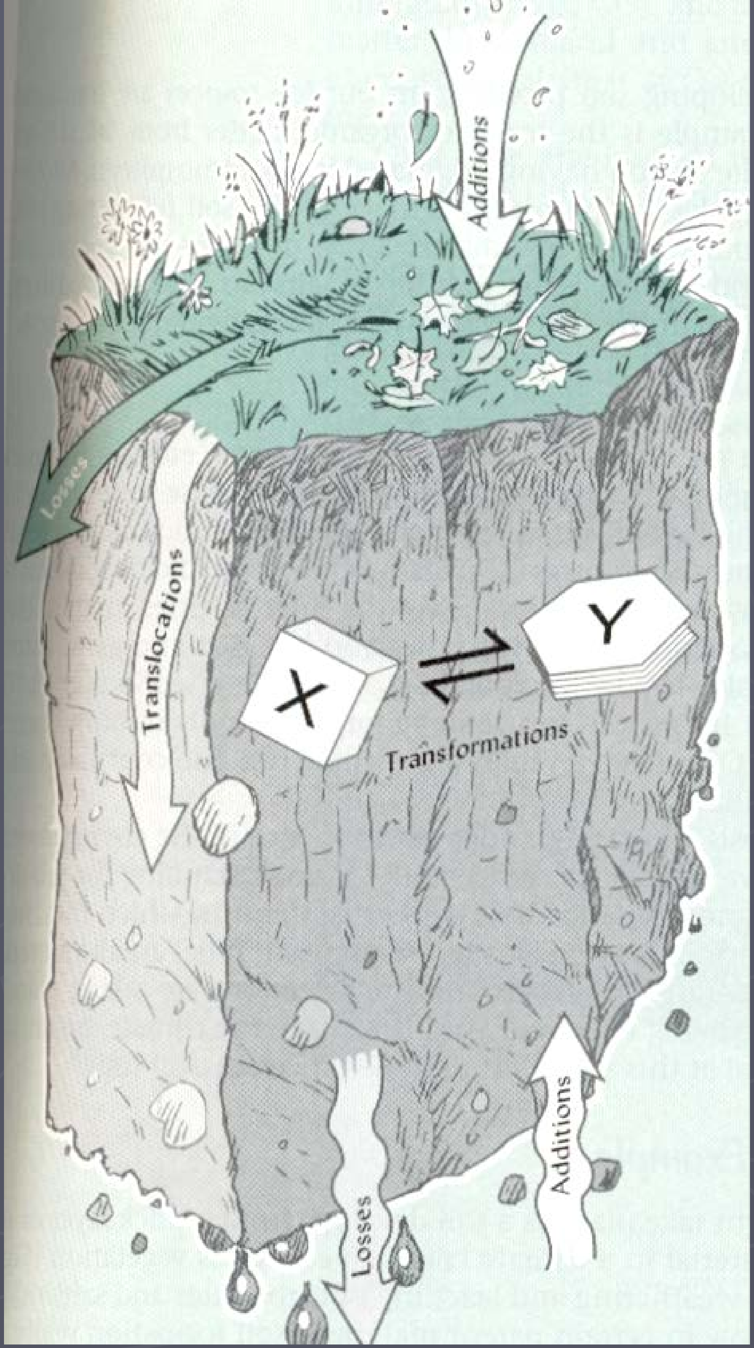
- Eluviation, The removal of soil material in suspension from a layer or layers of soil (leaching)
- Illuviation: A soil layer or horizon in which material is carried from an overlying layer. (A layer of accumulation).

Additions

- Organic matter
- Precipitation, aqueous, salts/silica (evaporation)
- Deposition

Losses

- Leaching
- Evapotranspiration
- Erosion



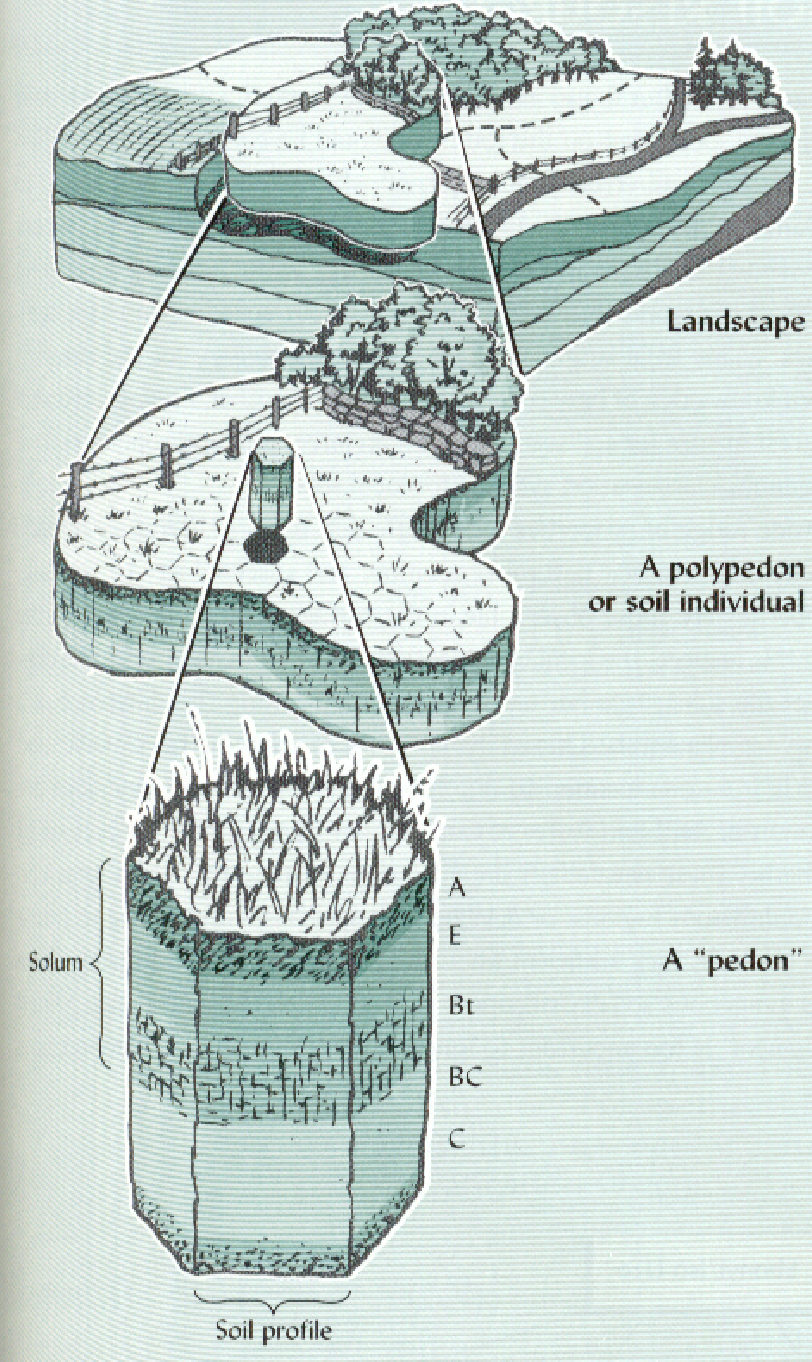
The four processes of soil formation

- These processes, Transformations, Translocations, Additions, and Losses operate under specific environmental factors and provide a framework to investigate the relationships between soils and the landscapes/ecosystems in which they are active.

Soil Classification

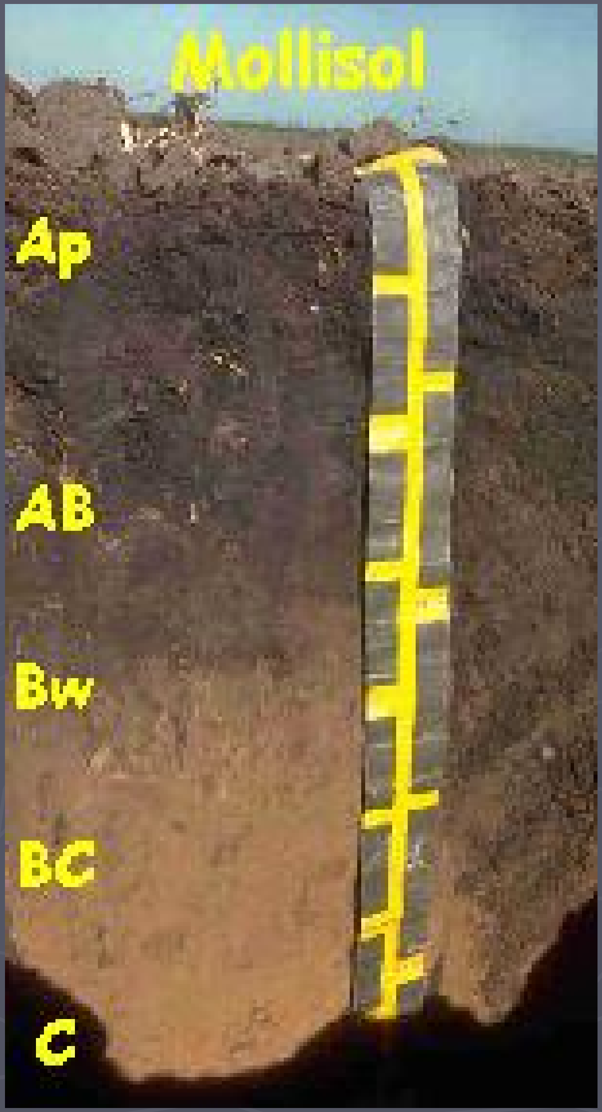
- Landscape/Environment, Polypedon, pedon, epipedon

Soil landscape



Epipedon

- Includes the upper portion of the soil that is darkened by organic matter and/or the upper eluvial horizons.
- The epipedon may extend into the B-horizon if it is darkened by organic material.

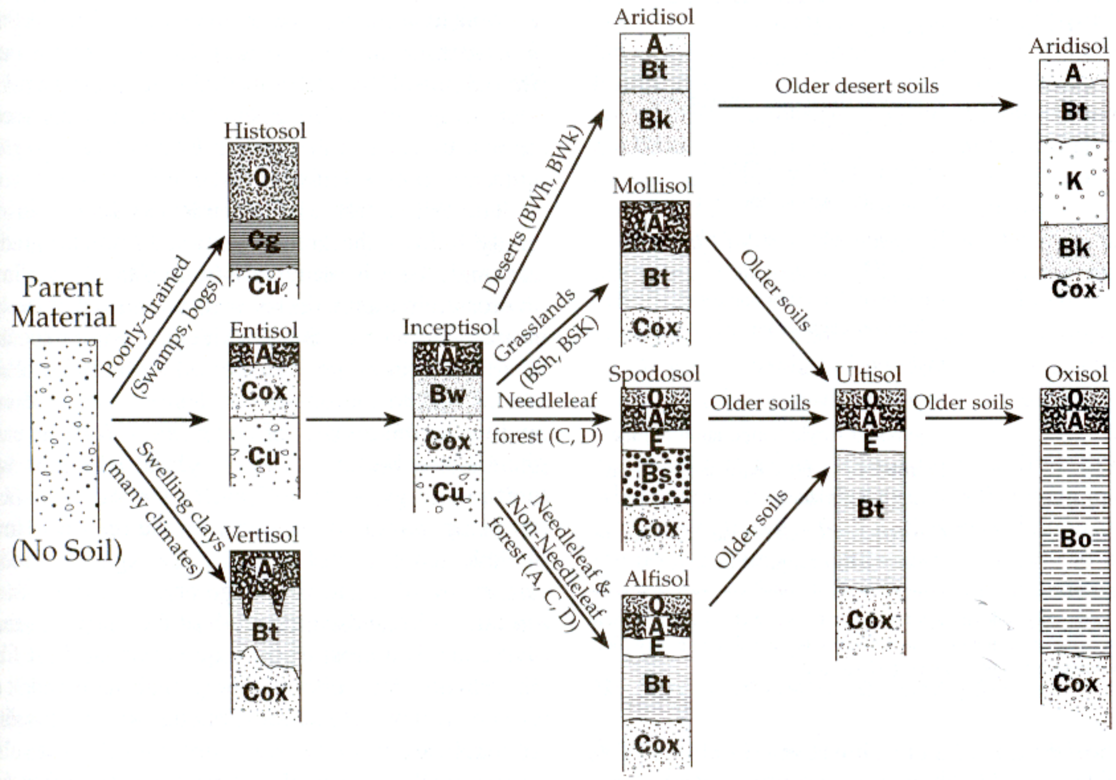


Soil Taxonomy

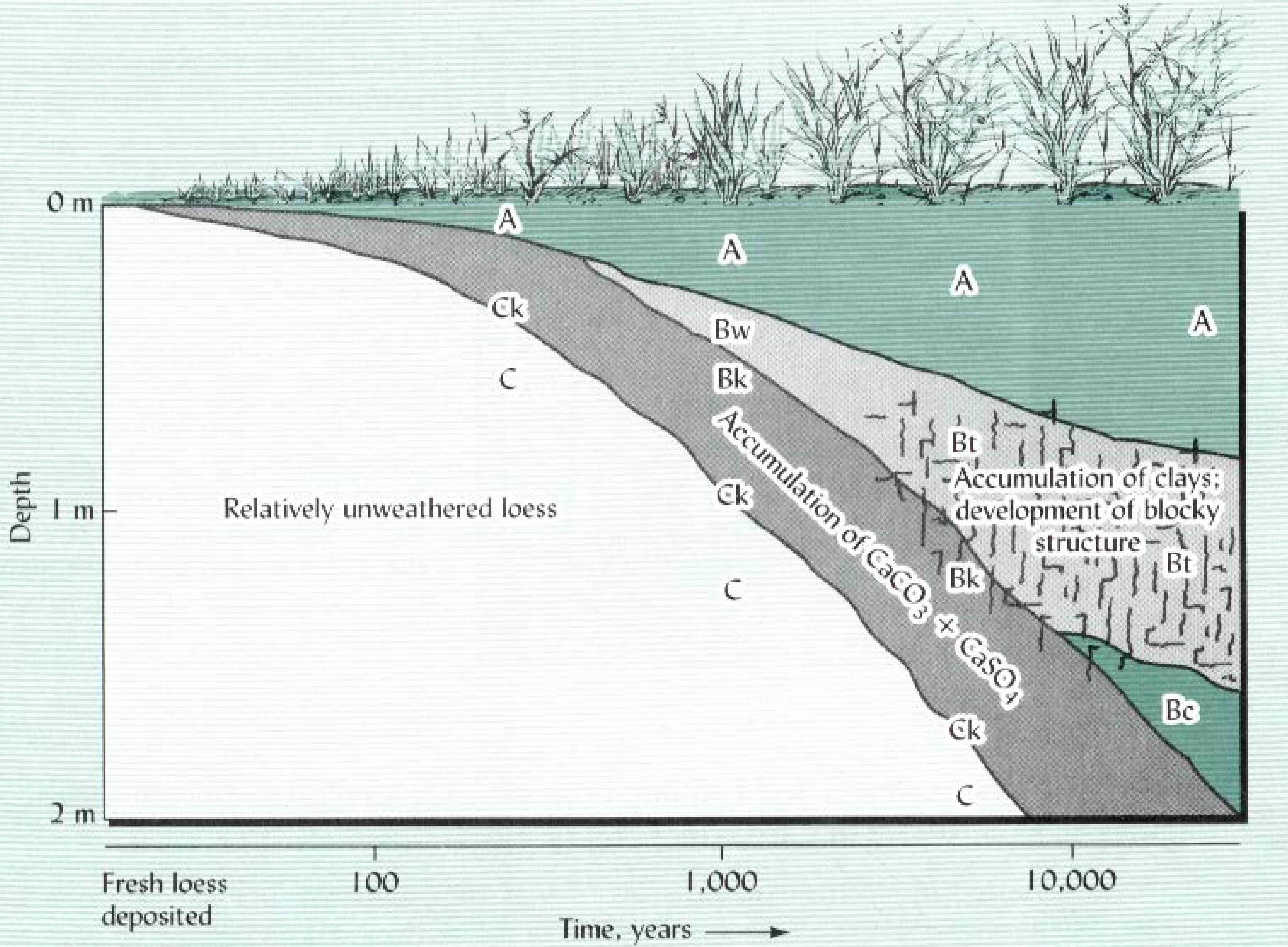
- Order 12
- Suborder 63
- Great Group 319
- Sub Group 2, 484
- Family 8, 000
- Series 19, 000

Soil and Time

Soil Development Chart

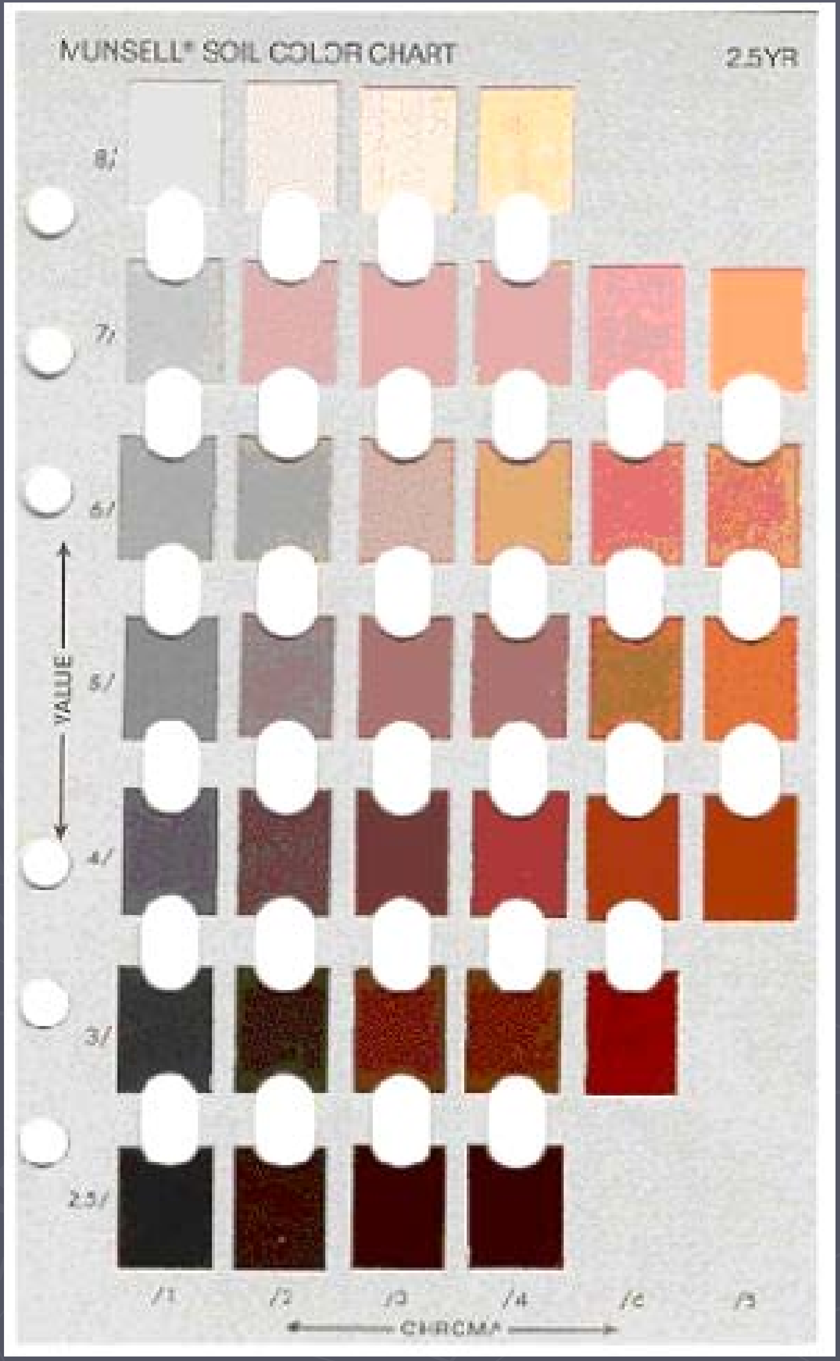


O Horizon:	Surface horizon dominated by organic matter (e.g., leaves) in various stages of decay
A Horizon:	Surface horizon or beneath O horizon dominated by mineral matter, but with sufficient humus to darken color
E Horizon:	A light-gray subsurface horizon that has been leached of pigments by organic acids produced by the decay of needleleaf litter
Bw Horizon:	A young B horizon that has been slightly reddened by oxidation, but is not yet clay-enriched
Bs Horizon:	Illuvial accumulation of amorphous organic matter – sesquioxide (Al_2O_3; Fe_2O_3) complexes
Bk Horizon:	A light-colored B horizon due to the coating of mineral grains by carbonates
Bt Horizon:	A 'mature' B horizon that is reddened by oxidation as well as clay-enriched
Bo Horizon:	A deep red, highly weathered and leached B horizon rich in residual sesquioxides; usually restricted to very old soils in tropical climates
Cox Horizon:	An oxidized horizon beneath a B or A horizon
K Horizon:	Similar to a Bk horizon, but so greatly enriched in carbonates that the horizon is white
Cg Horizon:	A 'gleyed' subsurface horizon that shows patchy zones of blue, gray, and green colors from reduced conditions; may be local areas of oxidized material
Cu Horizon:	Unweathered parent material


0 m
1 m
2 m
Depth
A
A
A
A
Ck
Bw
Bk
C
Relatively unweathered loess
Accumulation of $CaCO_3$ + $CaSO_4$
Ck
C
Bt
Accumulation of clays; development of blocky structure
Bt
Bk
Bc
Ck
C
Fresh loess deposited
100
1,000
10,000
Time, years

Describing a soil

- Color
- Thickness
- Structure
- Texture

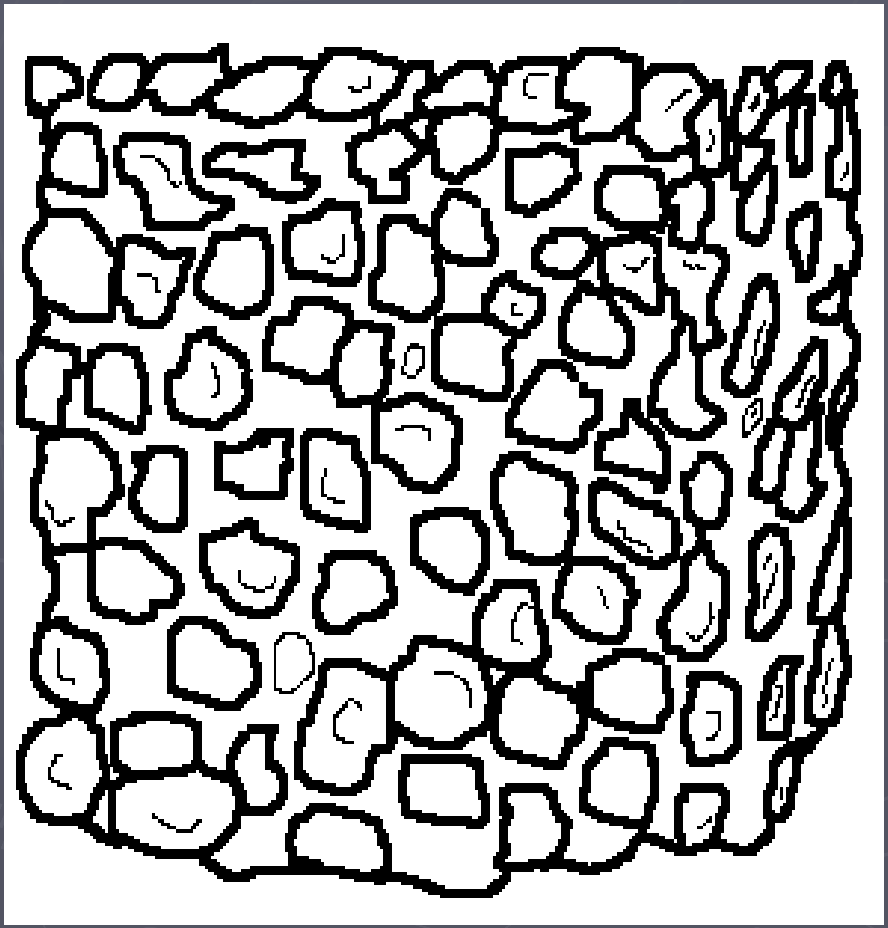


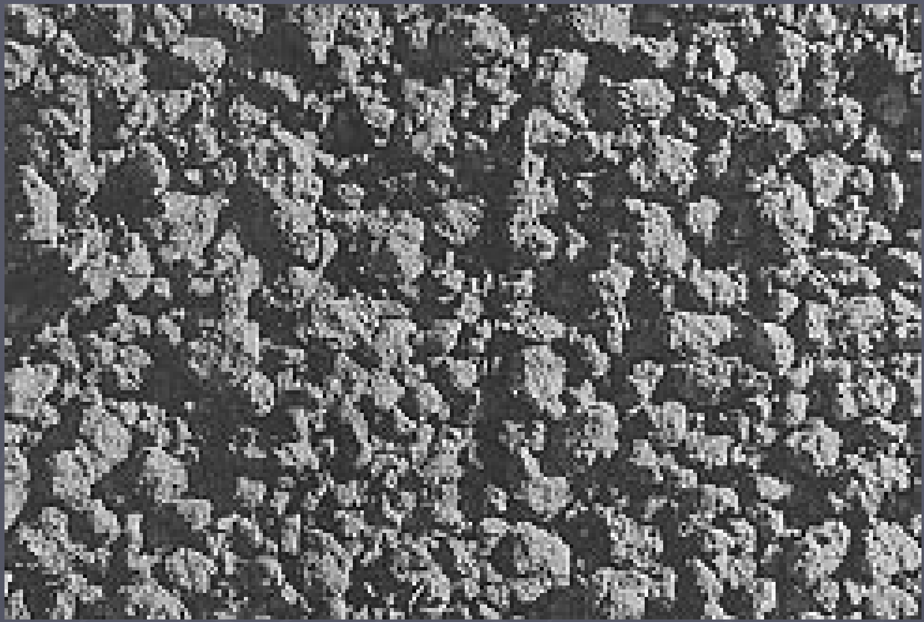
MUNSELL® SOIL COLOR CHART
2.5YR
8/
7/
6/
5/
4/
3/
2.5/
VALUE
/1
/2
/3
/4
/6
/8
CHROMA

Structure

- As a soil develops, soil peds begin to form shapes or a structure

Granular

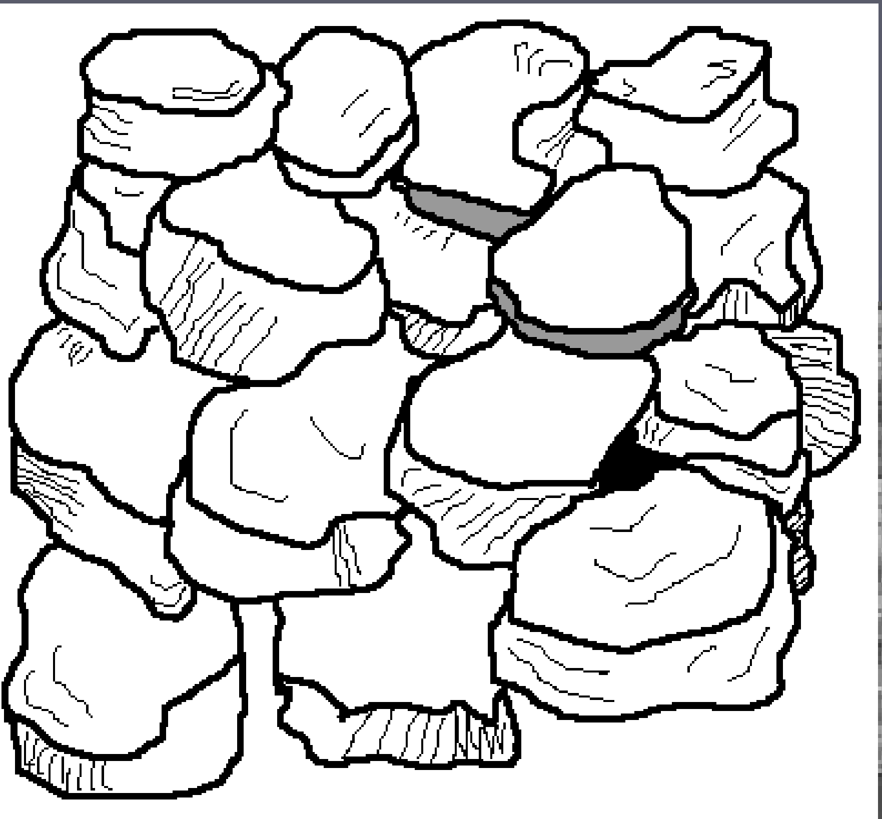


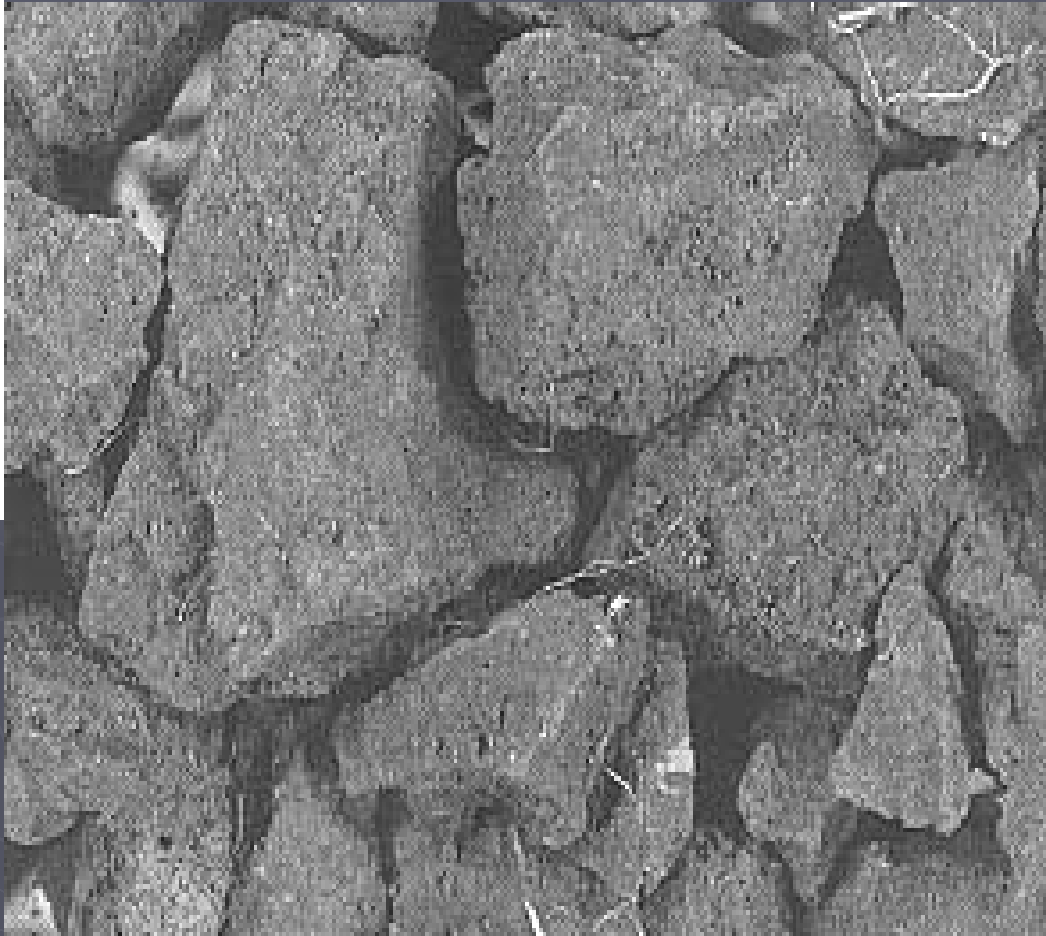


A-horizon

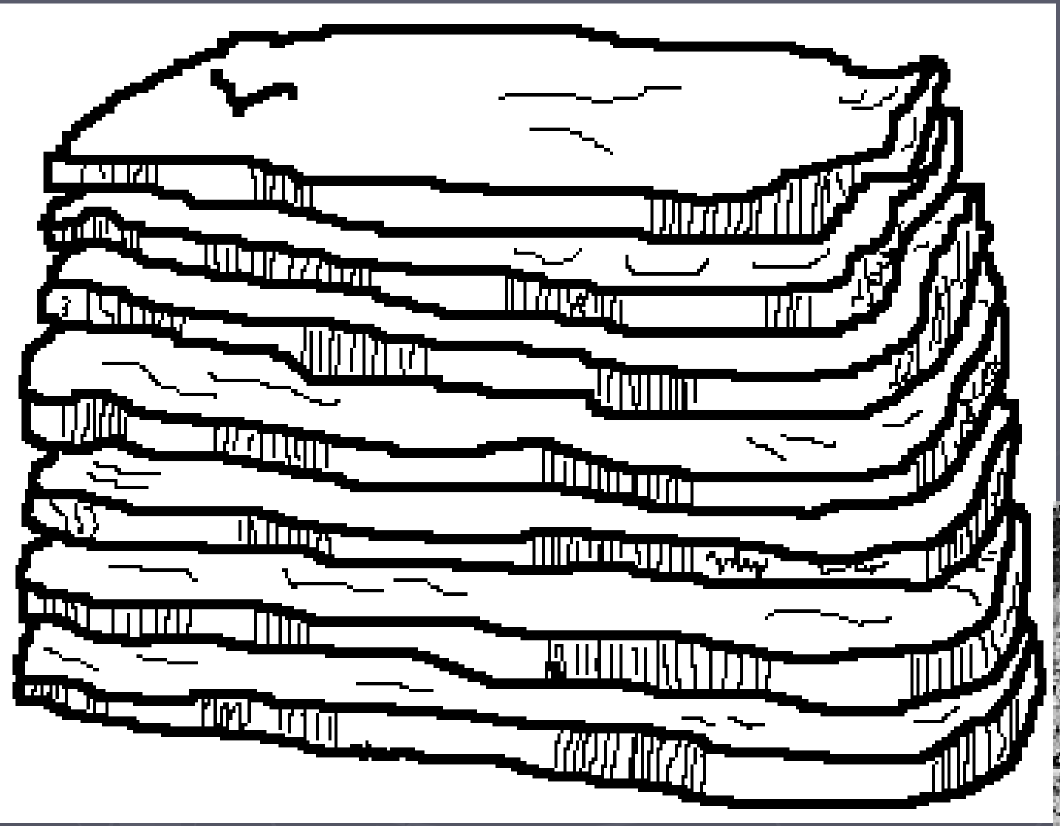
Blocky

B-horizon

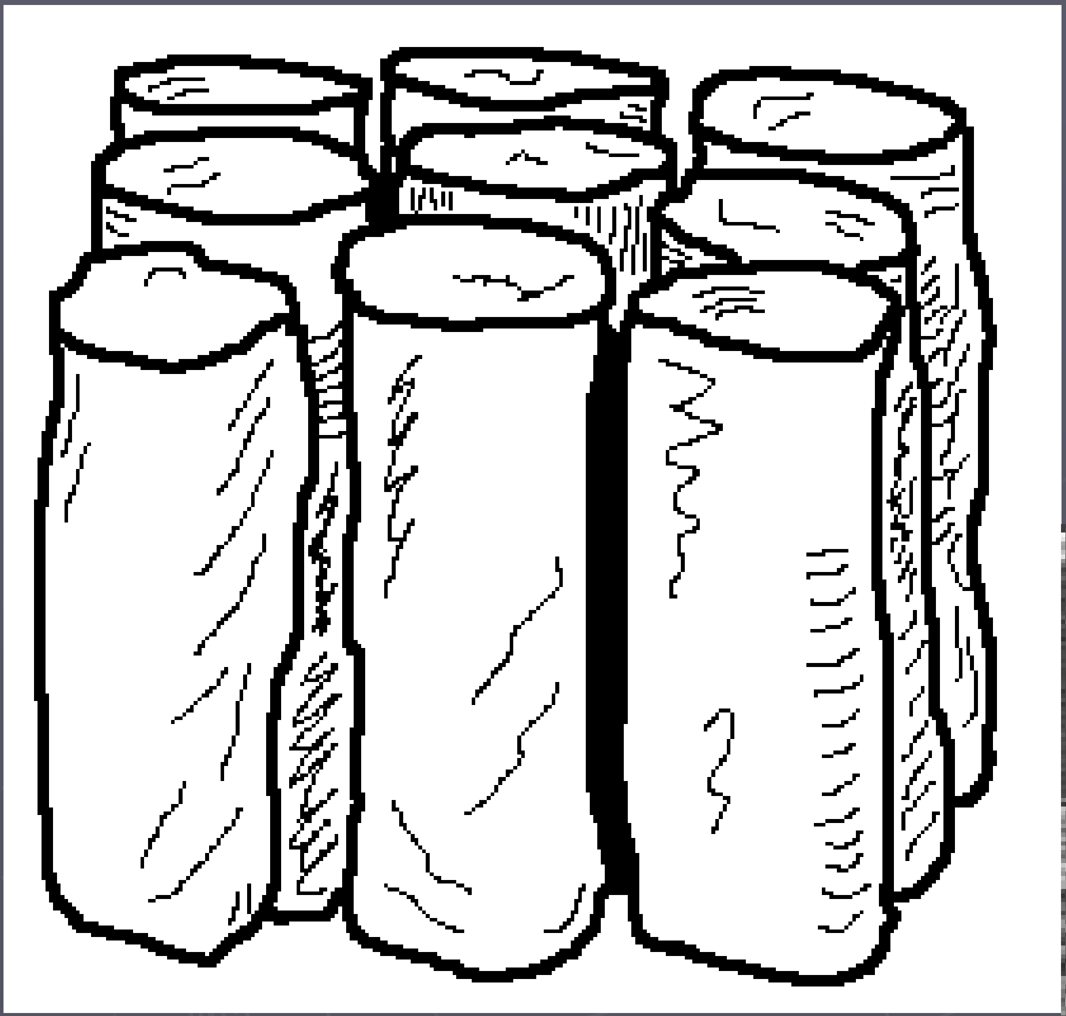




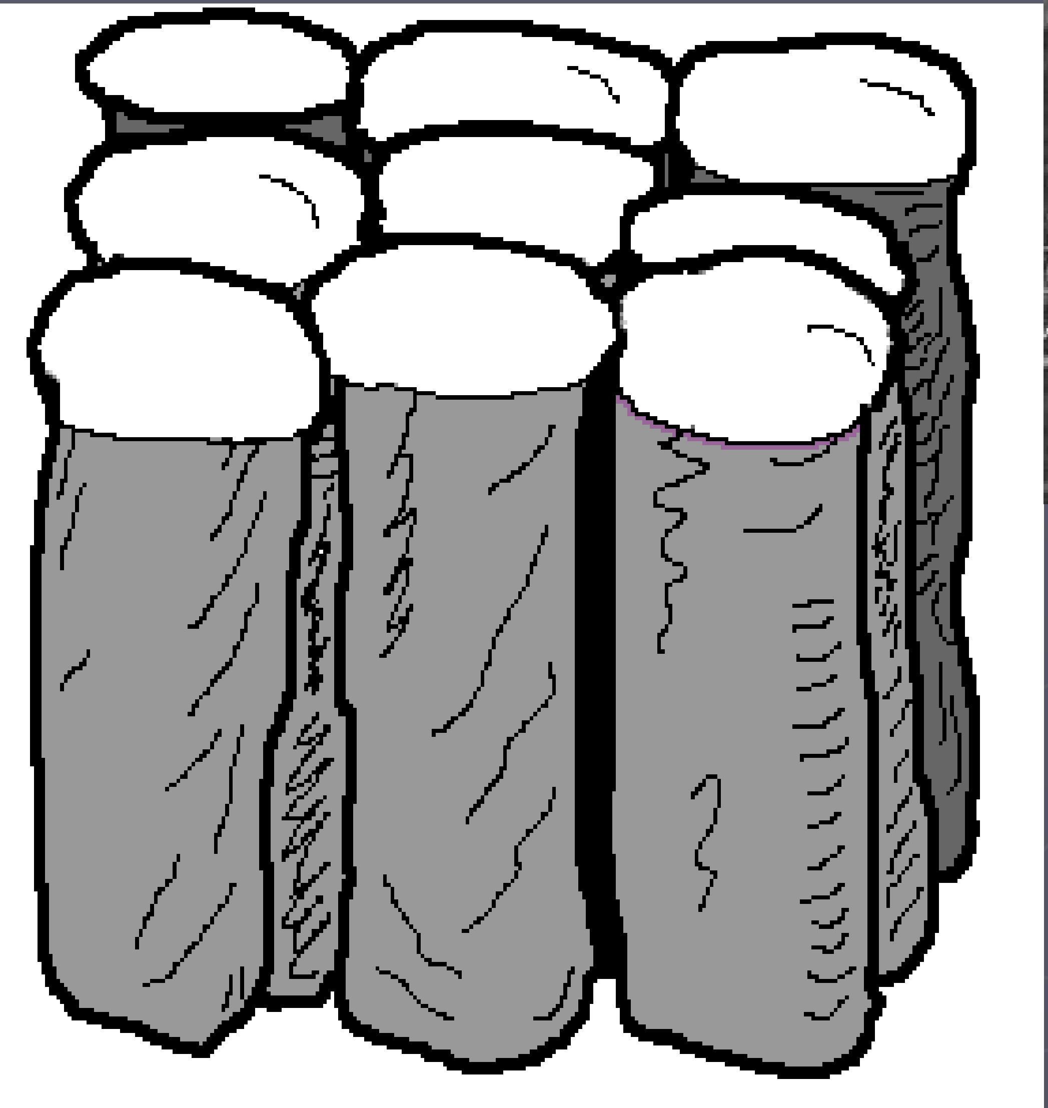
Platy

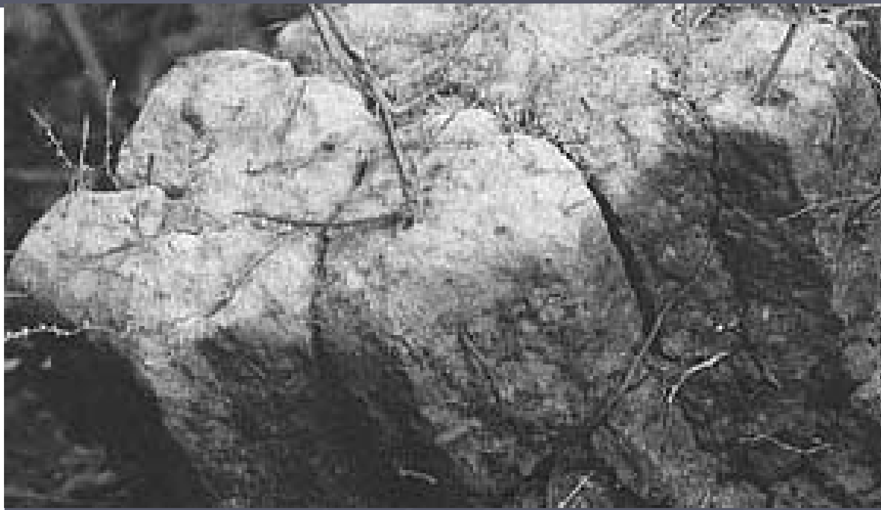


Prismatic



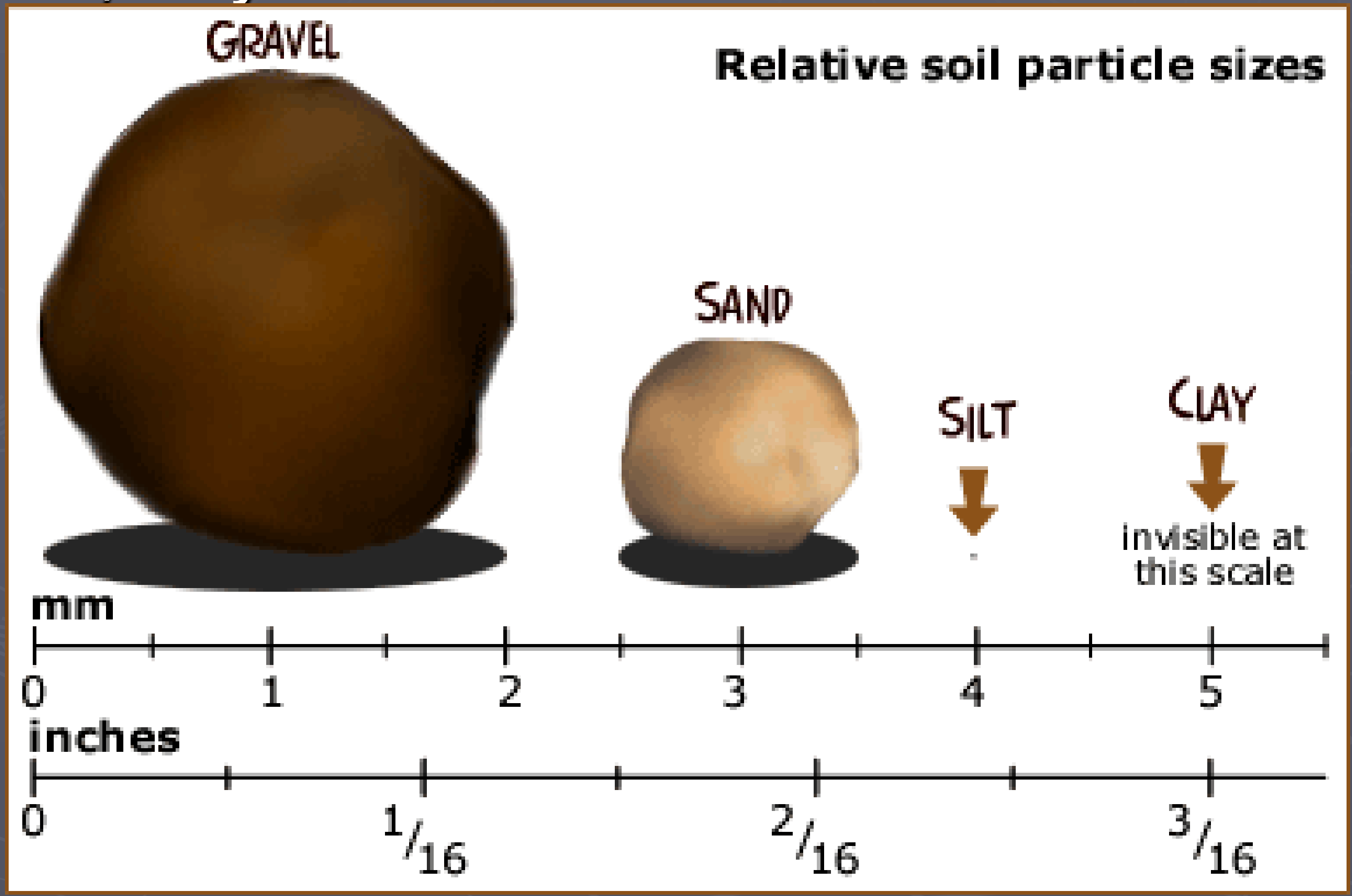
Columnar



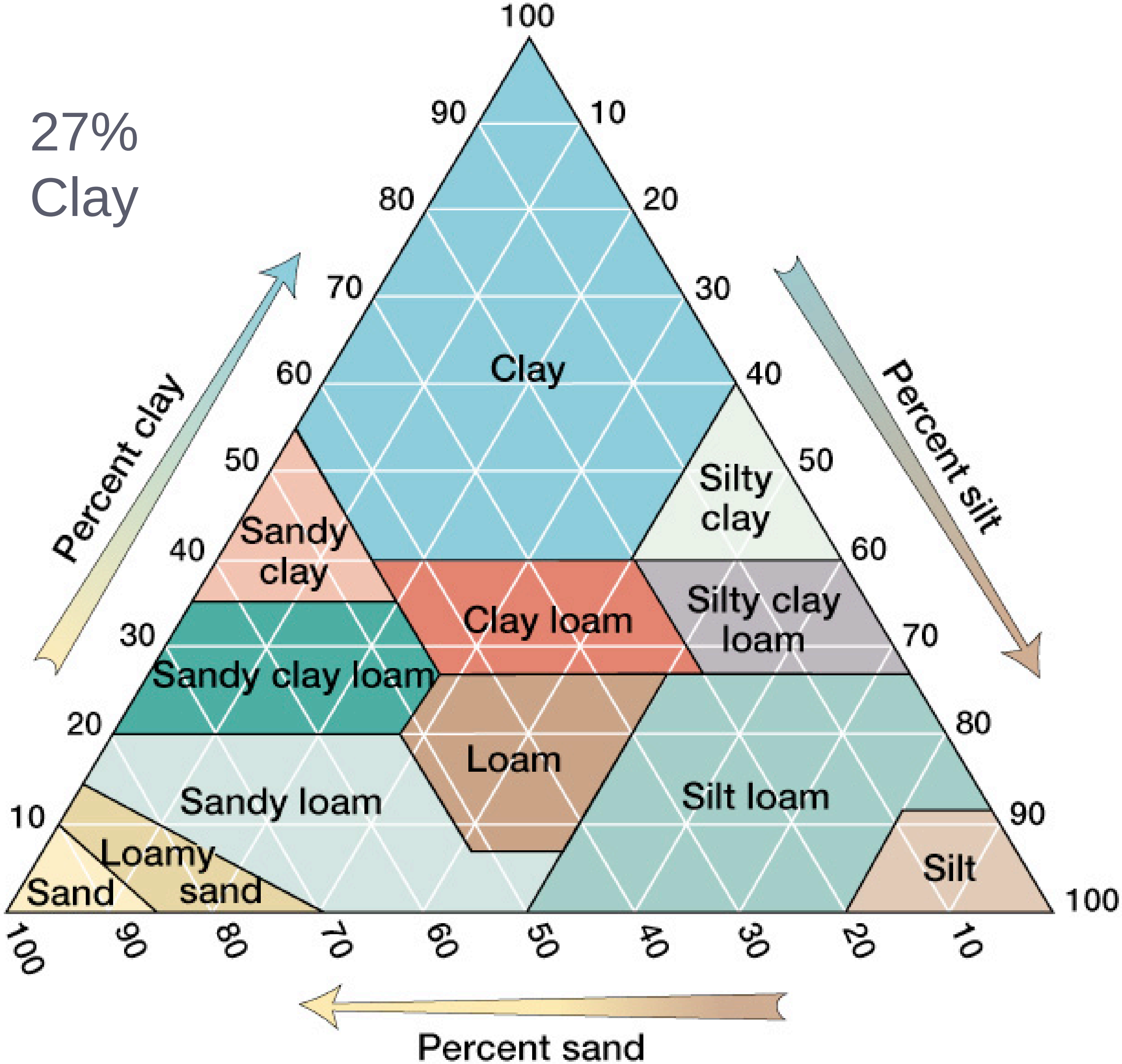


Texture

- Size of the individual peds
  - Sand, Silt, Clay



27%
Clay



100
90
80
70
60
50
40
30
20
10
Percent clay
Percent silt
Percent sand
Clay
Silty clay
Sandy clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Sandy loam
Silt loam
Loamy sand
Sand
Silt

Soils and Geomorphology

- The Geography of Soil Development
- Importance:

    what, why, WHERE?

It is important to understand where developing soil assemblages occur.

Agriculture, engineering, septic tank placement, etc.

Geographic variability and Soils

Small scale

Your back yard

Medium scale

Iowa

Large scale

The Great Plains

Small scale soil variability

A product of small changes in topography and thickness of parent material and/or the effects of organisms.

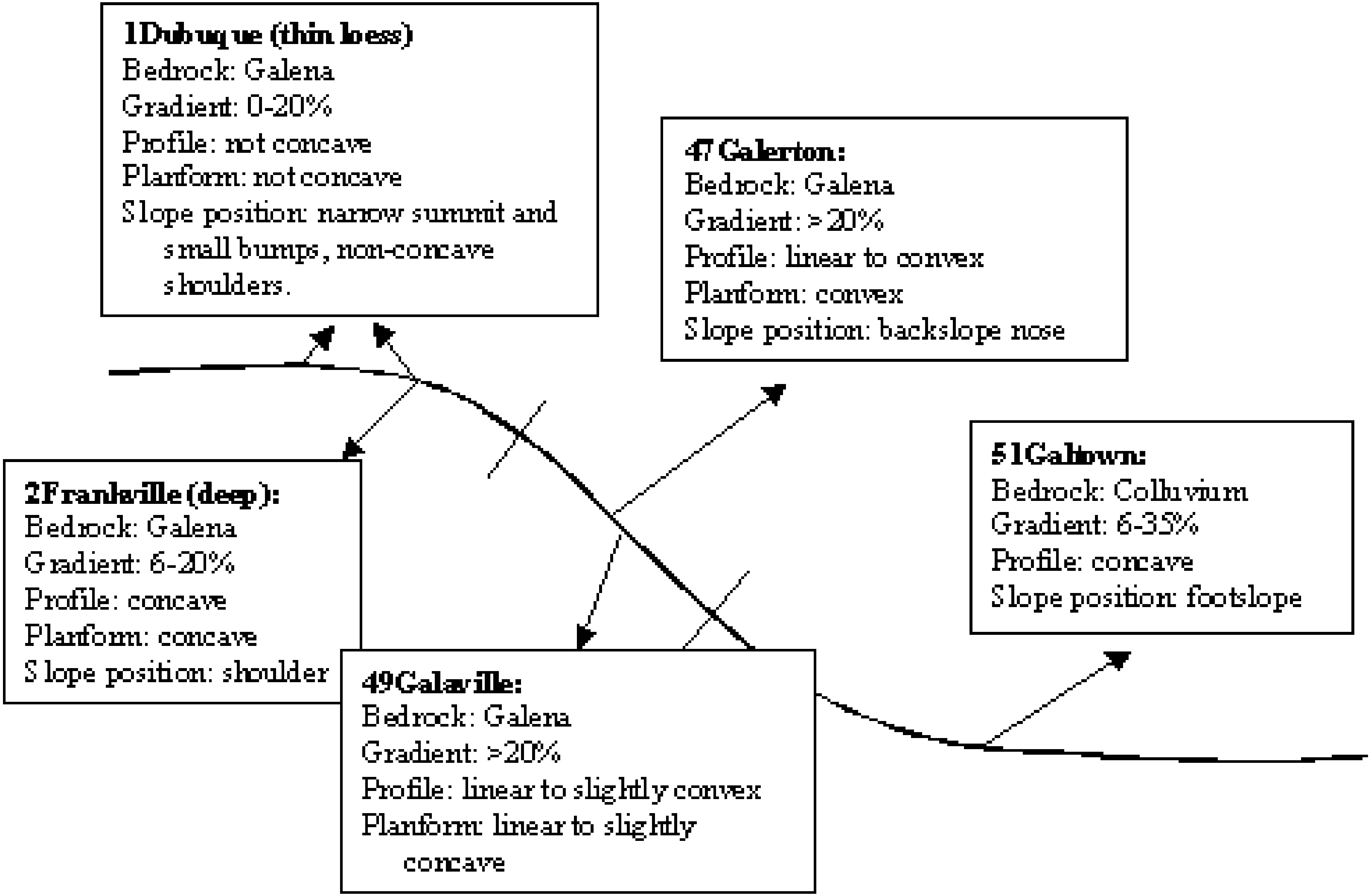
Medium scale soil variability

- Soil forming factors and individual soil assemblages
- Lithosequences
- Chronosequences
- Toposequences

    E.g. inceptisols

The Catena concept

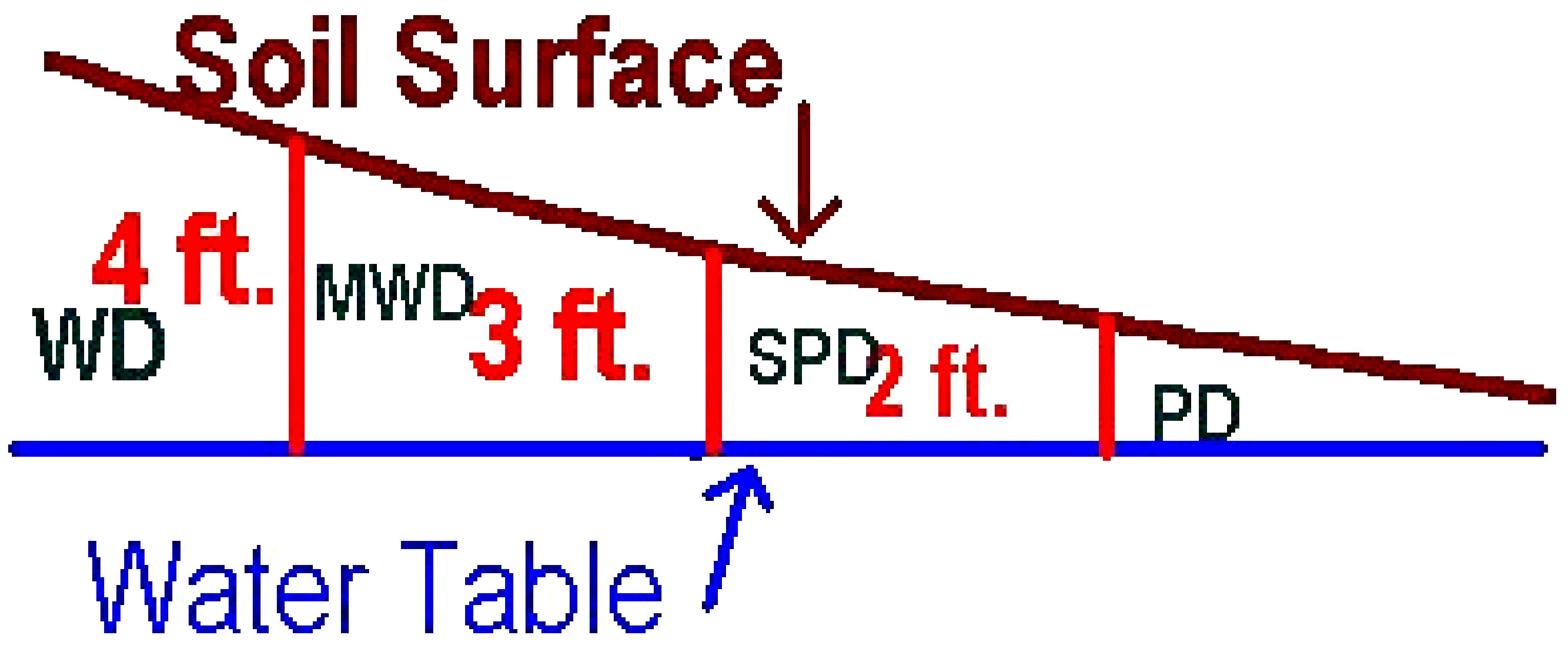
A sequence of different soils formed under similar conditions except for the effect of their relief positions effect the drainage and erosion rates of each different soil.



1Dubuque (thin loess)
Bedrock: Galena
Gradient: 0-20%
Profile: not concave
Planform: not concave
Slope position: narrow summit and small bumps, non-concave shoulders.
47 Galerton:
Bedrock: Galena
Gradient: >20%
Profile: linear to convex
Planform: convex
Slope position: backslope nose
51Galtown:
Bedrock: Colluvium
Gradient: 6-35%
Profile: concave
Slope position: footslope
2Frankville (deep):
Bedrock: Galena
Gradient: 6-20%
Profile: concave
Planform: concave
Slope position: shoulder
49Galaville:
Bedrock: Galena
Gradient: >20%
Profile: linear to slightly convex
Planform: linear to slightly concave


Soil catena
SOIL CATENA IN THE TAI BIOSPHERE RESERVE, IVORY COAST
0
10
20
30
40
50
60
70
80
90
100
110
120
130

Catena

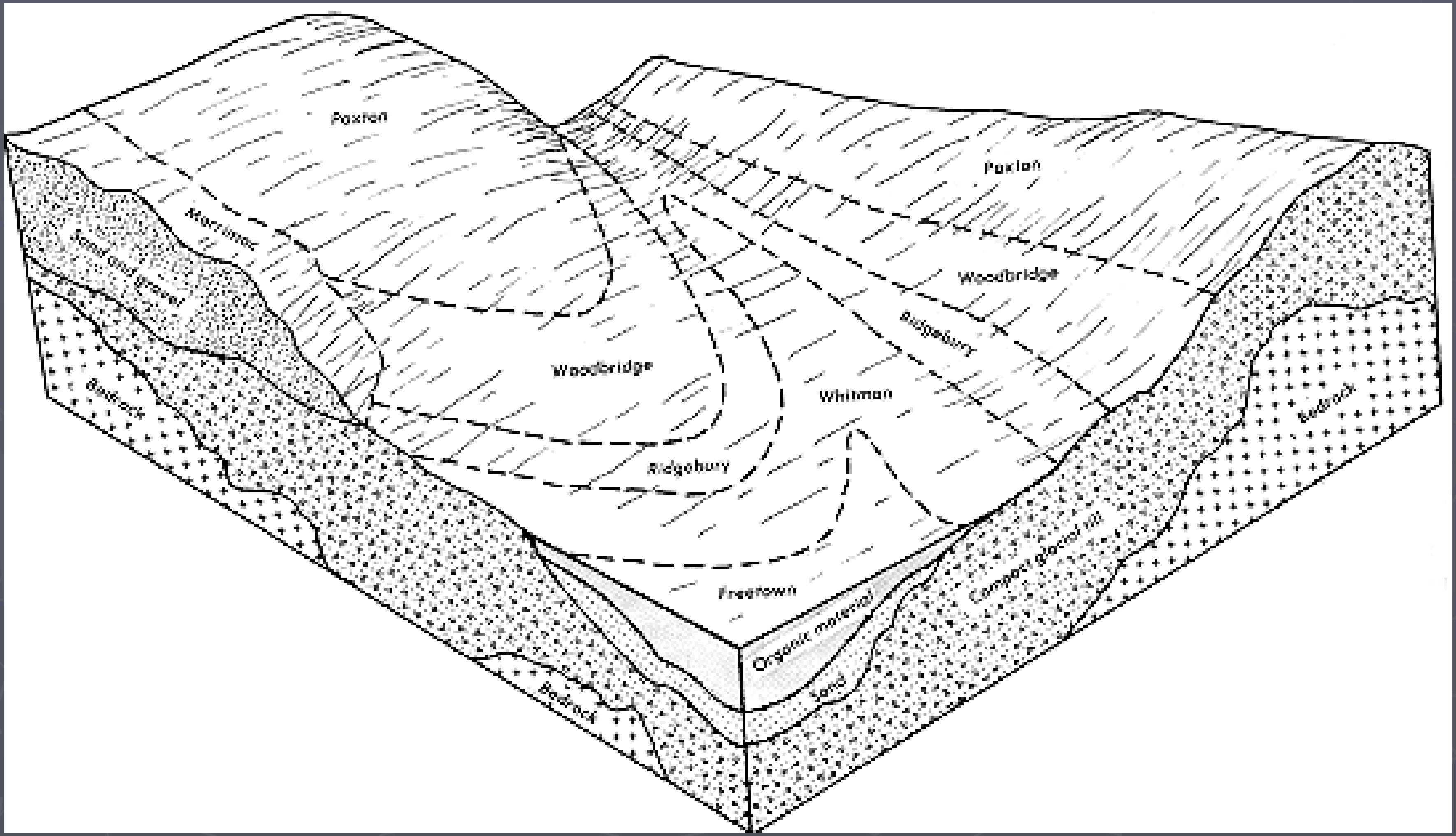


Helps relate soils to a particular landscape

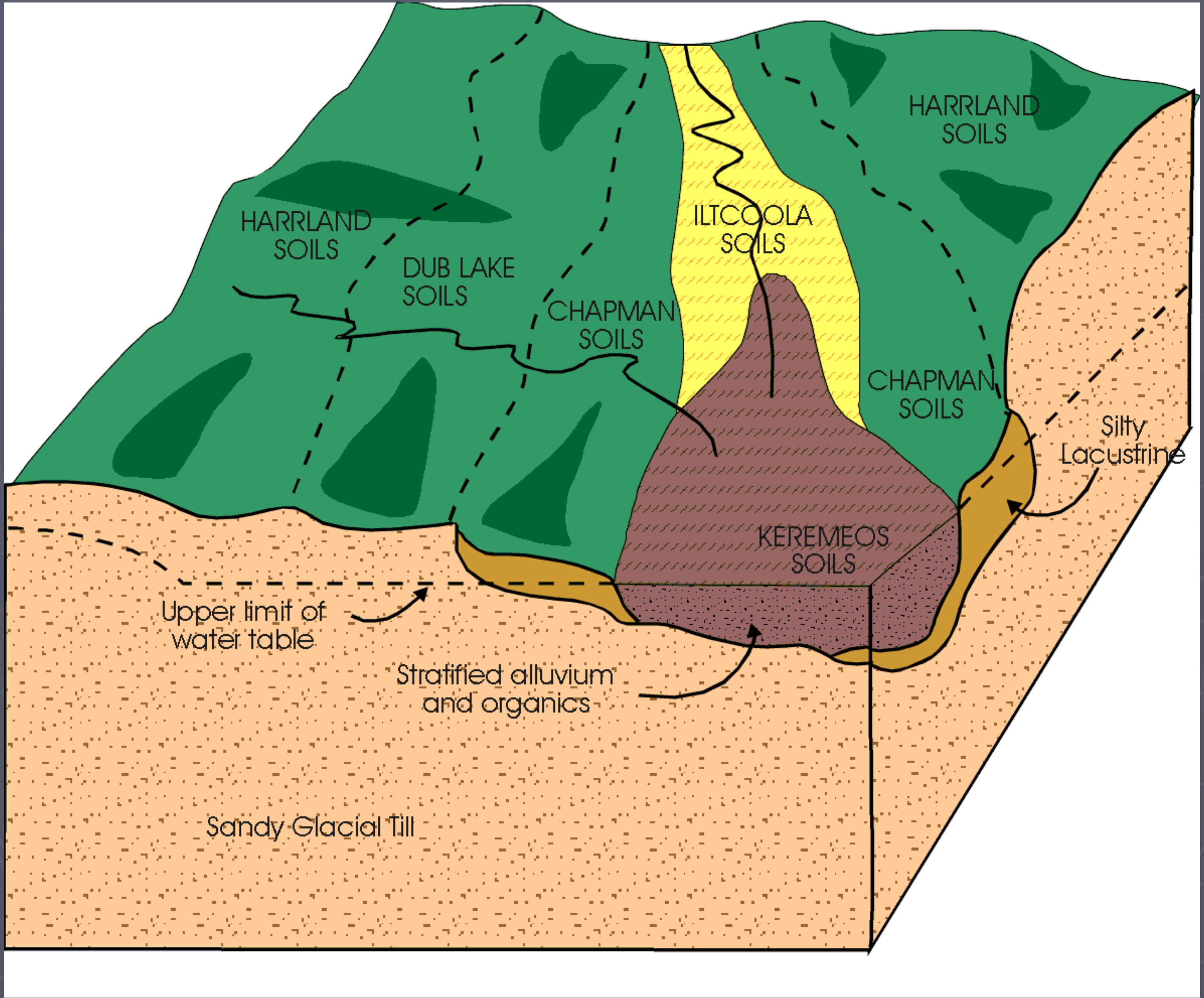
Soil associations

A general grouping of individual soils that occur together in a particular landscape.

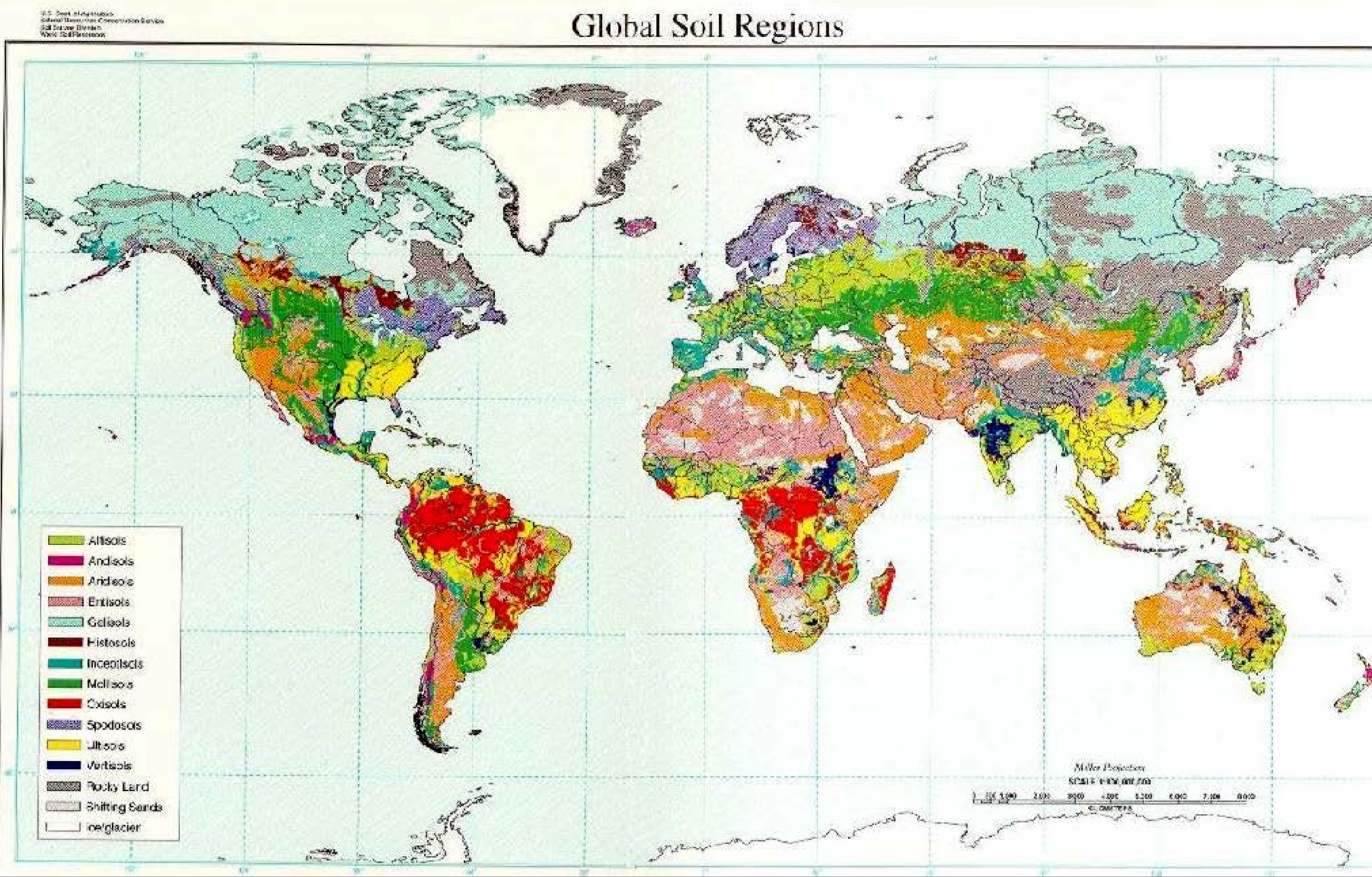
Soil associations



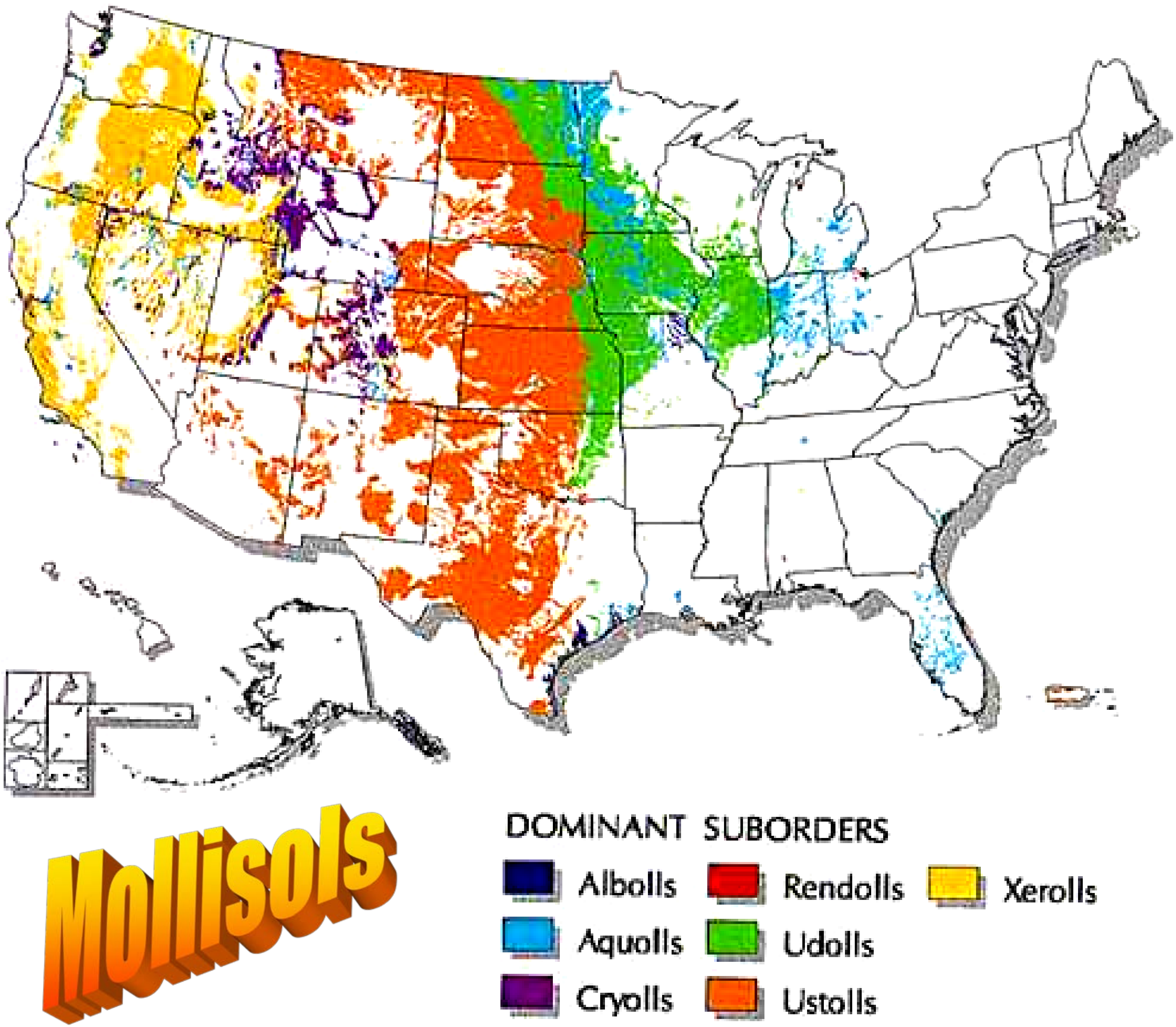
Soil associations



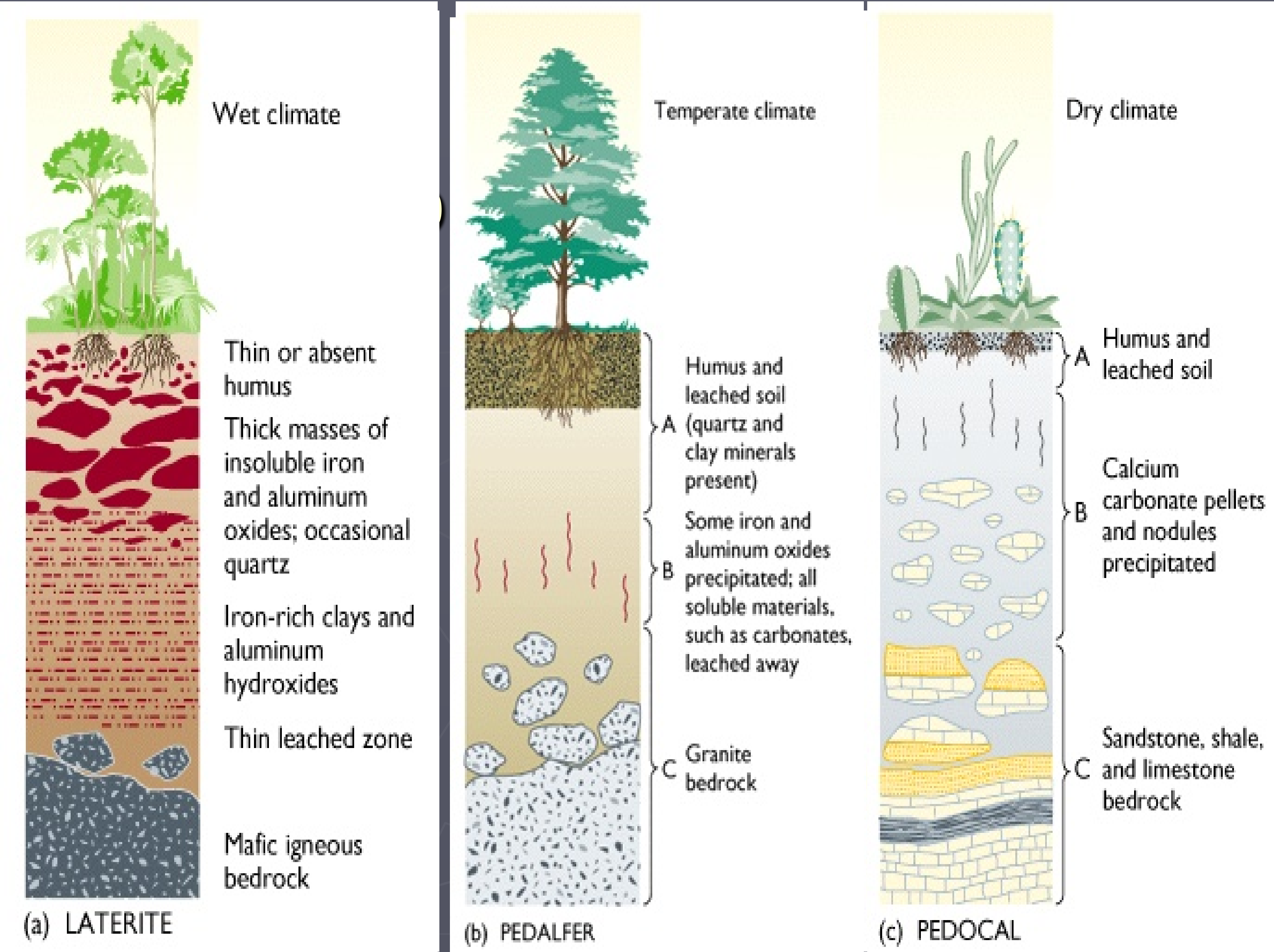
Large-scale soil variability



Mollisols


DOMINANT SUBORDERS
Albolls
Aquolls
Cryolls
Rendolls
Udolls
Ustolls
Xerolls

- E.g. Oxisols, found in hot, humid, regions
  Mollisols, found in Semi-arid grasslands
  Aridisols, found in desert regions


Wet climate
Thin or absent humus
Thick masses of insoluble iron and aluminum oxides; occasional quartz
Iron-rich clays and aluminum hydroxides
Thin leached zone
Mafic igneous bedrock
(a) LATERITE
Temperate climate
A Humus and leached soil (quartz and clay minerals present)
B Some iron and aluminum oxides precipitated; all soluble materials, such as carbonates, leached away
C Granite bedrock
(b) PEDALFER
Dry climate
A Humus and leached soil
B Calcium carbonate pellets and nodules precipitated
C Sandstone, shale, and limestone bedrock
(c) PEDOCAL

Paleosols

- A soil that formed on a landscape of the past. –Ruhe 1965
- A soil that formed in a previously existing climate and may know be buried.

Paleosols

- Paleosols are ancient or fossil soils preserved in the stratigraphic record
- Paleosols generally occur beneath unconformities
- Paleosols provide good clues for the interpretation of paleoenvironments and paleoclimates

Paleosols

Criteria for recognizing paleosols:

Presence of recognizable soil horizons

- Organic upper horizon
- Subhorizons exhibting increasing clay and/or reddish color
- Uppermost surface sharply truncated
- Chemically different than parent material including gradational mineral content, with unstable minerals decreasing in abundance up-section

1. Presence of soil structures (e.g. peds)
2. Laterally extensive
3. Root traces, or other disruption of original sedimentary structures by organic activity

Paleosol types

- Relict soils, exposed, unearthed, paleosols
- Fossil soils, paleosols buried in a geologic section and now lithified.

Paleosol Controversy

- Paleosol, Vs. Environmental Change (Intensity/time/geography)
- The Holocene
- Soils developed on old surfaces that have underwent significant changes yet do NOT contain characteritics of a previous environment
- Diagenesis

A Paleosol

Soil structures:
Root traces