



United States Department of Agriculture

# Enhancing Accuracy and Applicability of U.S. Soil Taxonomy



Andrew G. Brown

 [andrew.g.brown@usda.gov](mailto:andrew.g.brown@usda.gov)

Dylan E. Beaudette

 [dylan.beaudette@usda.gov](mailto:dylan.beaudette@usda.gov)

SSSA 2020 — Future of Pedology  
Symposium

Natural  
Resources  
Conservation  
Service

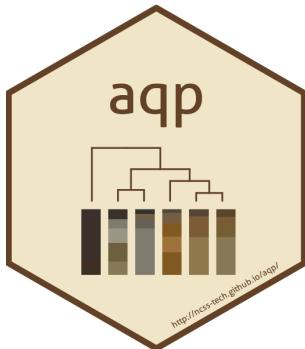
[nrcs.usda.gov/](http://nrcs.usda.gov/)

# Who am I?



**Andrew G. Brown**

- Soil Scientist in Sonora, CA, Southwest Soil Survey Region
- Area of responsibility: Sierra Nevada Foothills & Mountains (MLRAs 18 & 22A)
- Western Region National Cooperative Soil Survey (NCSS) Standards Committee (2018, 2020)
- Contributor to *Algorithms for Quantitative Pedology* Project (<http://ncss-tech.github.io/AQP/>)



Natural  
Resources  
Conservation  
Service

nrcs.usda.gov/

# The Keys to Soil Taxonomy are like a set of sieves

KST Lookup App: <https://brownag.shinyapps.io/KSTLookup>

KST Preceding Taxa App: <https://brownag.shinyapps.io/KSTPreceding>



# The Keys to Soil Taxonomy are like a set of sieves

KST Lookup App: <https://brownag.shinyapps.io/KSTLookup>

KST Preceding Taxa App: <https://brownag.shinyapps.io/KSTPreceding>

## Keys to Soil Taxonomy (12th) - Preceding Taxa Lookup Tool [alpha]

Enter a taxon name:

Showing taxa that key out before:

*Entisols*

Show 25 ▾ entries

Search:

Content	Ch.	Pg.	Key	Taxa	Code	Logic
A <i>Gelisols</i> , p. 157	4	38	Soil Orders	*	A	NEW
B <i>Histosols</i> , p. 167	4	38	Soil Orders	*	B	NEW
C <i>Spodosols</i> , p. 273	4	39	Soil Orders	*	C	NEW
D <i>Andisols</i> , p. 87	4	39	Soil Orders	*	D	NEW



# The Keys to Soil Taxonomy are like a set of sieves

KST Lookup App: <https://brownag.shinyapps.io/KSTLookup>

KST Preceding Taxa App: <https://brownag.shinyapps.io/KSTPreceding>

## Keys to Soil Taxonomy (12th) - Taxon Criteria Lookup Tool [alpha]

Enter a taxon name:		Results for						English	
<input type="text" value="Glacisels"/> ▼		<i>Glacisels</i>						<input type="text"/> ▼	
Show <input type="button" value="25"/> entries		Search: <input type="text"/>							
Content		Ch.	Pg.	Key	Taxa	Code		Logic	
1	A. Soils that have:	4	38	Soil Orders	*	A	FIRST		
2	1. Permafrost within 100 cm of the soil surface; or	4	38	Soil Orders	*	A	OR		
3	2. Gelic materials within 100 cm of the soil surface and permafrost within 200 cm of the soil surface.	4	38	Soil Orders	*	A	END		
4	Gelisols, p. 157	4	38	Soil Orders	*	A	NEW		
5	AA. Gelisols that have organic soil materials that meet one or more of the following:	9	157	Suborders	Gelisols	AA	OR		
6	1. Overlie cindery, fragmental, or pumiceous materials and/or fill their interstices and directly below these materials have either a densic, lithic, or paralithic contact; or	9	157	Suborders	Gelisols	AA	OR		
7	2. When added with the underlying cindery, fragmental, or pumiceous materials, total 40 cm or more between the soil surface and a depth of 50 cm; or	9	157	Suborders	Gelisols	AA	OR		
8	3. Comprise 80 percent or more, by volume, from the soil surface to a depth of 50 cm or to a glacic layer or a densic, lithic, or paralithic contact, whichever is shallower.	9	157	Suborders	Gelisols	AA	END		
9	Histels, p. 157	9	157	Suborders	Gelisols	AA	NEW		



# Diagnostic Features and Properties



United States  
Department of Agriculture



## Keys to Soil Taxonomy

Twelfth Edition, 2014



Times Used in Subgroup to  
Order Keys

Feature	Count
Paralithic Contact	390
Aquic Conditions	317
Argillic Horizon	259
Volcanic Glass	241
Lithic Contact	231
Andic Soil Properties	201
Slickensides	160
Mollie Epipedon	159
Linear Extensibility	159
Kandic Horizon	158
Duripan	115

# Soil v.s. Nonsoil and Soil Depth

*"The lower boundary that separates soil from the nonsoil underneath is most difficult to define ... In some instances the more weakly cemented bedrocks ... have been described below the lower boundary of soil and used to differentiate soil series (series control section, defined in chapter 17). This is permissible even though the paralithic materials below a paralithic contact are not considered soil in the true sense." (Keys to Soil Taxonomy, 12th ed., p. 1)*

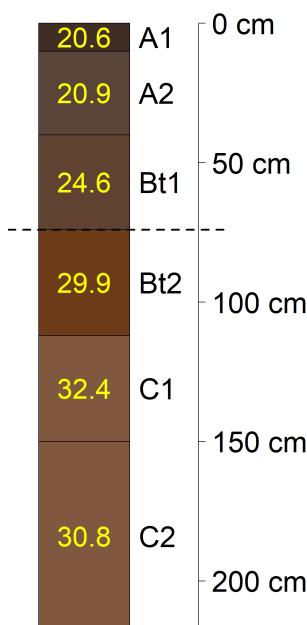


# The Argillic Horizon



**Cohasset - Fine-loamy, mixed, active, mesic Ultic Haploxeralfs**

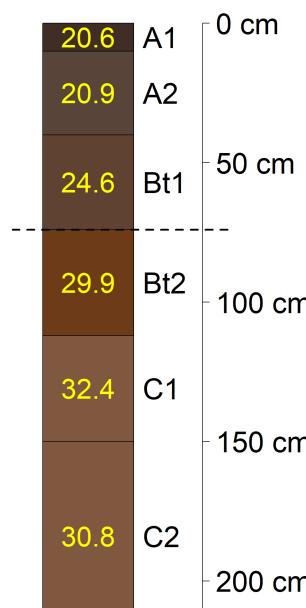
Official Series Description: [https://soilseries.sc.egov.usda.gov/OSD\\_Docs/C/COHASSET.html](https://soilseries.sc.egov.usda.gov/OSD_Docs/C/COHASSET.html)



# The Argillic Horizon

**Cohasset - Fine-loamy, mixed, active, mesic Ultic Haploxeralfs**

Official Series Description: [https://soilseries.sc.egov.usda.gov/OSD\\_Docs/C/COHASSET.html](https://soilseries.sc.egov.usda.gov/OSD_Docs/C/COHASSET.html)



**Laboratory measured clay content (%), "increase matrix"**

##	20.6	20.9	24.6	29.9	32.4	30.8
## A1	20.6	.	FALSE	FALSE	FALSE	FALSE
## A2	20.9	.	FALSE	FALSE	FALSE	FALSE
## Bt1	24.6	.	TRUE	FALSE	FALSE	FALSE
## Bt2	29.9	.	.	FALSE	FALSE	FALSE
## C1	32.4	.	.	.	FALSE	FALSE
## C2	30.8	.	.	.	.	.

- A difference in clay content of 0.5% in the **Bt1** horizon shifts the top of the Particle-Size Control Section downward by 34 cm (to the top of the **Bt2**).
- The Argillic Horizon and Particle-Size Control Section start at 74 cm.

# The Argillic Horizon



## Problems

- *Upper boundary of Argillic Horizon* – tied to Particle-Size Control Section boundary.



# The Argillic Horizon



## Problems

- *Upper boundary of Argillic Horizon* – tied to Particle-Size Control Section boundary.
- *Bottom of the Argillic Horizon* – depends on (lack of) clay films or other accumulation.



# The Argillic Horizon



## Problems

- *Upper boundary of Argillic Horizon* – tied to Particle-Size Control Section boundary.
- *Bottom of the Argillic Horizon* – depends on (lack of) clay films or other accumulation.
- *Truncated Argillic Horizons* – depends on a lithologic discontinuity or exposure.



# The Argillic Horizon



## Problems

- *Upper boundary of Argillic Horizon* – tied to Particle-Size Control Section boundary.
- *Bottom of the Argillic Horizon* – depends on (lack of) clay films or other accumulation.
- *Truncated Argillic Horizons* – depends on a lithologic discontinuity or exposure.
- *"Wimpy" Argillic Horizons* – low total clay content, marginal clay increase, limited development of morphology (e.g. clay films)



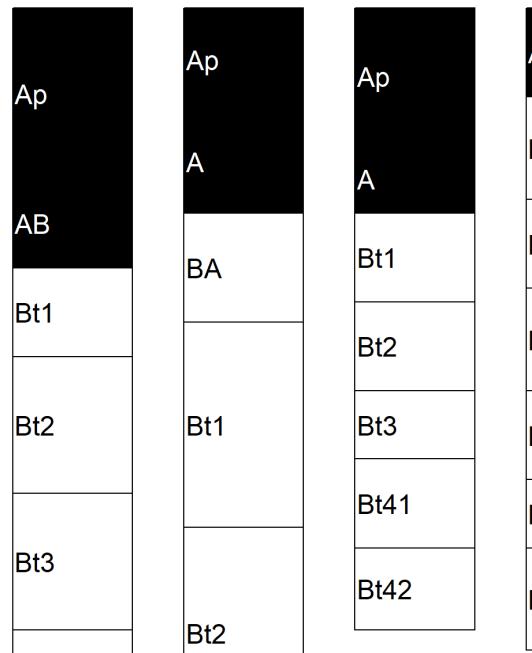
# The Mollie Epipedon



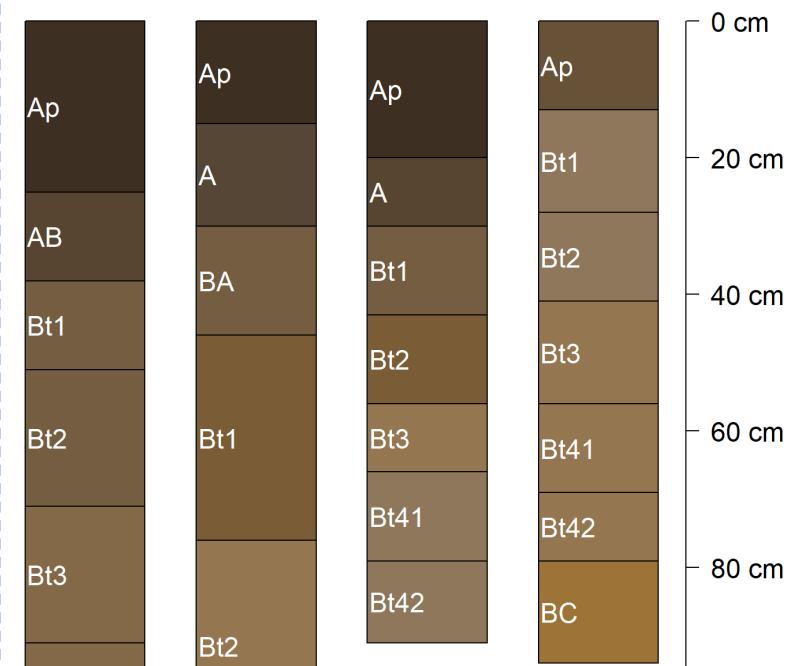
**Tama - Fine-silty, mixed, superactive, mesic Typic Argiudolls**

Official Series Description: [https://soilseries.sc.egov.usda.gov/OSD\\_Docs/T/TAMA.html](https://soilseries.sc.egov.usda.gov/OSD_Docs/T/TAMA.html)

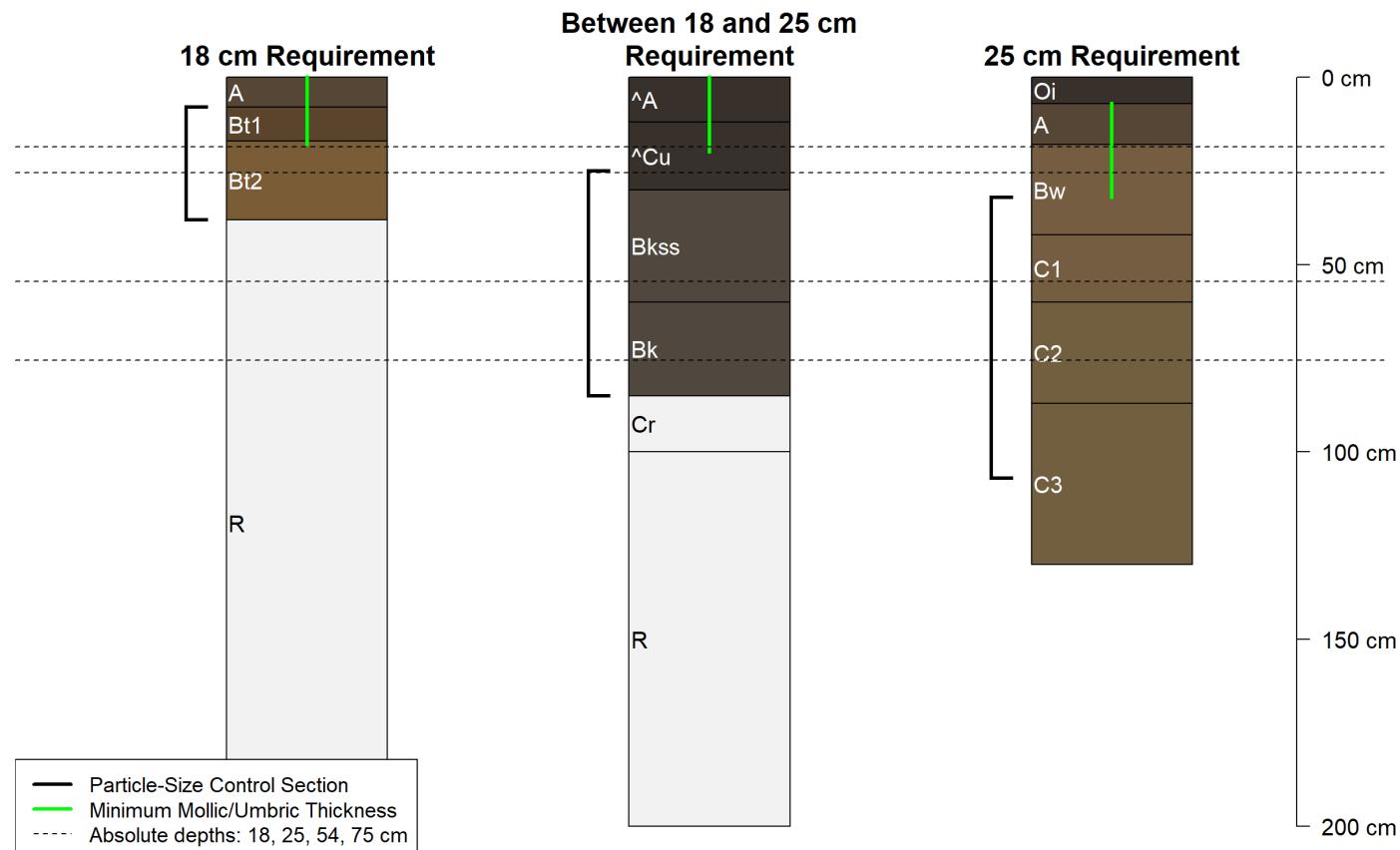
*is\_mollie\_color*



*moist\_color*



# The Mollie Epipedon





# The Mollie Epipedon



## Problems

- Physical mixing criteria are confusing, impossible to apply retroactively, and subjective when materials are very dissimilar in composition or density.



# The Mollie Epipedon



## Problems

- Physical mixing criteria are confusing, impossible to apply retroactively, and subjective when materials are very dissimilar in composition or density.
- The sliding scale thickness requirement is commonly misinterpreted and may be difficult to apply consistently.



# The Mollie Epipedon



## Problems

- Physical mixing criteria are confusing, impossible to apply retroactively, and subjective when materials are very dissimilar in composition or density.
- The sliding scale thickness requirement is commonly misinterpreted and may be difficult to apply consistently.
  - Simultaneous dependency on: texture class of subhorizons, distribution of organic carbon with depth, identifiable secondary carbonates, petrocalcic/duripan/fragipan, densic/lithic/paralithic contacts, and argillic, cambic, natric, oxic, or spodic horizons. Not only does it depend on presence or absence, but required thickness is determined by *depths to top or bottom* of these features.



# The Mollie Epipedon



## Problems

- Physical mixing criteria are confusing, impossible to apply retroactively, and subjective when materials are very dissimilar in composition or density.
- The sliding scale thickness requirement is commonly misinterpreted and may be difficult to apply consistently.
  - Simultaneous dependency on: texture class of subhorizons, distribution of organic carbon with depth, identifiable secondary carbonates, petrocalcic/duripan/fragipan, densic/lithic/paralithic contacts, and argillic, cambic, natric, oxic, or spodic horizons. Not only does it depend on presence or absence, but required thickness is determined by *depths to top or bottom* of these features.
- Several exceptions: keeping depositional phases in the Mollisols, aridic soil moisture regimes, and unique color and organic carbon requirements in materials with a high content of carbonate





# Soil Series



- The soil series is the lowest, most detailed taxonomic level in U.S. Soil Taxonomy.



# Soil Series



- The soil series is the lowest, most detailed taxonomic level in U.S. Soil Taxonomy.
- Nominally, a soil series has a *single* family-level classification. This is in the *Official Series Description* (OSD).



# Soil Series



- The soil series is the lowest, most detailed taxonomic level in U.S. Soil Taxonomy.
- Nominally, a soil series has a *single* family-level classification. This is in the *Official Series Description* (OSD).
- The *Range in Characteristics* (RIC) should **not** range outside the series family.



# Soil Series (Fayette RIC)

**Fayette - Fine-silty, mixed, superactive, mesic Typic Hapludalfs**

**Official Series Description:** [https://soilseries.sc.egov.usda.gov/OSD\\_Docs/F/FAYETTE.html](https://soilseries.sc.egov.usda.gov/OSD_Docs/F/FAYETTE.html)

## RANGE IN CHARACTERISTICS:

Depth to carbonates--greater than 100 centimeters

Content of clay in the particle-size control section (weighted average)--24 to 32 percent

Content of sand in the particle-size control section (weighted average)--less than 5 percent

Coarse silt to fine silt ratio in the particle-size control section--0.9 to 1.5

A horizon:

Hue--10YR

Value--2 or 3

Chroma--1 or 2

Texture--silt loam

Clay content--15 to 27 percent

Reaction--very strongly acid to neutral

Ap horizon (if present):

Hue--10YR

Value--4

Chroma--2 or 3

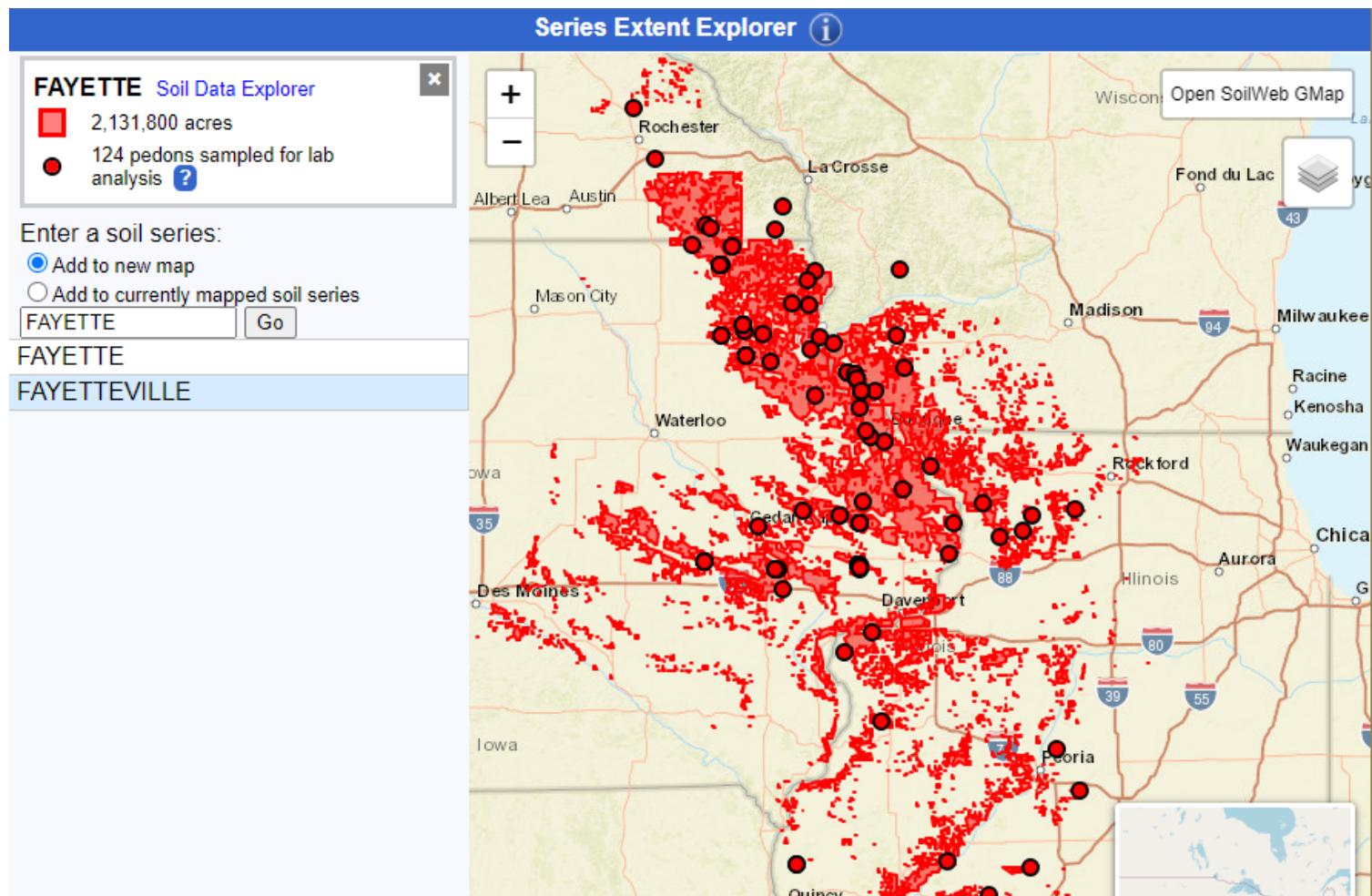
Texture--silt loam

Clay content--15 to 27 percent

Reaction--very strongly acid to neutral



# Soil Series (Fayette Extent)

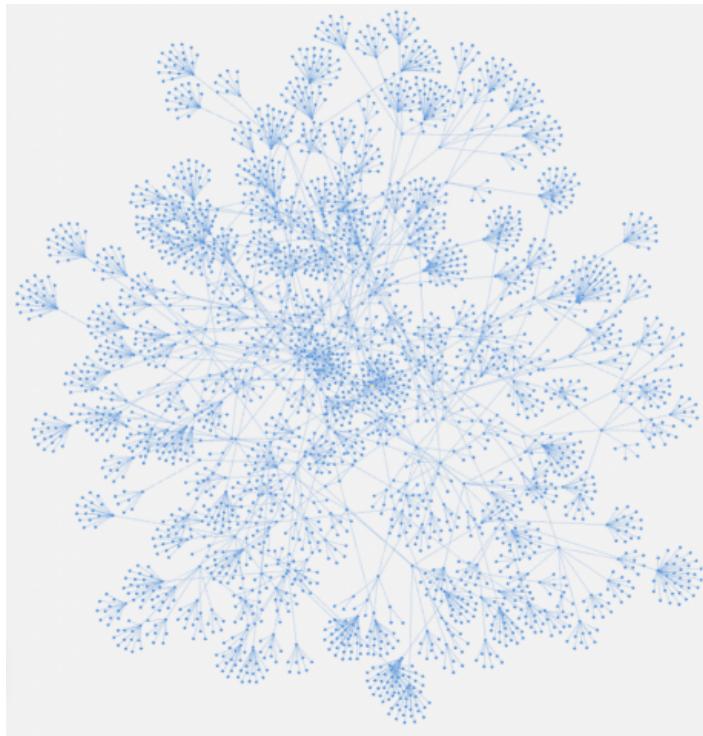


# Soil Series in Soil Mapping

- Soil map unit component ranges need not exactly match those of the series RIC; often they are wider.
- In practice, especially in less-detailed (Order 3+) mapping, series-level components in the U.S. include:
  - Soils *within* the RIC of the series
  - Soils *outside* the RIC that *have same family* as the named series (generally: "similar soils," formerly: "variant")
  - Soils *not* in the same family (taxadjuncts or less-prevalent series) that *interpret* the "same" based on local model
- *Dissimilar* soils are separated based on interpretive difference(s) from the dominant condition in a map unit.
  - Dissimilar, *non-limiting* soils may not be reflected consistently in more general mapping if they are not extensive.



# Future of Soil Taxonomy



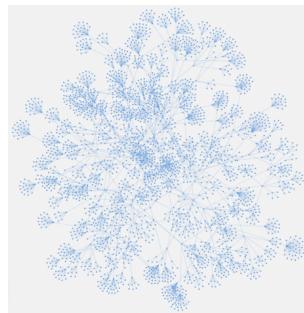
All 3082 subgroup to order level taxa in U.S. Soil Taxonomy, "rooted" to a common node.

To reconcile the "divisive" nature of the Keys and questions of "similarity" — *what do we need?*

- Graph databases capable of querying complex relationships between taxa, criteria, and metadata
- A U.S. Soil Taxonomy ontology to define our terms and serve as a scaffold for other National Cooperative Soil Survey Standards



# Future of Soil Taxonomy



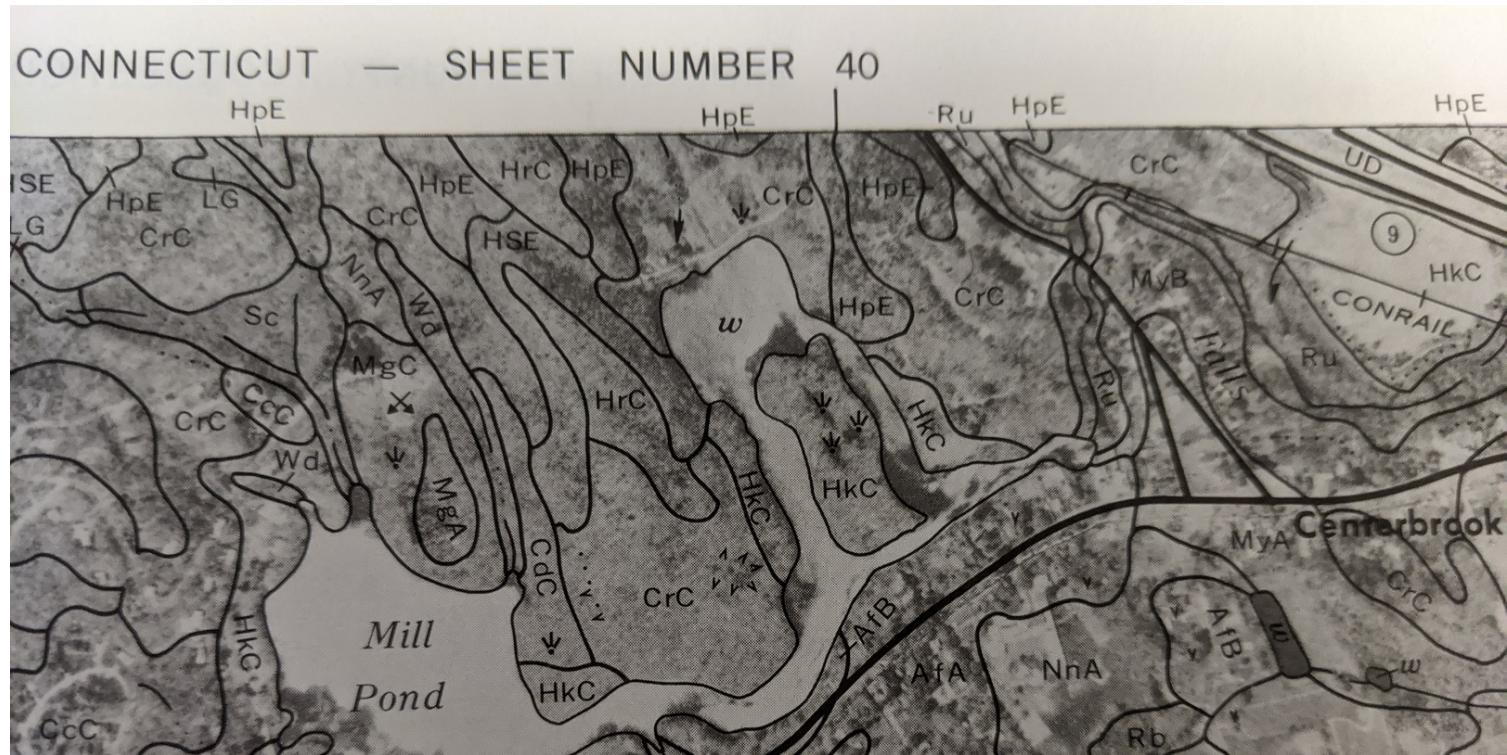
## Goals and dreams

1. "Fuzzy taxon membership" developed using *defined* weights, assumptions, and heuristics
2. Sensitivity analysis using properties *and* geometry for "most likely" profile taxonomic placement
3. Regional/purposive subsets or "views" of the complete taxonomy: to aid in education, reduce fatigue, and increase accessibility for non-specialists
4. Justification (and possible simplification) of concepts
5. Quantification of impacts and a unit-testing suite for proposed revisions



# Impacts on Soil Mapping

- All soils are "different" — defined rules and systems allow us to "consistently" reason over them.
- *Taxadjunct* is **not** a dirty word. Embrace the variations nature has to offer.



# Thank you for your attention!



**Andrew G. Brown, Soil Scientist, MLRA Soil Survey Office, Sonora, CA**

✉ andrew.g.brown@usda.gov  
👤 brownag  
🐦 @humus\_rocks



**Dylan E. Beaudette, Soil Scientist, National Soil Survey Center (duty station: Sonora, CA)**

✉ dylan.beaudette@usda.gov  
👤 dylanbeaudette  
🐦 @dylanbeaudette

*USDA is an equal opportunity provider, employer, and lender.*



Natural  
Resources  
Conservation  
Service

[nrcs.usda.gov/](http://nrcs.usda.gov/)

# References



Beaudette, D.E., P. Roudier, and A.T. O'Geen. 2013. Algorithms for Quantitative Pedology: A Toolkit for Soil Scientists. *Computers & Geosciences*. 52:258 - 268.

National Cooperative Soil Survey. National Cooperative Soil Characterization Database. Available online. Accessed [10/1/2020].

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

Soil Survey Staff. 2014. Keys to Soil Taxonomy, 12th ed. USDA-Natural Resources Conservation Service, Washington, DC.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available online. Accessed [10/1/2020].

Xie, Y. 2020. xaringan: Presentation Ninja. R package version 0.17.1.  
<https://github.com/yihui/xaringan>



Slides: <https://github.com/brownag/SSSA2020>