Diagnostic Subsurface Horizons

Usually (but not always) B horizons

There are ***many*** of them in Soil Taxonomy (30+)

Horizons of translocation: movement of material

- Argillic, kandic, natric: illuvial clay (Bt)
- Calcic, gypsic, salic: other illuvial mineral or salts (Bk,m,n,y,z)
- Spodic: illuvial Fe and/or organic materials (Bh,s)
- Albic: eluvial horizon (E)

Horizons of alteration: formed (more-or-less) in place

- Oxic, cambic: weathering products (Bw, Bo)
- Fragipan, duripan: cementation (Bx)

Argillic Horizon

- Subsurface horizon with a significantly higher percentage of phyllosilicate clay than the overlying soil material
  -- Must show evidence of clay illuviation as clay films or in other forms
- Translocation is favored by seasonal moisture deficit
  - Wetting of dry soil enhances dispersion
  - Subsequent drying slows or stops downward movement
- Fact that clays are translocated does not imply that all of the clay increase in an argillic horizon is the result of illuviation
  - Clay increase may in part be the result of in-situ clay formation

Many Bt’s are argillic, but NOT ALL of them… horizon nomenclature and soil taxonomy are NOT 1:1 correspondence (unfortunately).

Note that nearly all argillics are Bt’s but DON’T HAVE TO BE!

Identification

- Rock structure in <1/2 of the volume
- At least 7.5 cm thick (15 cm if composed of lamellae)
- Clay increase between eluvial and argillic horizon
  - Eluvial horizon with 15 to 40% clay
    - Clay content in argillic horizon ≥ 1.2 times eluvial horizon clay content
      - 20% in eluvial horizon: ≥ 24% in argillic
  - Eluvial horizon with <15% clay
    - Clay content in argillic horizon 3% more than eluvial horizon
      - 11% in eluvial horizon - ≥ 14% in argillic horizon
  - Eluvial horizon with >40% clay
    - Clay content in argillic horizon 8% more than eluvial horizon
      - 43% in eluvial horizon - ≥ 51% in argillic horizon
  - Transition from eluvial to argillic horizon <30 cm thick
  - Top of argillic horizon is depth where clay increase is met

Identification

- Must also have evidence of translocation of clay:
  - Oriented clay as clay films, bridges, or coatings (ped face in field or lab thin sections); or
  - Ratio of fine clay (<0.2 µm) to total clay 1.2 times larger in argillic horizon than in the overlying horizons
    - Translocated clay is mostly fine clay

Occurrence

Common in “mature” soils on stable landscapes where P>ET sufficient to move clay downwards

Note that required clay increase may NOT indicate a different textural class:

20% clay increase (1.2 x) from 20% clay to 24%:

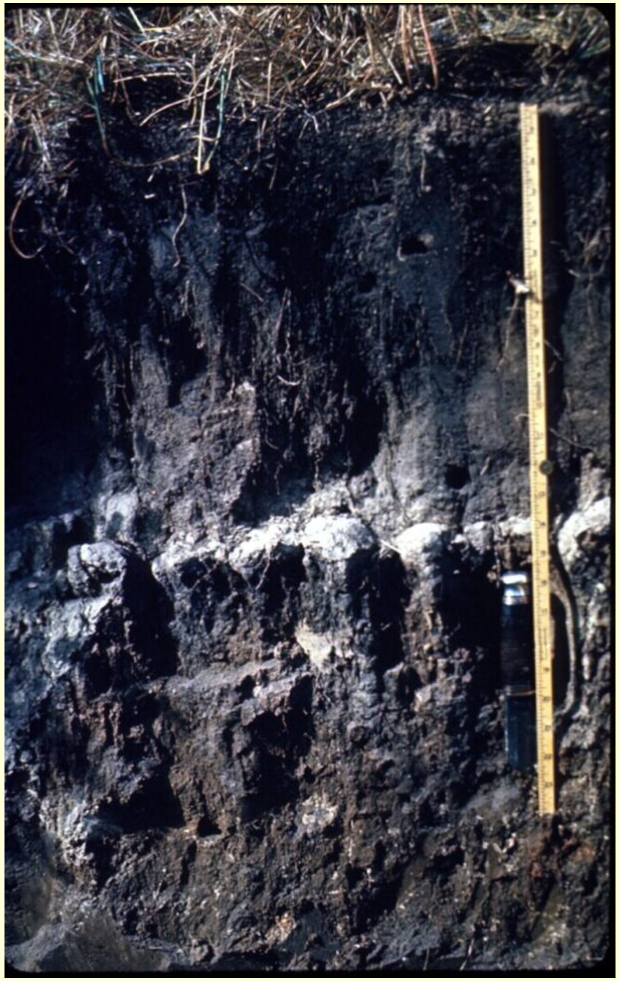
textural class is still sl or sil, not scl or sicl

May not be able to ID this in the field; lab data (particle size analysis) often required . . .

Natric Horizon

- Special kind of argillic horizon with high Na
  - Clay dispersion
    - Disrupts soil structure
      - Columnar or coarse prismatic structure
    - Reduced pore size and very low K_s
  - Toxic to Na sensitive plants
  - Dispersion and translocation of organic matter
    - Dark colored Bt horizons (black alkali soils)

Common in semi-arid regions (Na not fully leached out)



Natric Horizon

- The natric horizon has, in addition to the properties of the argillic horizon:
- *Either:*
  - Columns or prisms in some part, which may break to blocks; *or*
  - Both blocky structure and eluvial materials, which contain uncoated silt or sand grains and extend more than 2.5 cm into the horizon;
- *And:*
  - An exchangeable sodium percentage (ESP) of 15 percent or more (or a sodium adsorption ratio [SAR] of 13 or more) in one or more horizons within 40 cm of its upper boundary.

  - Requires lab testing to measure % of sodium on CEC sites, or SAR or pore water (saturated paste).

Kandic Horizon

- Bt horizons (clay increase) with "low activity" clays;
  - argillic horizon - clay increase between A or E and Bt horizons; clay films=translocation
  - oxic horizon - low activity clays (kaolinite, Fe oxides, gibbsite); "altered"=weathered in place
- Commonly in humid semi-tropics on old landscapes (SE U.S.)
  - "old": 2:1's have mostly weathered to 1:1's, oxides
  - "low activity": low CEC of clay fraction (i.e., kaolinite)

Many Ga Bt's meet requirements of both argillic AND kandic…

Kandic Horizon Criteria

- Clay increase requirements:
  - If A/Ap < 20% clay: ≥ 4% increasse (absolute)
  - If A/Ap has 20 to 40% clay: ≥ 20% (relative) increase (1.2 X surface horizon clay content)
  - If A/Ap >40% clay: ≥ 8% increase (absolute)
  - Increase must occur in less than 15 cm
- Has texture of loamy very fine sand or finer; *and*
- Horizon must be 30 or more cm thick; and
- Clay activity (CEC measured in lab):
  - CEC (pH 7) ≤16 cmol(+)/kg clay *and*
  - ECEC ≤12 cmol(+)/kg clay
- Thickness of low clay activity
  - Clay activity requirements must be present in ≥50% of the thickness between the point where the clay increase requirements are met and depth of 100 cm below that point (≥1/2 upper 100 cm of Bt)

CEC (cation exchange capacity): Review

- CEC: cation holding ability of soil material
  - Composed of permanent and variable charge
- Measured two ways:
  - Effective CEC (ECEC): neutral salt extract ($BaCl_2$)
    - Σ bases (Ca, Mg, Na, K) + acids (H, Al) = CEC
    - CEC at whatever "field" pH happens to be …
  - CEC(pH 7): NH_4-acetate (pH 7) saturation, then displace NH_4 with K, measure NH_4 retained
    - Measures potential of cations to be held at given pH (7)
- CEC(pH 7) is always higher, since more variable charge at higher pH

- Note that “base saturation” (%BS) is calculated using BOTH of these measurements:

- BS = Σ basic cations (ECEC) / total CEC (pH 7)

  – This is kinda weird, and not technically correct, but it is the way it is done…

Textural Differentiation for Kandic Horizon

- Clay eluviation and illuviation
  - Clay films may be completely absent
    - Destroyed by biological activity or pedoturbation processes
- Clay destruction in the epipedon
  - Weathering of clay may lead to a relative loss
- Selective erosion (bioturbation)
  - Raindrop splash and subsequent erosion cause the smallest soil particles to be moved farther downslope than the larger particles
- Deposition of coarse textured surface materials may result in an "apparent" kandic horizon
- Textural differentiation by any of these processes qualify for a kandic horizon
- Argillic horizon *requires* that there is evidence of clay translocation

Significance of a Kandic Horizon

- Provides a basis for differentiation among soils with a clay increase in the subsoil
  - Argillic horizon does not differentiate all Ultisols and Alfisols from Oxisols and Inceptisols
  - Fairly recent addition to Soil Taxonomy
- Suggests a high degree of weathering
- Other accessory properties include:
  - Low nutrient retention
  - Few weatherable minerals
  - Potential for increased P fixation

Oxic Horizon

- Mineral subsurface horizon in an advanced stage of weathering
  - Low activity clays (kaolinite and Fe and Al oxides that have low charge)
  - Small amounts of weatherable minerals (<10% in the sand separate)
  - Similar to the kandic horizon, but lacks clay increase kandic horizon
- Summary of Properties
  - at least 30 cm thick
  - has a particle size of sandy loam or finer
  - has ECEC <12 cmol(+)/kg clay and CEC (pH 7) <16 cmol(+)/kg clay
  - has <10% weatherable minerals in the 0.05-0.2 mm fraction
  - has diffuse upper particle-size boundary (insufficient clay increase for argillic or kandic horizon)
  - does not have andic (volcanic P.M.) properties
  - has <5%, by volume, with rock structure

Significance

- Weathering has been so extreme that only Fe and Al oxyhydroxides, a little 1:1 clays, and highly insoluble minerals such as Ti minerals exist in the horizon
- Clay content is nearly constant with depth
  - Stable and immobile clay
  - Many are clay textural class throughout
  - Many have very high Fe contents (50% Fe; very little Si remaining)
- Few or no primary minerals that release bases on weathering
- P in forms unavailable to plants
- High hydraulic conductivity even if clay content is high because of well-formed stable structure
- Low erodibility because of high infiltration rate and stable structure

Processes of Fe Concentration

- Latosolization (oxic horizon formation)
  - removal of weatherable components leaving a residual accumulation of Fe and Al oxides, quartz, and kaolinite
  - Environment with high rainfall, free drainage, and strongly desilicating conditions
  - Weathering and leaching of weatherable minerals and 2:1 clay minerals results in concentration of kaolinite, gibbsite, and Fe oxides
- Laterization (plinthite and petroplinthite (laterite) formation)
  - Fe accumulation in subsoils to form plinthite, ironstone, etc.
  - Fe may come from within the horizon or from an external source
  - Redox related process: Fe mobility due to dissolution/ppt
- Si is more mobile than Al and Fe in freely drained conditions
  - $Fe(OH)_3$ and $Al(OH)_3$ precipitate and remain in the soil
  - $Si(OH)_4$ (H_4SiO_4; mono-silicic acid) is soluble in water and mobile

Processes of Fe Concentration

Component	Parent Material	Bo horizon (latolization)	Bc horizon (laterization)
SiO_2	50	1	1
Al_2O_3	17	47	11
Fe_2O_3	3	23	74
MgO	7	0	0
CaO	9	0	0
K_2O	0.2	0	0

Cambic Horizon

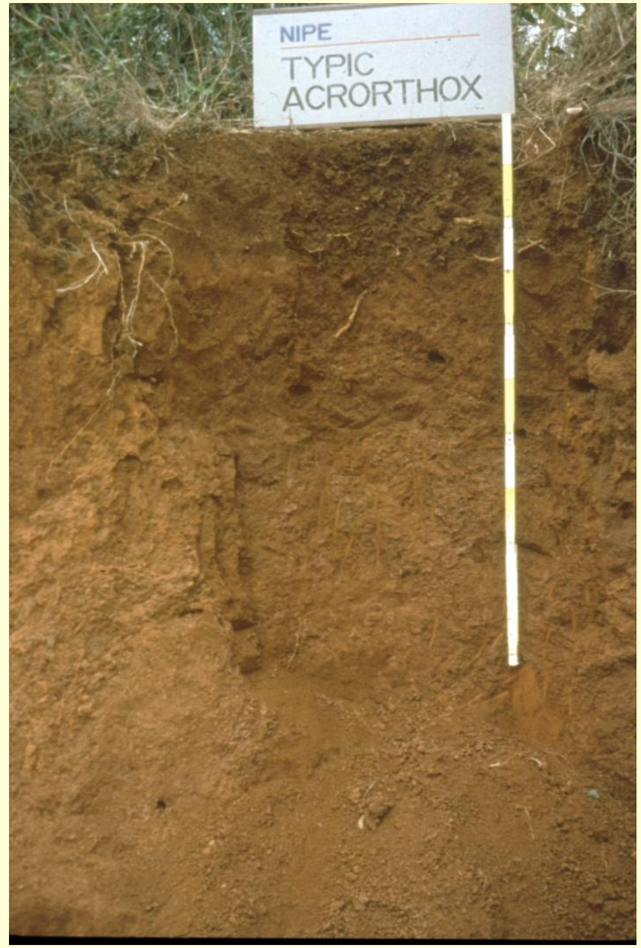
- Altered subsoil horizon often considered to represent the initial stages of soil development
  - Bw horizon
- Intent is to recognize subsoil horizons that have evidence of soil development without mineral accumulation or extreme weathering
  - Horizon transitional to a horizon with more strongly expressed genetic features such as an argillic horizon is excluded from a cambic horizon, i.e. BA, BE, or BC horizons transitional to Bt horizon
- Evidence of alteration: either:
  - Reduction and loss of Fe with decomposition of organic matter
  - Mineral weathering that liberates Fe from primary minerals
    - Reddening and formation of prismatic or blocky structure.
  - Loss of carbonates from the horizon
  - Destruction of rock structure with or without formation of soil structure

Properties of Cambic Horizon

- Texture is very fine sand, loamy very fine sand or finer, and
- Soil structure or absence of rock structure, and
- Evidence of alteration in one or more or the following forms
  - Aquic conditions within 50 cm of the surface, with both the following:
    - <2 chroma matrix colors and redox concentrations,and
    - Soil structure or absence of rock structure in > ½ horizon volume.
    - Equivalent to “Bg” nomenclature
  - No aquic conditions, soil structure formation in > ½ volume, and *one or more* of the following:
    - higher chroma, redder hue, or higher clay content than the underlying horizon, or
    - evidence of removal of carbonates, or
    - if carbonates are absent in the parent material, the required evidence of alteration is satisfied by the presence of soil structure and absence of rock structure.
    - Equivalent to “Bw” nomenclature.
- Properties that do not meet the requirements of an argillic, spodic, or kandic horizon, and
- No cementation or induration and no brittle consistence when moist, and
- At least 15 cm in thickness

Cambic horizon
(Blue Ridge)

Oxic subsoil
(Puerto Rico)



Albic Horizon

Albic Horizon

- L. albus, white; distinct "E" horizon
- Light-colored horizon from which clay and Fe oxides have been removed and color is determined by color of sand, silt
  - Mostly equivalent to an E horizon, but has rigidly defined color.
- Summary of Properties
  1. At least 1 cm thick and
  2. Contains at least 85% (by volume) albic materials
- Albic materials
  1. Chroma of 2 or less and value of 4 or more, <u>or</u>
  2. Chroma of 3 or less and.value of 6 or more.

Often above spodic (Bh) horizons, but not always

Spodic Horizon

- Horizon with concentration of "active" amorphous materials composed of organic C and Al with or without Fe (Bh, Bs, Bhs)
  - High pH dependent charge
  - High surface area
  - High water retention
- Found almost exclusively in soils developed in sandy parent material with vegetation that produces acidic leachate
  - Coniferous (pine/spruce/fir) or tannin-containing plants (live oak, myrtle, bayberry, palmetto—coastal)

Spodic Horizon - Morphology

- Recognized in the field by color (black: Bh; dark reddish brown: Bs)
- Textures commonly sand, loamy sand, or occasionally sandy loam.
- Abrupt upper boundary with marked change in hue, value, and chroma.
- Structure may be absent if s or ls.
- Pronounced albic horizon (E horizon) commonly above the spodic horizon

Podzolization

- Translocation of Fe and Al under the influence of organic matter
  - Chelation of Fe and Al by water soluble organic compounds produced by leaching surface litter under acid conditions
  - Organo-metal chelates move downward through the soil until stopped
    - Desiccation
    - Concentration of chelates exceeds their solubility
      - Solubility related to the C:metal ratio
      - pH change may alter solubility of the chelates.
- Deposition of organo-metal complexes forms the spodic horizon
- Differences in chelate solubility
  - Bh horizon (Al-organic complexes)
  - Bs horizon (Fe-organic complexes)

Spodic Horizon

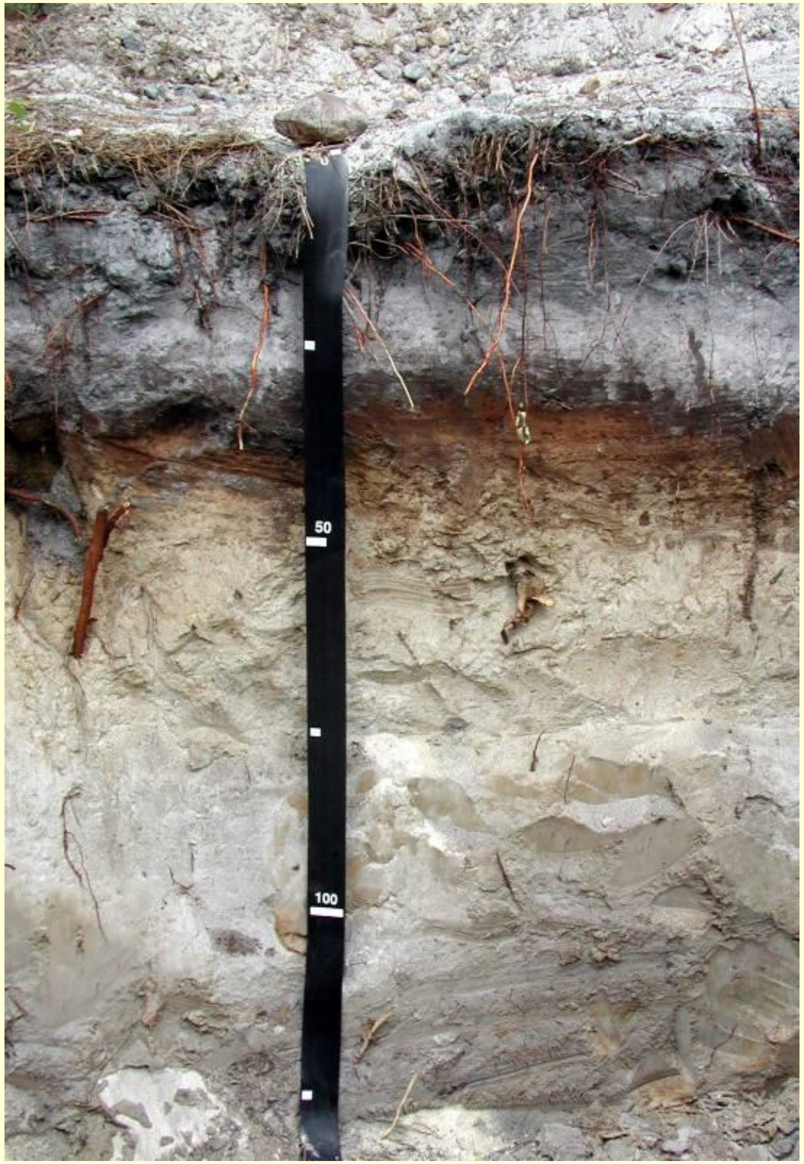
Podzolization

- Alternate development pathway for SE Spodosols
  - Shallow ground water is acid and contains Al and dissolved organic C
  - Possibility that the vector for movement of organic C and Al may be upward from the ground water
    - Has been likened to a bath-tub ring with the spodic horizon forming at the upper limit (average?) of the seasonal water table.
- There is a vegetation relationship with Spodosols in the southeast (origin of “blackwater” surface water)
- The spodic horizon can become cemented by organic C (and Al)
  - Known as "ortstein“; crunchy in auger borings
  - Weak cementation common in the southeast
    - Spodic horizons locally known as “hardpans”
    - Cementation is not enough to restrict root growth or water movement

Podzolization

- Spodosols in the southeast developed in sandy parent materials with shallow ground water tables (ground-water podzols)
  - Low contents of Fe
  - Spodic horizons are composed of illuviated organic C and Al
    - Very low Fe contents
    - (Bh without Bs horizons)
  - Saturation and reduction may be prerequisite to spodic horizon formation in these conditions
    - Reduction of the low amounts of Fe associated with clay coating sand grains
    - Clay dissolution releases Al

Georgia Spodosols



SPODIC HORIZONS IN MAINE SOIL

Bhs-- 5 to 8 inches; dark reddish brown (5YR 3/3) fine sand; weak fine and medium subangular blocky structure; friable; common very fine, fine, medium and few coarse roots; 20 percent ortstein nodules; 2 percent rock fragments; strongly acid; clear irregular boundary

Bs1-- 8 to 14 inches; brown (7.5YR 4/4) fine sand; weak fine and medium subangular blocky structure; friable; common very fine, fine, medium and few coarse roots; 20 percent ortstein nodules; 2 percent rock fragments; strongly acid; clear wavy boundary.

Bs2-- 14 to 23 inches; dark yellowish brown (10YR 4/4) fine sand; weak medium subangular blocky structure; very friable; few very fine, fine, medium and coarse roots; 5 percent ortstein nodules; 2 percent rock fragments; strongly acid; gradual wavy boundary.

SPODIC HORIZON FROM GEORGIA SOIL

Bh1--15 to 18 inches; 50 percent dark brown (7.5YR 3/3) and 50 percent black (7.5YR 2.5/1) sand; weak medium and coarse subangular blocky structure; firm; common fine and medium roots; many fine and medium pores; more than 95 percent of sand grains have organic coatings; extremely acid; clear smooth boundary.

Bh2--18 to 22 inches; dark brown (7.5YR 3/4) sand; weak medium and coarse subangular blocky structure; firm; few fine and medium roots; common fine and medium pores; more than 95 percent of sand grains have organic coatings; extremely acid; clear wavy boundary. (Combined thickness of the Bh horizons ranges from 4 to 35 inches)

Calcic Horizon

- A subsurface horizon with an accumulation of calcium carbonate (Bk– field notation)
- A calcic horizon must be:

1. 15 cm or more thick;
2. not indurated or cemented;
3. Has 15% or more $CaCO_3$ equivalent (5% for sandy and/or rocky soils)
4. Evidence that the $CaCO_3$ is pedogenic instead of inherited from the parent material

Evidence that $CaCO_3$ is Pedogenic

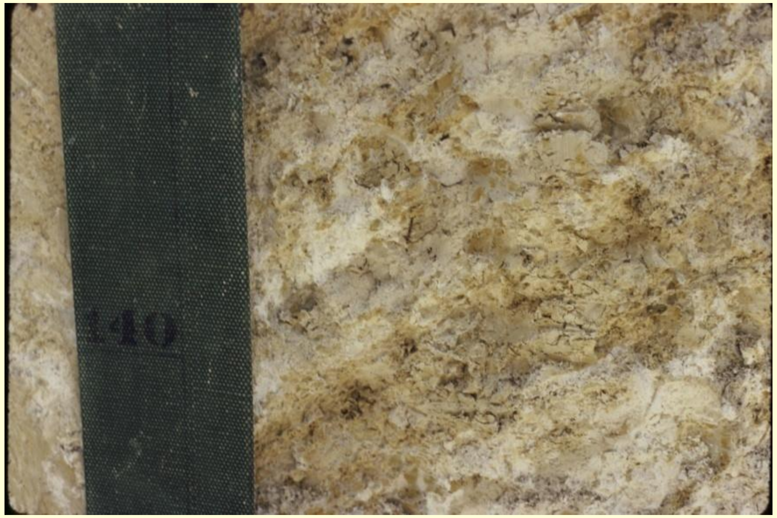
- $CaCO_3$ equivalent is 5 percent or more (absolute) higher than that of an underlying horizon
  - calcic horizons in soils developed from non-calcareous or low carbonate parent materials
    - Translocation and accumulation will produce a zone with higher carbonate content than underlying horizons; OR
- 5 percent or more (by volume) identifiable secondary (pedogenic) carbonates
  - Calcic horizons in soils developed from high carbonate parent materials
  - Calcic horizon will not have higher calcium carbonate equivalent than underlying horizons
  - Evidence that the horizon has been pedogenically altered is identification of "secondary carbonates"
    - **Films and threads, soft masses, pendants on pebbles, and concretions**
  - Separation of pedogenic from inherited carbonates may not be simple

Calcic Horizon

- Air dry fragments will slake in water
- Accumulation of calcium carbonate is important and extensive in Great Plains of North America and other Steppe areas of the world
  - Central Russia, Australia, South America
  - These regions commonly have grassland vegetation and mollic epipedons.

Calcic Horizon

Calcic Horizon



Petrocalcic Horizon

- Indurated horizon that has formed by pedogenic accumulation of calcium carbonate
  - All capillary pores are filled with calcium carbonate
- 70 to 90% calcium carbonate
- Dry fragments of a petrocalcic horizon will not slake in water but will slake in HCl.
- “Bkk” in field….

Gypsic and Petrogypsic Horizon

- Gypsic horizon (By)
  - Pedogenic accumulation of gypsum ($CaSO_4 \cdot H_2O$)
- Petrogypsic horizon (Byy)
  - Cemented gypsic horizon
  - Normally 60% or more gypsum
  - Dry fragments do not slake in water or HCl

Salic Horizon

- Subsurface horizon with pedogenic enrichment of salts more soluble than gypsum
  - NaCl, KCl, MgCl, $NaSO_4$, $MgSO_4$, etc.
  - Defined by EC (electrical conductivity): at least 30 dS/cm in saturated paste
- "Bz", or Bnz, Byz, etc

Other Diagnostic Features

- Abrupt Textural Change: Abrupt clay increase between an ochric epipedon or albic horizon and an argillic horizon.
  - If ochric or albic has <20% clay, clay content must double within 7.5 cm or less.
  - If ochric or albic has >20% clay, increase of 20% clay (absolute) within 7.5 cm, and clay content in some part of argillic should be double that of ochric/albic.
- Coefficient of linear extensibility (COLE): measure of shrink-swell potential
  - COLE = (Lm-Ld)/Ld
    - Lm = length moist; Ld = length dry
  - Also can be calculated from moist and dry bulk density.

Other Diagnostic Features

- Lithic Contact: Boundary between soil and hard bedrock (R horizon).
  - Bedrock must be sufficiently coherent when moist that digging with spade is impractical.
  - Average spacing between cracks must be >10 cm.
- Paralithic Contact: Similar to lithic contact except underlying rock is not as hard (Cr horizon).
  - Can be dug with difficulty with a spade when most.
  - Criteria for cracks same as lithic.
- Petroferric Contact: Boundary between soil and a continuous layer of indurated material in which Fe is the important cement and organic C is absent or present in trace amounts.
  - Fe_2O_3 content normally 30% or more.

Other Diagnostic Features

- Sulfidic Materials: Mineral or organic materials that contain oxidizable sulfur (pyrite, marcasite, etc. (sulfide minerals)).
  - Material will have pH drop of more than 0.5 units to a pH of 4.0 or less in 8 weeks.
  - Primarily found in salt marshes or other brackish water areas.
  - If such soil material is drained, sulfuric horizons are likely to be produced.
- Sulfuric horizon - horizon (either mineral or organic) with pH of 3.5 or less and with evidence that the low pH is caused by sulfuric acid
  - sulfuric acid evidence - jarosite concentrations, underlying sulfidic materials, 0.05% water-soluble sulfate

Other Diagnostic Features

- Fragipan: dense, brittle layer (Bx)
  - >15 cm thick, few roots
  - Firm or stronger moist consistence, brittle failure (“shatters”)
- n value: Used as predictor of bearing capacity of a soil.
  - n > 0.7: soil flows between fingers at field moisture content
- Weatherable minerals:
  - Clay-sized minerals: All 2:1 layer lattice clay minerals except Al-interlayered vermiculite.
  - Sand and silt-sized minerals: feldspars, feldspathids, ferromagnesian minerals, glass, micas, zeolites, and apatite.
  - Does not include calcite, gypsum, and more weatherable minerals (water soluble).

Slickensides

- Poish/grooved ped surfaces, > 5 cm dimension
  - Shear failure on slopes as soil slips downward, or
  - Shrink/swell of highly smectitic (2:1) clays

  Common in Vertisols (2:1 clays + wet/dry season)

Andic Soil Materials

- Soil material with properties characteristic of volcanic ash, cinders, and other pyroclastic materials
- Volcanic materials have an abundance of amorphous silicate components such as allophane and imogolite
  - Low bulk density (0.9 g/cm^3)
  - High P fixation
  - High amounts of Fe and Al extracted with acid oxalate
  - -- Volcanic glass (>5%): amorphous SiO_2
  - Oxalate extraction will dissolve amorphous Fe, Si, and Al components but not crystalline components
- Andic criteria are designed to separate soils with a high content of amorphous components from soils with crystalline components

Using the Key

- Determine the diagnostic horizons and other diagnostic properties/features of the soil.
- Go to the key for the orders
  - Start at the beginning of the key and follow it through in order
  - The first set of criteria that fit the particular soil defines its order
  - **STOP!!!!** If you go further, other sets of criteria may fit your soil. **The keys in Soil Taxonomy are meant to be used as dropout keys. The first class that fits is correct; not the one that fits the best.**
- Go to the beginning of the suborder key for the order selected
  - Make sure that the definition of the order fits the soil
  - Follow the criteria until a suborder that fits is found
- Follow the same procedure for other categories