Some thoughts on Soil Taxonomy and Soil Classification

A good classification system should be flexible and adaptable as new ideas, observations, concepts, and information emerges. Our textbook author makes an excellent point about 'avoiding rigor mortis in classification'

On order to classify anything, certain defining class boundaries must be set up. These boundaries should not be randomly selected. They should be meaningful and based on a fundamental understanding of the individuals being classified. Te classification system should be capable of encompassing any and all soils, regardless of global location (or galactic someday?)

Soils occur as a continuum across the landscape. In contrast, most classification systems have well defined boundaries. How do we put reality into conceptual boxes? Reality is far too complex to neatly slice up and place into taxonomic classes.

Classification systems must be based on objectives and practical aspects.

Objectives:

What will we do with this information?
Who will use it?

Practical Aspects:

What costs are involved with measurements?
Can differentiating characteristics / criteria be accurately measured?

Some reasons for classification:

1. Organize knowledge
2. Communicate knowledge
3. Shorthand system for remembering properties of individual classified
4. Examine relationships between individuals and classes
5. Group individuals into classes that have similar behavior, use, genesis, productivity, morphology
6. Countless others hat we could spend eternity discussing.

Soil morphology, genesis, and potential use – interpretations can be communicated with the shorthand of Soil Taxonomy very easily if some effort is put into understanding the framework of the system.

Classifiers must not get lost in the classification system (don't allow the tail to wag the dog). It can be very hazardous to think that all soils fit neatly into 12 big boxes (presently 12 soil orders).

Other soil classification systems exist besides Soil Taxonomy. This is not the only system and it may not be the best system depending on the user's objectives. There are other methods of classifying soils.

Soil taxonomy relies heavily on morphologic properties but maintains a strong genetic thread.

Soil Taxonomy is a hierarchical, multi-category classification system that utilizes formative elements to name classes.

Plant Classification

Phylum	Sperrmatophyta
Class	Angiospermae
Subclass	Monocotledonae
Order	Graminules
Family	Graminae
Genus and Species	Triticum aestivum
Common name	Wheat

Soil Taxonomy system of classification

Order	Mollisol
Suborder	Aquoll
Great Group	Endoaquoll
Subgroup	Typic Endoaquoll
Family	Fine-silty, mixed, superactive, mesic, Typic Endoaquoll
Series	Drummer

Series level information si not contained in the text of soil taxonomy. Many series will have the same family level classification but can be distinguished locally based on parent material, landscape position…..

Soil Taxonomy was initially devised for field use although there is an increasing reliance on an overwhelming amount of laboratory data. Not everyone is thrilled with this trend.

Remember that soil classification is a tool to communicate and organize knowledge. We should not be so consumed with classification that we lose sight of what is really out there on the landscape. Besides, the U.s. alone has had several different soil classification systems this century. This system will be replaced completely or evolve into something unrecognizable from it's present condition sometime in the future.

This is a generalized discussion of classification criteria. Use the most current "Keys to Soil Taxonomy" for actual criteria and guidelines while classifying. Do not rely on this information for "real world" purposes. It is or generalized teaching purpose only. Master horizon associations listed are not all encompassing, they are simply common associations. Exceptions are everywhere.

This handout was prepared using the 1998 version of "keys to Soil Taxonomy. Remember, as new information, observations, concepts, and ideas emerge, the science changes.

Taxonomy Roadmap

STEP 1
Complete a detailed soil description and obtain key characterization data.

STEP 2
Determine if the soil under examination is mineral or organic. Identify the appropriate diagnostic surface horizons (epipedons) and diagnostic subsurface horizons.

Diagnostic horizons are not equivalent to master horizons although common associations exist.

Some diagnostic horizons may overlap in profile location. For example, a Bt horizon may be part of a mollic epipedon and an argillic horizon if it meets the criteria for both.

Mineral soils - (Note: all mineral soils must have ONE epipedon)

A. Diagnostic Surface Horizons (Epipedons) - formed at the surface, may be buried
Typically made up of O and A master horizons. Some may include portions of E, Bt, Bw, Bg …… though.

1. **Anthorpic**
   - Significant disturbance by humans
   - Mollic criteria
     and
   - High P levels
2. **Folistic**
   - Organic material
   - Saturated with water X<30 days annually
3. **Histic** (Greek for tissue)
   - Organic material
   - Saturated with water X>30 days annually
4. **Melanic**
   - Contains andic soil properties (Typically found in andisols)
   - High content of volcanic minerals (allophane …., Typically v. fertile)
5. **Mollic**
   - Thick, 'base'-rich, (K, Ca, Mg, ..) dark colored, organic-rich mineral material
   - Genetically associated with grassland soils
   - Color requirements
     - Moist 3/3 or darker (lower#)
     - Dry value of 5 or less
   - % Base saturation X > 50% (Ca, Na, Mg, K)
   - X > 0.6 % organic carbon
   - Thickness requirements:
     - X > 10 cm if directly underlain by bedrock or cemented horizons
     - X > 18 cm and a minimum of 1/3 of the solum thickness up to 75 cm thick solum or
     - X > 25 cm

6. **Ochric**
   - Genetically associated with forested soils (common)
   - Often too light colored to be mollic or umbric…
   - Does not meet the criteria of any other of the seven epipedons
   - Extends down to the first underlying diagnostic illuvial horizon
     - Argillic
     - Kandic
     - Natric
     - Spodic

     Or

     If cambic or oxic present, lower boundary of plow layer or 18 cm if no plow layer present
   - The mineral soil "Garbage Can" epidpedon
7. **Plaggen**
   - Human made by long term application of animal manure
   - X > 50cm thick
   - Commonly contains artifacts
8. **Umbric**
   - Same criteria as mollic *except* that Base Saturation is X < 50%

B) Diagnostic Subsurface Horizons – formed below the surface, may be exposed due to erosion.

1. **Agric** (rare, Germany)
   - Illuvial accumulation of hummus, silt, and clay immediately under the plow layer
   - Found in soils that have undergone centuries of cultivation
2. **Albic**
   - Strong eluvial horizon
   - Associated with strongly expressed E-horizons
   - X > 85% albic materials (white)
     - Light color resulting from uncoated sand and silt grains
     - 4/2, 5/2, 6/2….. moist color
     - 6/3, 7/3……moist color

3. **Argillic**

- Significant illuvial accumulation of silicate clays
- Associated with Bt horizons
- Must have clay films or bridges (t)
- If an eluvial horizon remains and there is no lithologic discontinuity between the eluvial and illuvial horizon, then the illuvial horizon must contain one of the following increases in clay

If the eluvial horizon contains:

X<15 % clay

Requires a 3% absolute increase in clay

If 9% in eluvial then it needs at least 12% in illuvial within 30cm

15 to 40% clay

Requires 1.2 times increase in clay relative to the eluvial.

If 20% in eluvial then it needs at least 24% in illuvial within 30cm (Most common)

X>40% clay

Requires an 8% absolute increase in clay

If 45% in eluvial then it needs at least 53% in illuvial within 30cm

- If the illuvial horizon is directly overlain by a plow layer or if there is a lithologic discontinuity between the eluvial and illuvial horizon or if the illuvial is at the surface:

  Then only clay films are required

4. **Calcic**

- Significant illuvial accumulation of secondary calcium carbonate (k)
- Associated with Bk and Ak horizons – Ck, pedogenic or geologic???
- X>15% $CaCO_3$ equivalent and 5% or more than parent material
- Visable secondary carbonates

5. **Cambic**

- A physically altered, chemically transformed subsurface horizon
- Has a texture of very fine sand, loamy very fine sand, or more fine
- Does NOT meet the criteria of any epipedon
- Does NOT meet the criteria for other subsurface diagnostic horizons The subsurface horizon "Garbage Can"
- Often associated with Bw or Bg horizons or Bt that does not make argillic or Bk that does make clacic

6. **Duripan**

- Silica cemented horizon
- Associated with Bqm horizons

7. **Fragipan**

- Coarse polygonal structure
- Aggregates slake in water
- Brittle
- Restrictive to roots and water movement
- Associated with Bx horizons

8. **Glossic**

- Degraded argillic, kandic, spodic, or nitric horizon
- Also contains eluvial portions
- “Tongueing” common
- Often associated with E and Bt combos

9. **Gypsic**

- Significant accumulation of secondary gypsum ($CaSO_4 * 2H_2O$)
- Associated with strongly weathered Bt horizons

10. **Kandic**

- Contains low activity clays (eg. Kaolinite …)
- CEC < 16 cmol(+)/kg clay
- Similar requirements as argillic except that the clay accumulation does not have to be illuvial, it can be formed in place.
- More ‘weathered’ than argillic
- Associated with strongly weathered Bt horizons
- Eg. S.W. USA (Ultisols) intensely weathered areas

11. **Natric**

- Significant illuvial accumulation of silicate clay and sodium
- Argillic requirements and
- Exchangeable sodium percentage (ESP) > 15% or sodium adsorption ratio (SAR)> 13.
- Columnar structure common
- Associated with Btn horizons
- Eg. Arid to Semi-arid environments with a lot of Na, the Great Salt Lake

12. **Orstein**

- Cemented spodic materials

13. **Oxic**

- More ‘weathered’ than kandic
- Low activity clays
- Low contents of weatherable minerals
- Residual accumulation of sesquioxides
- Thick fairly texturally uniform Bo horizons
- Commonly found in old, highly weathered tropical soils

14. **Petrocalcic** "Caliche"
- Cemented calcic horizon
- Often associated with Bym horizons

15. **Petrogypsic**
- Cemented gypsic horizon
- Often associated with Bym horizons

16. **Placic**
- Iron and organic matter thinly cemented horizons

17. **Salic**
- Significant accumulation of salts more soluble than gypsum
- High electrical conductives
- Often associated with Bz horizons

18. **Sombric**
- Illuvial humus accumulation under free draining soils
- Commonly restricted to cool moist soils of tropical mountains

19. **Spodic**
- Illuvial accumulation of spodic materials (Fe, Al, OM)
- Often associated with Bh, Bs, Bhs horizons

<u>STEP 3</u>

Attempt to key out the sample
Order
Suborder
Great Group
Family

The highest levels of the system are based on the presence or absence of diagnostic horizons. More features such as soil moisture regime, soil temperature regime, mineralogy class, cation exchange, class… and diagnostic features may need to be identified during the keying out procedure.

Other diagnostic soil characteristics
<u>Mineral soils</u>
Abrupt textural change
Albic materials
Andic materials
Anhydrous conditions
Coefficient of linear extensibility (COLE)
Durinodes
Fragic soil properties
Identifiable secondary carbonates
Interfingering of albic materials

Lamellae
Linear extensibility (LE)
Lithologic discontinuities
n-value
Petroferric contact
Plinthite
Resistant minerals
Slickensides
Spodic materials

Organic soils

Several unique criteria exist that we will not discuss in detail. We will briefly visit these topics when we talk about Histosols.

Mineral and Organic Soils

Lithic contact
- "solid bedrock"
- Commonly R-horizons

Paralithic contact
- "soft bedrock"
- Commonly Cr horizons

Sulfidic materials
Sulfuric horizons

Soil Moisture Regimes

Udic-

Ustic-

Ardic and torric-

Xeric-

Aquic-

Soil Temperature Regimes

Mean annual soil temperatures (MAST) measured at a specified depth (10-30cm; 20-60cm; or 30-90cm) depending on texture.

A rule-of-thumb that can be used as a rough estimate of MAST is to add 1° C to the mean annual air temperature.

Cold	Cyric – MAST < 8° C, no permafrost
	Frigid – MAST < 8° C, no permafrost, warmer summer than cryic
	Mesic – MAST > 8° C and < 15° C
	Thermic – MAST > 15° C and < 22° C
Hot	Hyperthermic – MAST > 22° C

Isofrigid – Frigid with < 5° C temp flux between winter and summer
Isomesic – Mesic with < 5° C temp flux between winter and summer
Isohermic – Thermic with < 5° C temp flux between winter and summer
Isohyperthermic – Hyperthermic with < 5° C temp flux between winter and summer

Architecture of Soil Taxonomy

The entire classification scheme can be pictured as a pyramid, with a small number of classes defined at the highest level using a few differentiating characteristics. The number of classes increases downward on the pyramid and the differentiating characteristics become increasingly focused.

Taxonomic nomenclature is constructed by combining formative elements

	# of classes
Order	12
Suborder	64
Great Group	317
Subgroup	> 2,400
Family	> 7,000
Series	> 19,000

Order
- Highest level of classification
- All soils are separated into 12 orders
- Major genetic pathways and morphologic expression are expressed and utilized
- End with 'sol' (Alfisol….)

Suborder
- Second highest level of classification
- 2 syllable word (Udalf…)
- Differentiating characteristics vary within order
    - Soil moisture regime
    - Soil Temperature regime
    - Diagnostic horizons / features present
- First syllable is a formative element (Udalf…)
- Second syllable comes from the order (Udalf..)

Great Group
- Third highest level of classification
- 3 or 4 syllable word (Hapludalf…)
- Differentiating characteristics very within order
    - Soil moisture regime
    - Soil Temperature regime
    - Diagnostic horizons / features present
- First syllable is a formative element (Hapludalf…)
- Second syllable comes from the suborder (Hapludalf…)
- Third syllable comes from the order (Hapludalf…)

Subgroup

- Fourth Highest level of classification
- 2 or 3 words (Typic Hapludalf…)
- Takes 1 of the three forms

  Typic

  Used for subgroups that represent the central concept of their great group
  Typic Hapludalf

  Intergrade

  Has properties that translational to some higher category

  Mollic Hapludalf is transitional towards a Mollisol but is a member of the Alfisol order.

  Extragrade

  Has properties not typical for their great group and are not transitional to any other higher category

  Lithic Hapludalf is not transitional to any higher class.

Family

- Includes characteristics that are significant to plant growth or engineering
- Family names include properties such as particle-size, mineralogy, cation exhange activity class, temperature regime…
- More detail will be presented in another handout
- Some soil orders with unique properties have additional modifiers like soil soil depth class, reaction class

  Fine-silty, mixed, superactive, mesic Typic Hapludalf

Soil Series

- Lowest and most specific category
- Groups soils that have essentially the same profile characteristics
- Concept originated inn the early 1900's and is much older than *Soil Taxonomy*
- Serves as a link between *Soil Taxonomy* and actual soils that are mapped during soil survey
- Soil mapping typically uses series name
- Named after the location where the soils were first described
- Criteria are not defined in *Soil Taxonomy*

Generalized Family Criteria in Soil Taxonomy

Example: Fine-silty, mixed, superactive, mesic Typic Hapludalf

Particle-size Classes

Used to characterize the grain size distribution of the whole soil, including both fine earth and coarse fragments

Control sections:

Depth interval in the soil profile to which classification criteria are applied

Generalized rules (See *Keys to Soil Taxonomy* for exact rules)

1. Soils < 36 cm to root limiting layers:
   Mineral soil surface to root limiting layers
2. Soils > 36 cm deep without an argillic, kandic, or natic:
   25 cm to 1 m or 25 cm to root limiting layer, whichever is more shallow
3. Soils > 36 cm deep with argillic, kandic, or nitric and NO strongly contrasting particle size classes or root limiting layer between top of argillic … and 1 m:
   Thinnest of whole argillic or
   Upper 50 cm of argillic
4. Soils > 36 cm deep with argillic, kandic, nitric and or either/or strongly Contrasting particle size classes or a root limiting layer:
   Top of argillic to root limiting layer
   Upper 50 cm of argillic… (if root limiting layer)
   Top of argillic… to 1 m (if strongly contrasting particle-size classes)
   Whichever is most shallow of the above three.

Root Limiting Layers

Duripan
Fragipan
Petrocalcic
Petrogypsic
Placic
Ortstein
Densic
Lithic
Paralithic
Petroferric

Mineralogy classes

Knowing the mineralogy of soils is useful in predicting behavior and responses to management.

Same control section is used as for particle-size class

Dominant mineral present is noted. If no dominant mineral then mineralogy class is 'mixed'

See the *Keys to Soil Taxonomy* for more details.

Cation-Exchange Activity Classes

Same control section is used as for particle size class

Do not use for the following soils: Histosols, Histels, Oxisols, Alfisols, and Ultisols with kandi or kanhap great groups or subgroups, fragmental, sand, or sandy-skeletal particle-size classes.

Used with mixed and siliceous mineralogy classes

Ratio of CEC (by NH_4Oac) to % clay
0.6 or more = superactive
0.4 – 0.6 = active
0.24 – 0.4 = semiactive
< 0.24 = subactive

Soil Temperature Classes

Gelisols

Hypergelic = MAST < - 10 C
Pergelic = -10 C < MAST < -4 C
Subgelic = -4 C < MAST < 1 C

Other soils with a difference of > 6 C between summer and winter MAST

Frigid = MAST < 8 C
Mesic = MAST < MAST < 15 C
Thermic = 15 C < MAST < 22 C
Hyperthermic = MAST > 22 C

All other soils

Isofrigid = MAST < 8 C
Isometric = 8 < MAST < 15 C
Isothermic 15 C < MAST < 22 C
Isohyperthermic = MAST > 22 C

Formative Elements Used in *Soil Taxonomy*

Orders	Formative element	Derivation	Simplified Connotation
Alfisol	alf		Pedalfer
Andisol	and	Jap. Ando, black soil	Volcanic
Aridisol	id	L., aridus, dry	Arid
Entisol	ent		Recent
Gelisol	el	L., gelare, to freeze	
Histosol	ist	Gr., histos, tissue	Histology
Inceptisol	ept	L., inceptum, beginning	Inception
Mollisol	oll	L. mollis, soft	mollify
Oxisol	ox	F., oxide, oxide	oxide
Spodosol	od	Gr., spodos, wood ash	Odd
Ultisol	ult	L., ultimus, last	Ultimate
Vertisol	ert	L., verto, turn	Invert