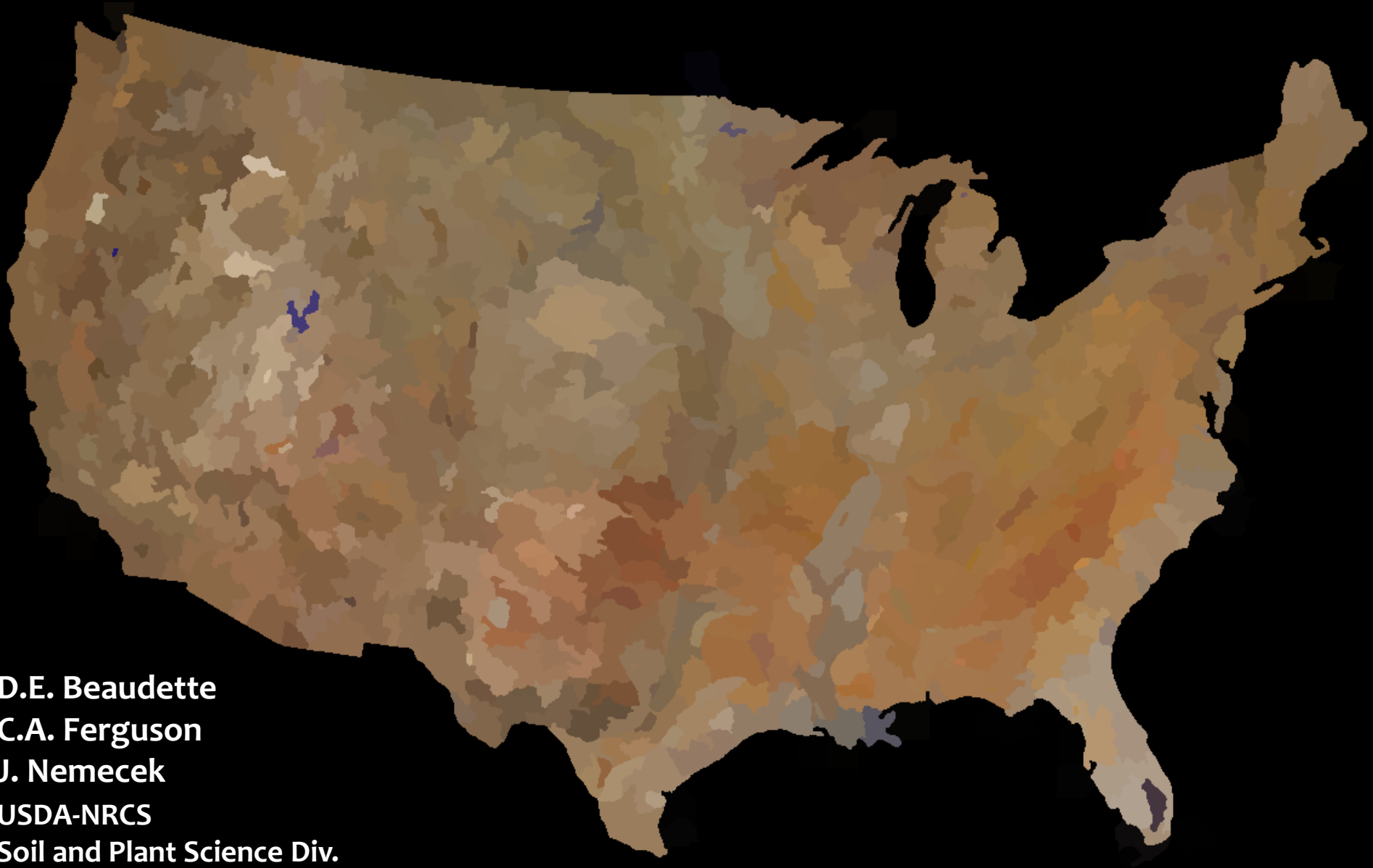
The Geography of Soil Color

Maps, Educational Narratives, and Database Describing the Soil Colors of the Continental United States



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C.A. Ferguson
J. Nemecek
USDA-NRCS
Soil and Plant Science Div.

Acknowledgments & Data Sources

- Charles Ferguson and Jason Nemecek
- Dr. Cynthia Stiles and Drew Kinney

- 100+ years of soil survey efforts
- Curation of 23,798 Official Series Descriptions
- SSURGO, the 1:24k detailed soil survey of the U.S.A.
- Dr. A.T. O'Geen: supported early efforts, pre-publication
- **R** color conversion functionality (`grDevices, farver`)

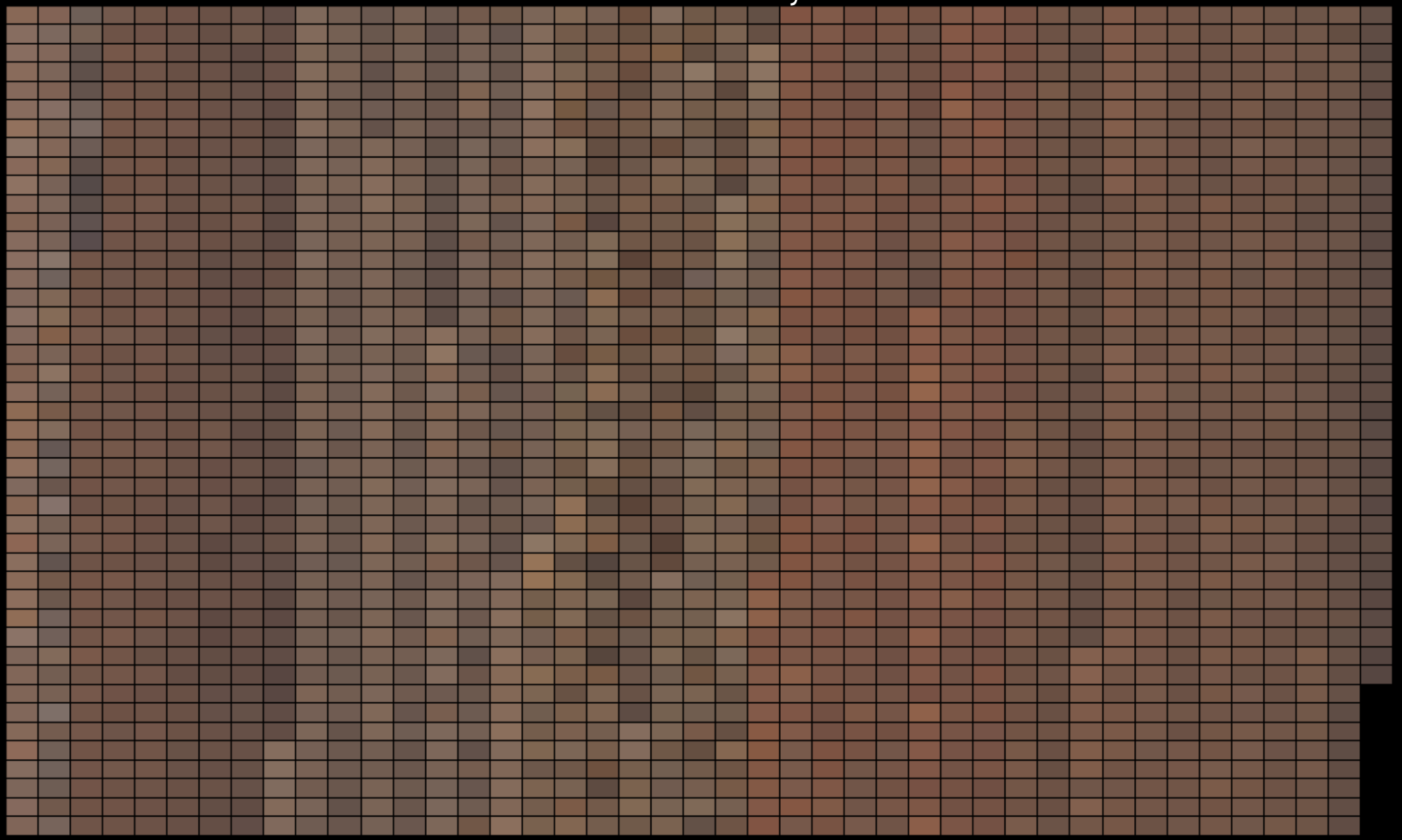
- 2005: Pinnacles National Monument soil survey
- 2009: SoilWeb OSD sketches with color (c/o T. Reinsch)
- 2011: OSD color database
- 2011: automated color conversion -- `aqp::munsell2rgb()`
- 2013: morphologic data added to `soilDB::fetchKSSL()`
- 2014: STATSGO soil color map (Z. Libohova & S. Peaslee)
- 2018: SSURGO soil color map (C. Ferguson & J. Nemecek)

Why?

- Soils are complex–we know this, but don't (can't?) always deliver a compelling narrative.
- It is hard to conserve what you don't understand.
- It is hard to understand what you don't perceive.
- Make soil properties / processes real.

When put into context, **soil color** tells a great story.

Soil Color



Liles, G. C., D. E. Beaudette, A. T. O'Geen, and W. R. Horwath. 2013.
Developing predictive soil C models for soils using quantitative color measurements. Soil Sci. Soc. Am. J. 77:2173-2181

Soil Color

Photos c/o G.C. Liles, I. Ainuddin, A. Conlin

Pigments

humus

todorokite

pyrite

iron sulfide

lepidocrocite-fine

hematite-fine

maghemite

ferrihydrite

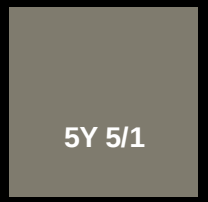
hematite-coarse

quartz

jarosite

akaganeite

lepidocrocite-coarse



glauconite

goethite-fine

schwertmannite

gypsum

dolomite

calcite

goethite-coarse

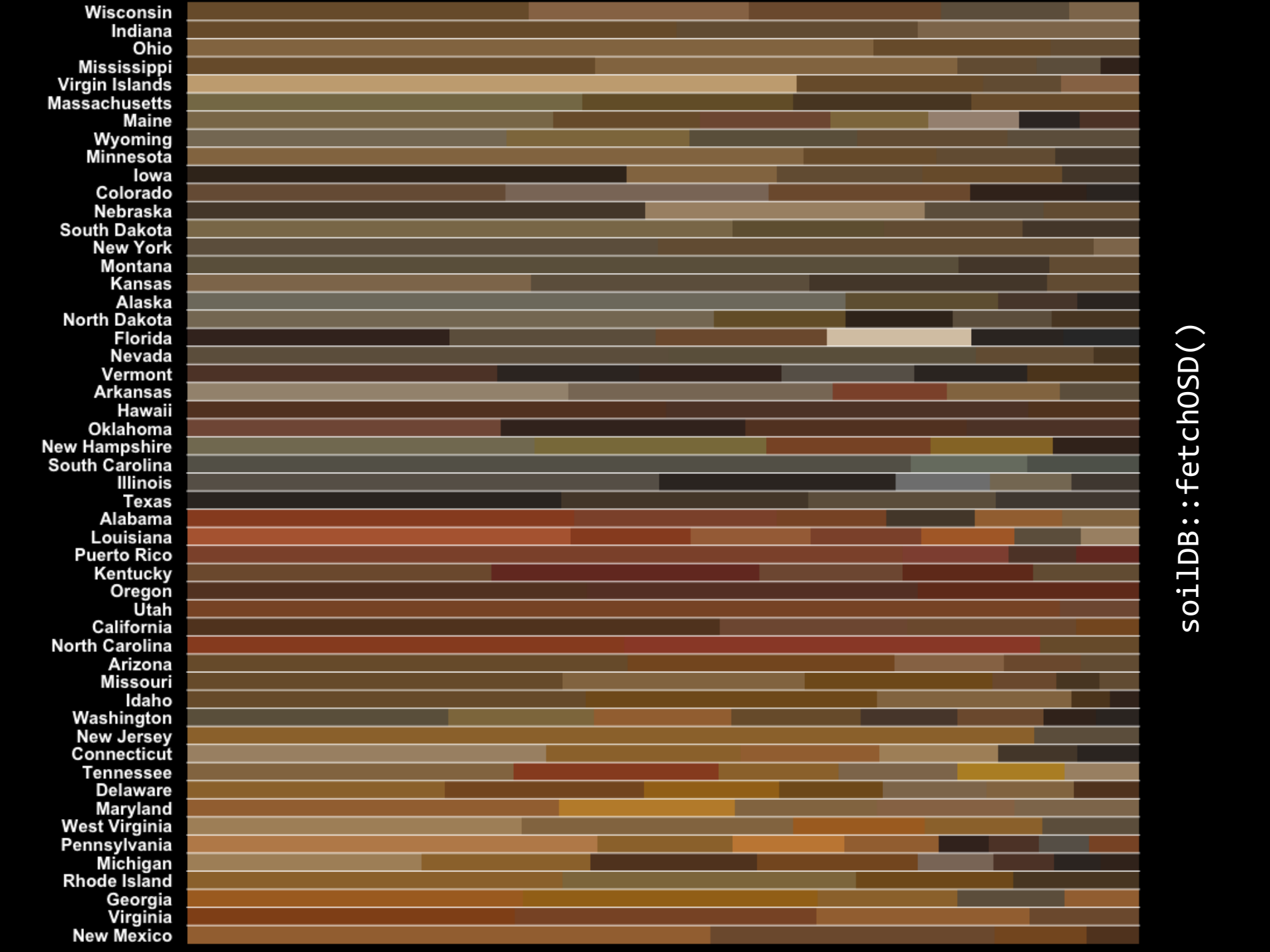
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054286

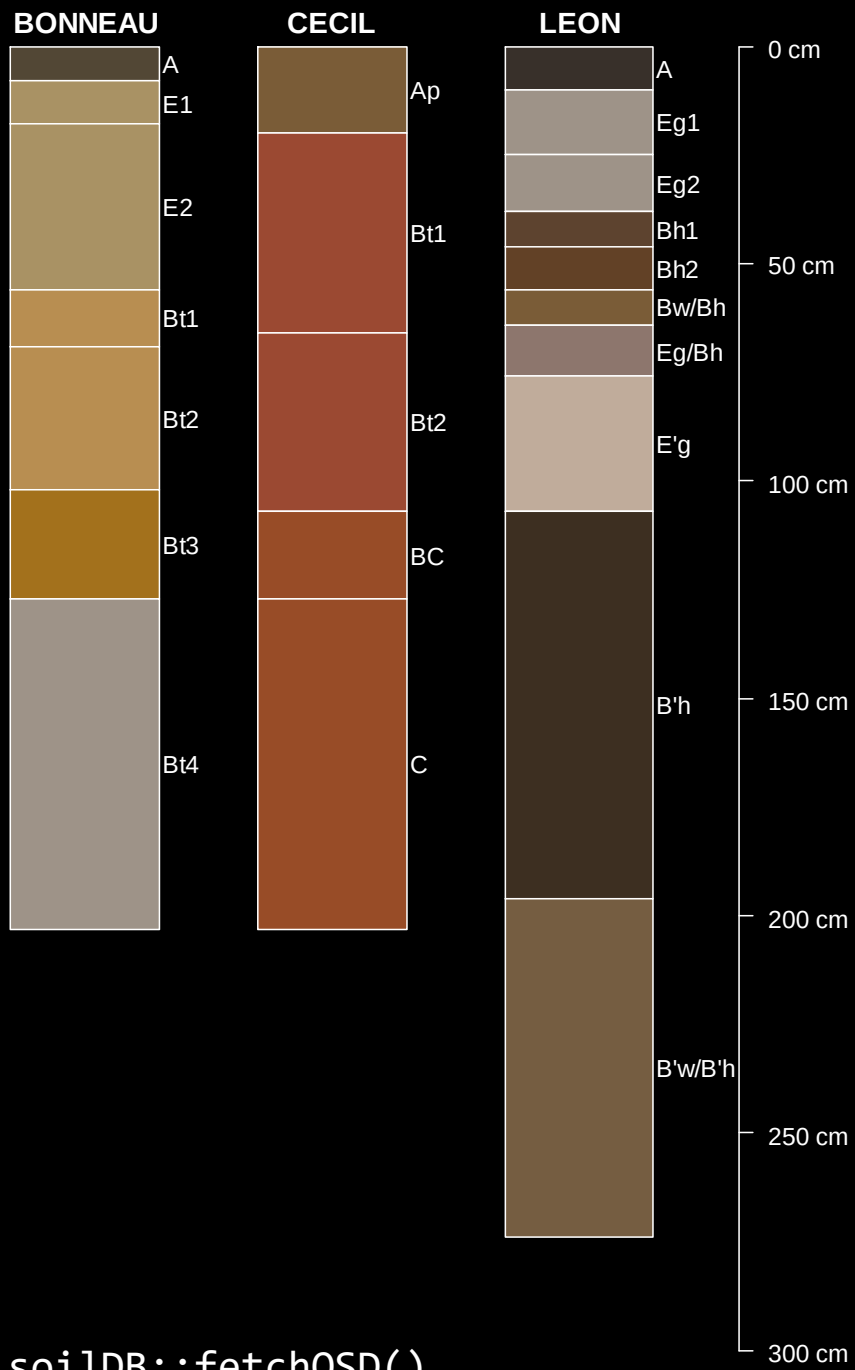
U. Schwertmann, 1993. SSSA Special Publication no. 31, pages 51--69

Colors from the OSDs

A--0.5 to 2 inches. (**1 to 5 cm**); reddish brown (**5YR 5/4**) gravelly loam. reddish brown (**5YR 4/3**) moist; 17 percent clay; moderate fine subangular blocky parting to moderate fine granular structure; hard. friable. nonsticky. slightly plastic; common very fine roots; many very fine irregular pores; 20 percent subangular metavolcanic gravel; moderately acid. pH 6.1 by Hellige-Truog; abrupt wavy boundary. (1 to 3 inches. (3 to 8 cm) thick)

`aqp::parseMunsell()`

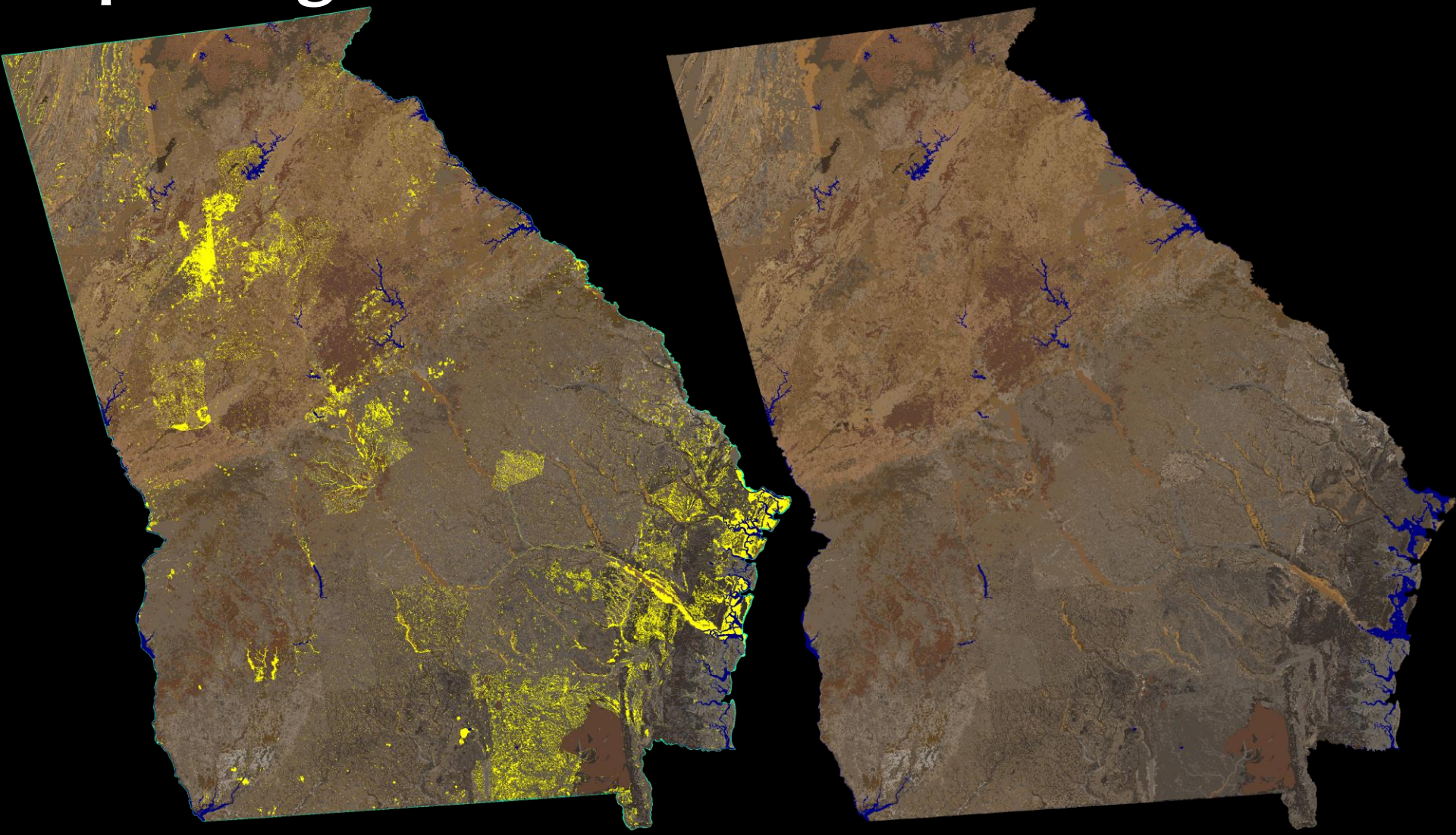

Wisconsin
Indiana
Ohio
Mississippi
Virgin Islands
Massachusetts
Maine
Wyoming
Minnesota
Iowa
Colorado
Nebraska
South Dakota
New York
Montana
Kansas
Alaska
North Dakota
Florida
Nevada
Vermont
Arkansas
Hawaii
Oklahoma
New Hampshire
South Carolina
Illinois
Texas
Alabama
Louisiana
Puerto Rico
Kentucky
Oregon
Utah
California
North Carolina
Arizona
Missouri
Idaho
Washington
New Jersey
Connecticut
Tennessee
Delaware
Maryland
West Virginia
Pennsylvania
Michigan
Rhode Island
Georgia
Virginia
New Mexico
soilDB::fetchOSD()



photos: John A. Kelley

`soilDB::fetchOSD()`

Gap-filling: Art and Science

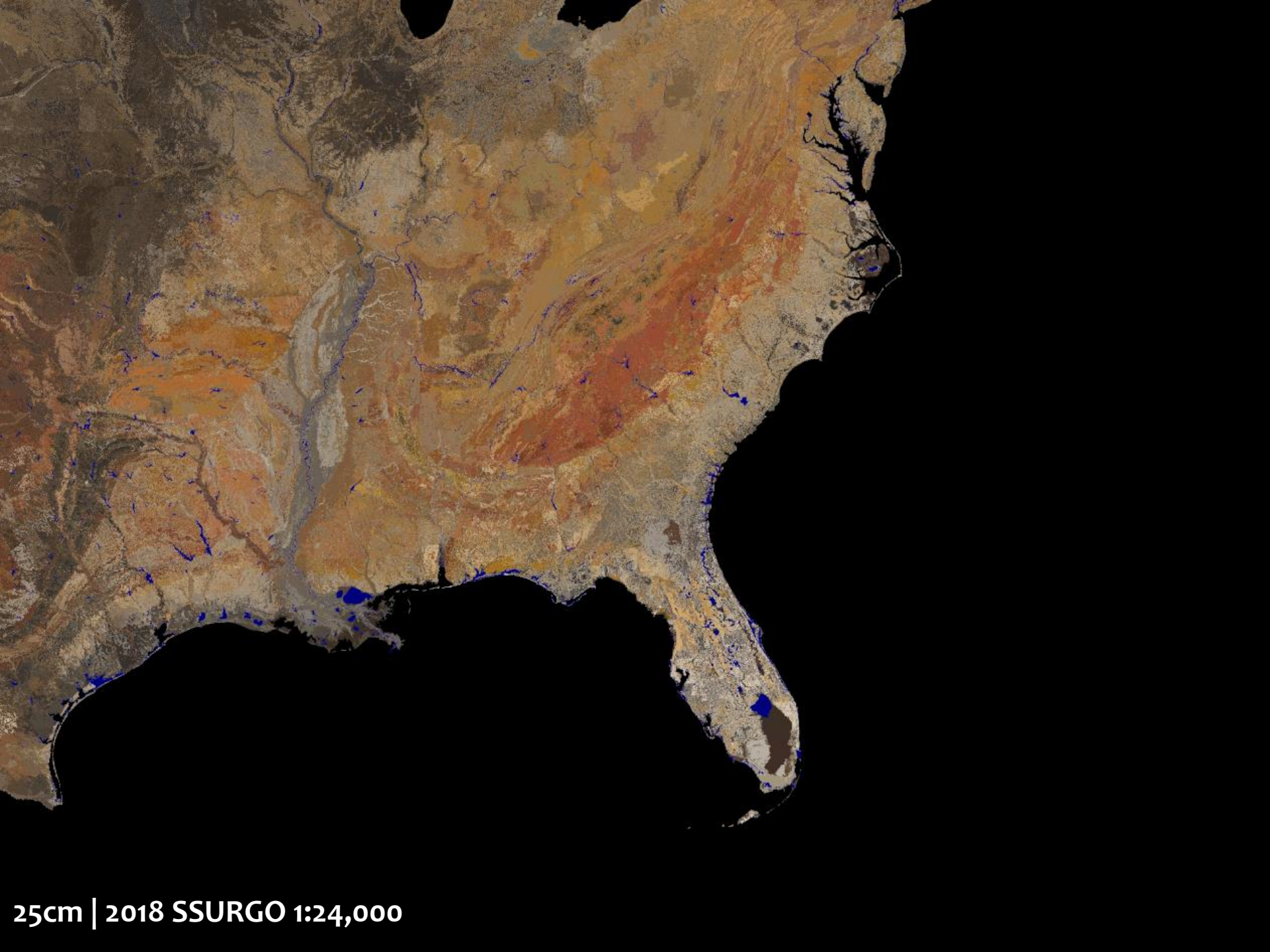


SSURGO → STATSGO
organic horizons w/out color → Oi, Oe: 7.5YR 2/2 Oa: 10YR 2/1
rock outcrop → grey
missing data → GIMP "heal selection"

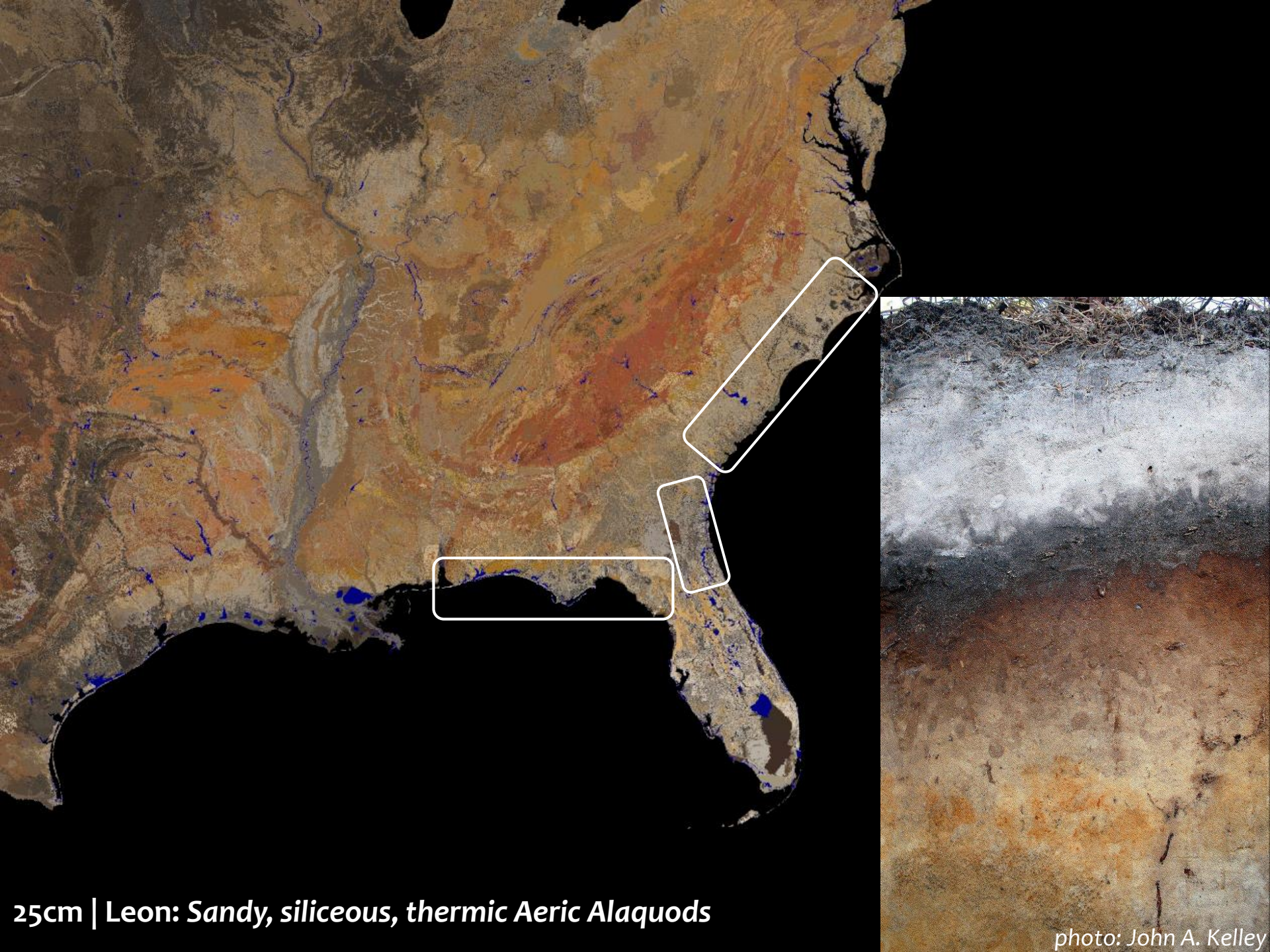
Results

Moist soil colors, available as: PNG, animated GIF, GeoTiff, web-maps

25cm | 2014 STATSGO 1:250,000

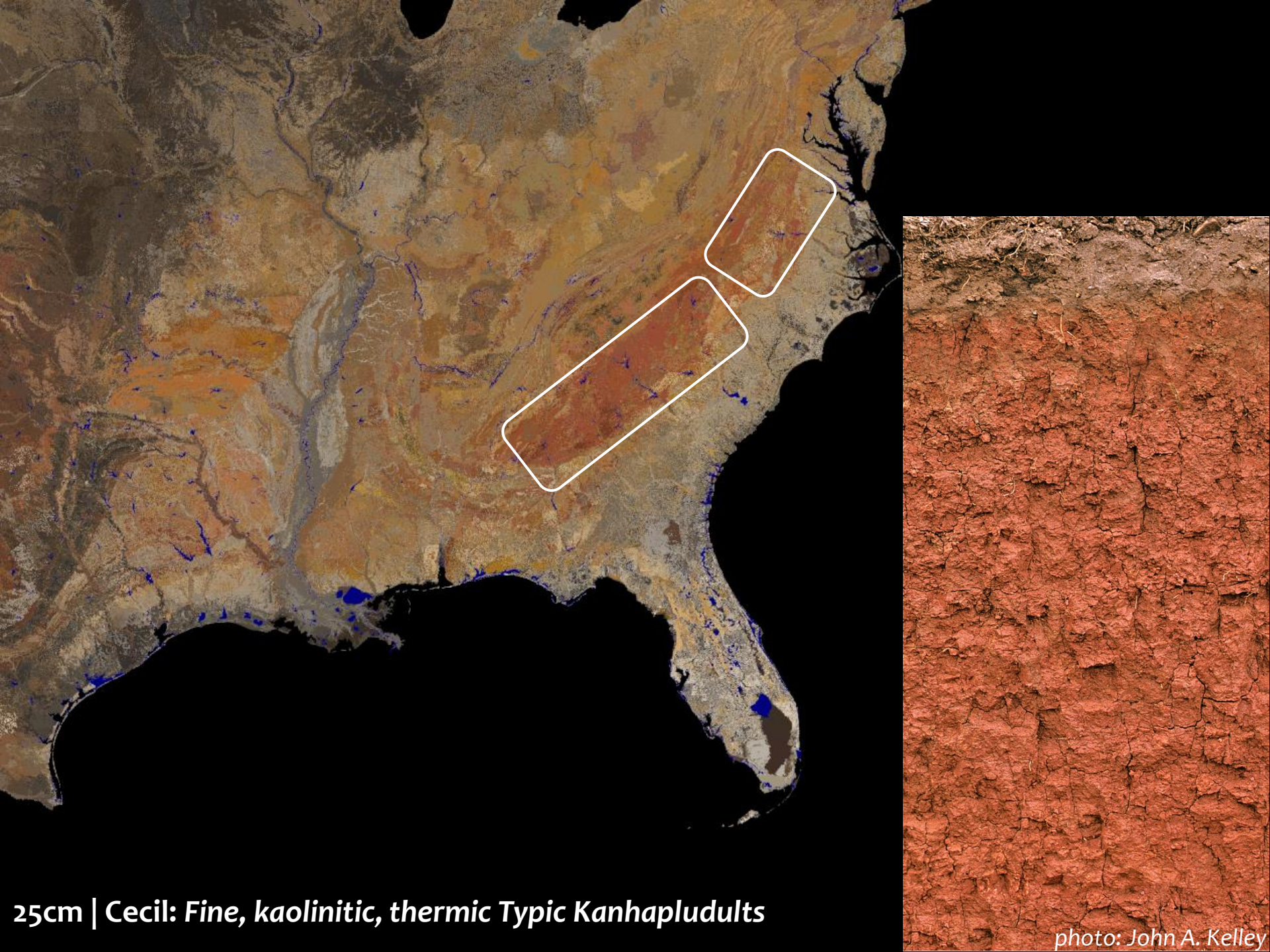


25cm | 2018 SSURGO 1:24,000



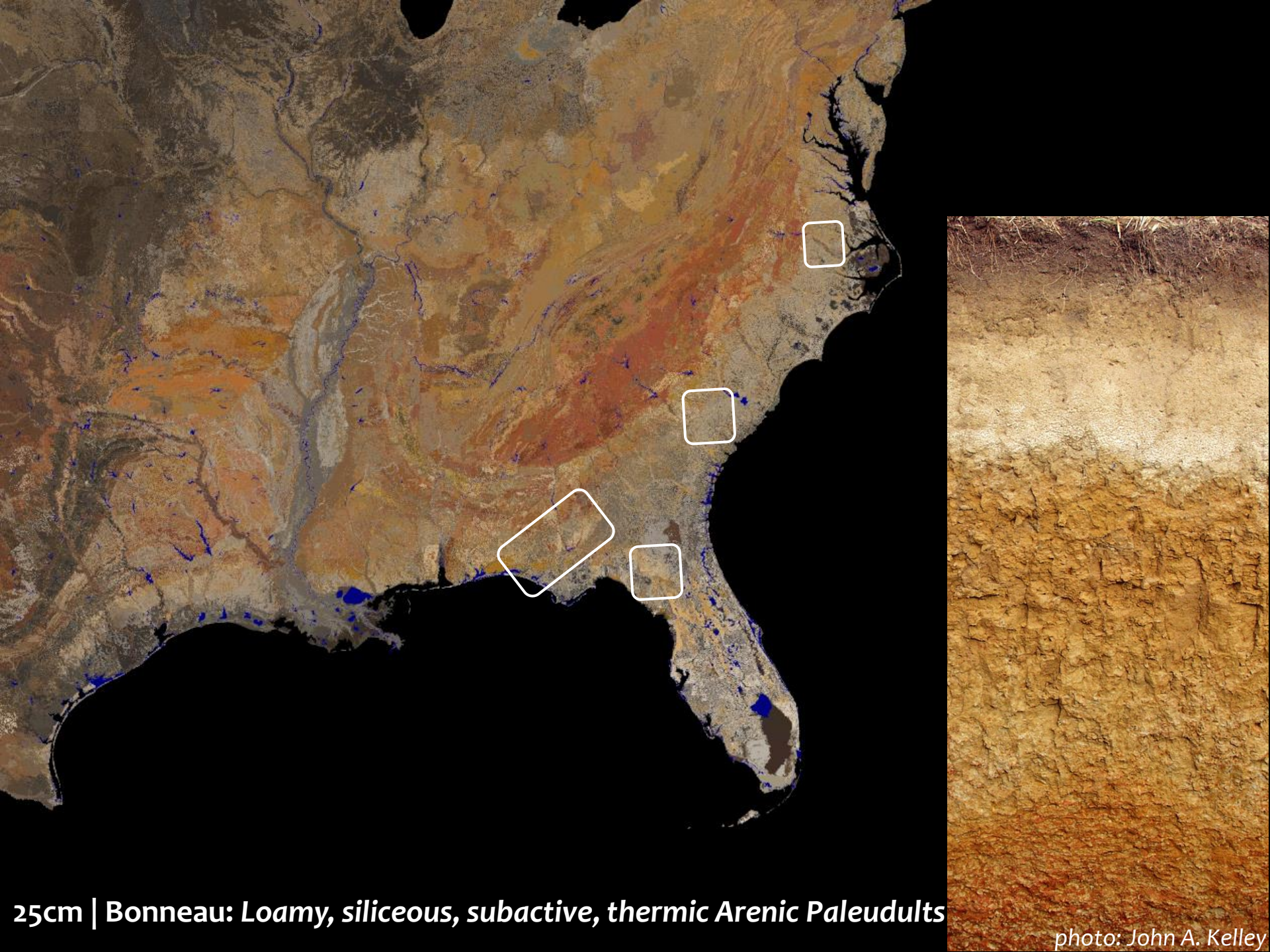
25cm | Leon: *Sandy, siliceous, thermic Aeric Alaquods*

photo: John A. Kelley



25cm | Cecil: *Fine, kaolinitic, thermic Typic Kanhapludults*

photo: John A. Kelley

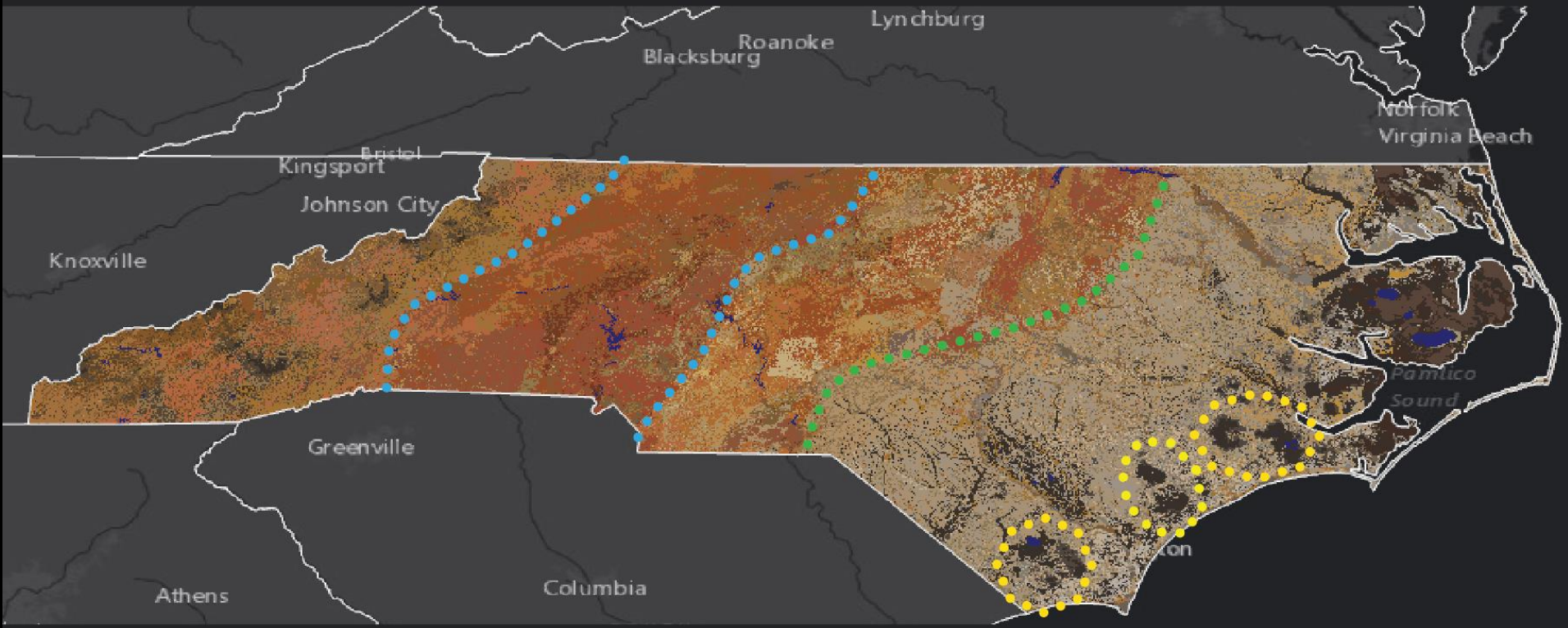


25cm | Bonneau: *Loamy, siliceous, subactive, thermic Arenic Paleudults*

photo: John A. Kelley

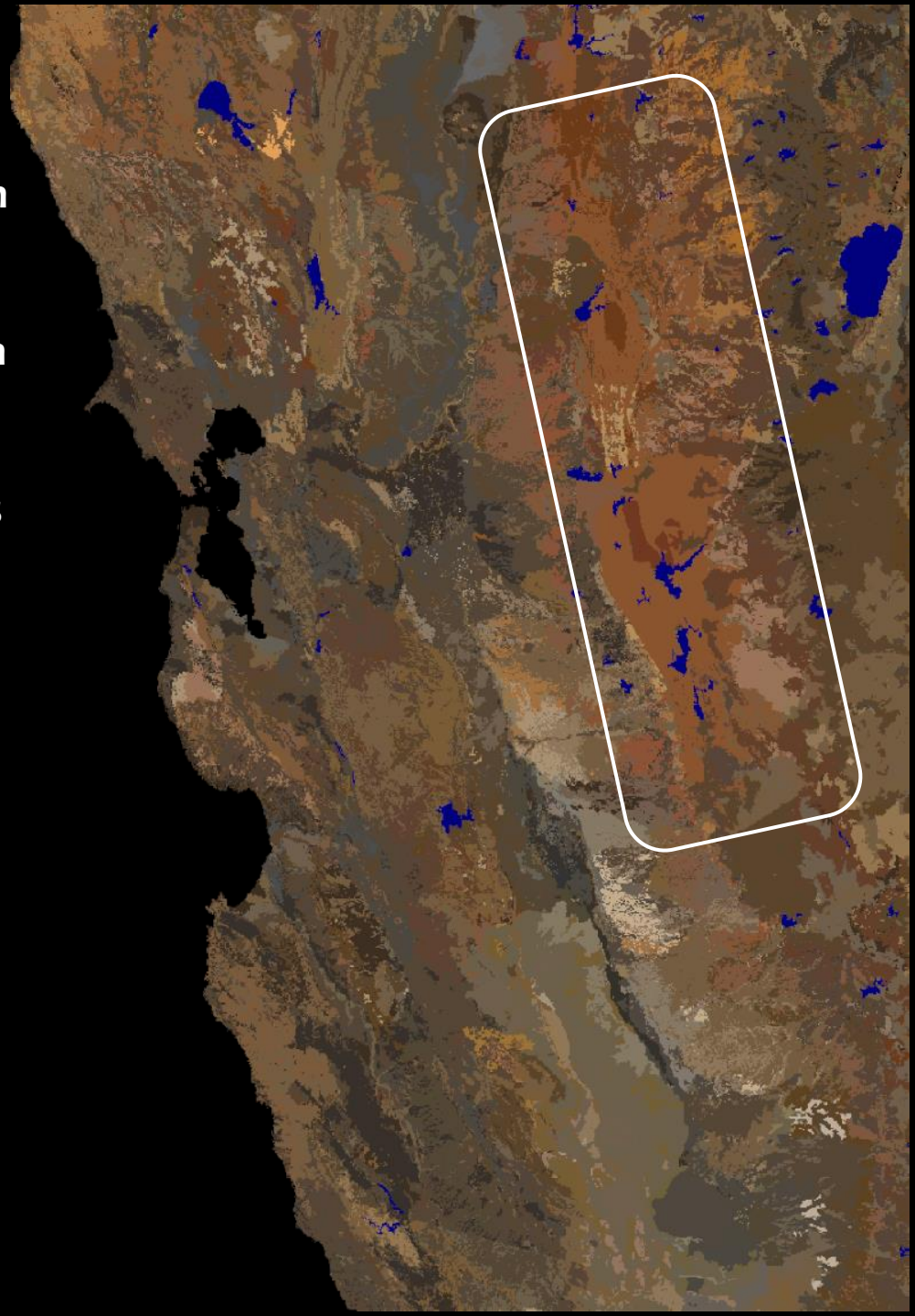
The area encompassed in blue identifies the Inner Piedmont Belt, characterized by highly metamorphosed gneiss and schist that weather to soils with deep red hues

The darker areas in yellow are pocosins. Pocosins are wetlands that occur higher on the landscape in very poorly drained, deep sand and peat soils.



The green line represents the break between the flat topography of the Coastal Plain (to the east) and rolling terrain of the Piedmont (to the west), referred to as the fall line. Many cities including Raleigh, NC, Columbia, SC, and Richmond, VA are founded here as the gradient of rivers became difficult for early settlers to overcome at this point. The Coastal Plain is dominated by soils with sandy surfaces and developed in marine sediments with high water tables. A high water table creates anerobic conditions resulting in soils with dull gray and yellow colors. Conversely, soils of the piedmont developed from bedrock, evident in the vibrant red and orange colors of the clay and silt rich material.

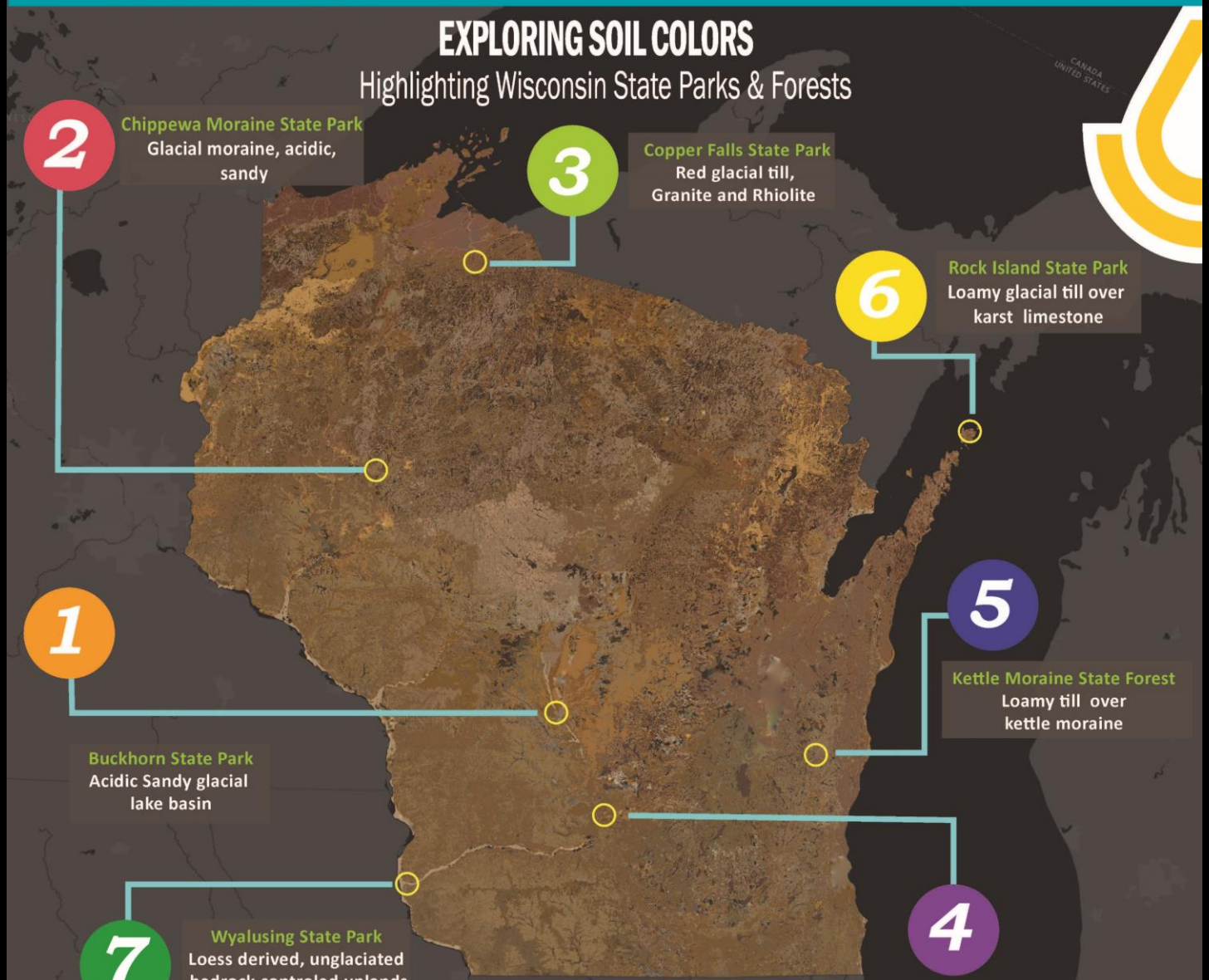
One spatially consistent pattern of soils in California is the red soil zone. This area extends in north-south direction across most of the Sierra Nevada Foothill Region and into the lower elevations (< 1500 m) of the Sierra. These red soils have large amounts of secondary iron oxides such as hematite. In the foothills these intensely weathered soils are derived from iron rich parent rocks such as basalt, greenstone, gabbro, serpentinite, and mafic phases of granitic rocks. In the low elevations of the Sierra Nevada (just below the rain-snow transition) intense weathering due to favorable climatic conditions is believed to be the main factor causing the expression of this soil color.



USDA
United States Department of Agriculture

EXPLORING SOIL COLORS

Highlighting Wisconsin State Parks & Forests



NCSS National Cooperative Soil Survey

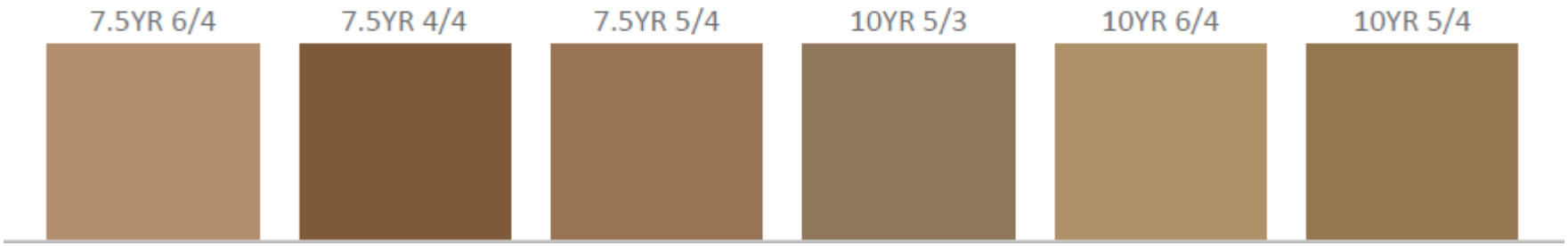
Rock Island State Park and Soil Colors

By Jason Nemecek, Soil Scientist USDA-NRCS State Office

The geologic origin of the majority of Rock Island State Park is the Liberty Grove Member of the Holy Hill Formation. This formation consists of material (glacial till) deposited by ice of the Green Bay Lobe. The soils in the park formed from glacial deposits during the Late Wisconsin Glaciation. Much of the landscape is an undulating, bedrock-controlled, glacial till plain. It has "karst" topography; that is, the underlying Silurian dolomite bedrock has been eroded by surface water or groundwater, resulting in ridges, sinkholes, and other characteristic landforms.

The soils in the area formed in brown to reddish-brown, calcareous, sandy loam to clay till. They have surface textures that include loam and silt loam. These soils are generally moderately well drained, but they range from well drained to somewhat poorly drained. They typically have a perched water table. They have moderate to slow permeability and moderate to high available water capacity.

Along the shoreline of the island, landforms were caused by deposition. The landforms include beaches, beach ridges, terraces, fans, dunes, and swamps. The soils in these areas are sandy or silty, are excessively drained to poorly drained, and typically have a water table. They have rapid to slow permeability and low to very high available water capacity. Wetlands are scattered throughout the island. The soils of the wetlands are very poorly drained or poorly drained and formed in non-acidic muck, loamy till, or sandy to silty lake deposits. The plant community on the island includes northern hardwood forest; northern wet-to-moderately-moist forest; forested seeps; and shaded cliff communities. The interior plateau of Rock Island contains a mature, moderately moist hardwood forest dominated by beech and sugar maple. Canopy associates include basswood and red oak.



Selection and spatial analysis of USDA-NRCS soil survey map units by soil color for forensic investigations

Christine E. Dong[1,3], Libby A. Stern[1], Dylan E. Beaudette[2,4], Charles Ferguson[2,4], Jason Nemecek[2,5]

FBI Laboratory[1], USDA Natural Resource Conservation Service[2],
ORISE Visiting Scientist Program[3], National Soil Survey Center[4], Wisconsin State Office[5]

NCSS National Cooperative Soil Survey

1. Role of color in forensic soil exams

Color in forensic soil examinations is one of *many* properties used for:

- *Comparison* of trace soils from items of evidence to soil at a crime scene or alibi location to potentially exclude a location as the soil's source.
- Constraint of the soil *provenance* (origin).

Such items of evidence include:

- Shovels
- Shoes
- Garments
- Vehicles

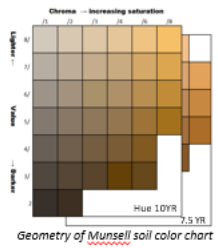
2. Soil Color in Soil Survey Data

Soil color is recorded during field soil characterization by the National Soil Survey (NASIS, not publically available) and thus Soil Survey Maps might provide context to spatial extent of similar soils in a forensic investigation. *Field-determined* Munsell soil colors are reported by horizon under *moist* and/or *dry* conditions.

Munsell Colors are determined by matching to *discrete* color chips organized by Hue, Value (lightness) and Chroma (saturation).

(H V/C or 10YR 4/3)

The Soil Survey data are organized by "**Soil Series**" or groups of soils with similar characteristic properties and the *typical* horizon-level properties of each soil series, including soil color, are described in "Official Soil Series Descriptions" or **OSDs**.



Geometry of Munsell soil color chart

SSURGO is the digitized (GIS-enabled) soil survey map in which **Map Units** consist of one or more components; unusually components are soil series, but currently soil color data are not available in SSURGO

3. Objectives

Enable (forensic) scientists with basic GIS skills to create soil color maps which are queryable by Munsell soil color parameters and soil depth based on the available digitized soil survey maps (SSURGO).

- Describe analysis/selection based on color of the "dominant" component and "any" components in SSURGO map units

4. Software, Data, and Tools Used

Software:

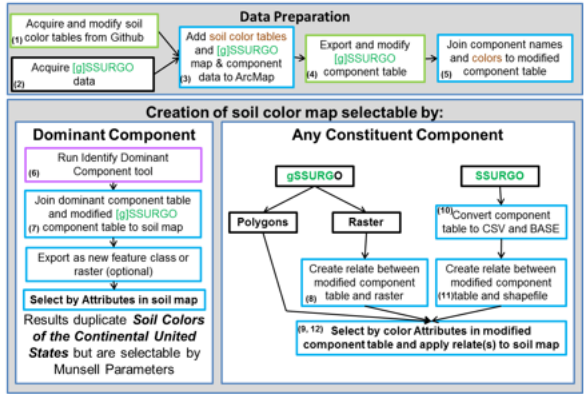
- ArcMap 10.x (Esri's ArcGIS)
- Microsoft Excel or equivalent program
- Soil Data Development Toolbox for ArcGIS™ (freeware)

Data:

- Most up-to-date soil survey data for area of interest (gSSURGO or SSURGO, available from the USDA Geospatial Data Gateway or Web Soil Survey)
- Most up-to-date tables of soil series colors parsed from OSDs for each depth of interest (5, 10, 15, 25, 50, 75, 100, and 125 cm) available online from Github : (https://github.com/ncss-tech/soil-color-book/tree/master/data) example The *osd_colors-xxcm.csv*

5. Workflow

Schematic steps required to enable queryable maps based on color from soil survey GIS data. ([g]SSURGO)

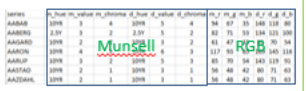


in Excel

In ArcGIS

with Soil Development toolkit

(1) osd_colors-xxcm.csv
m_=moist, d_=dry from:
https://github.com/ncss-tech/soil-color-book/tree/master/data

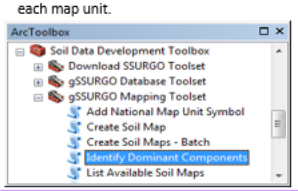


These typical colors of each soil series are derived from the **Official Soil Series Descriptions**. This works was carried out by Beaudette, Ferguson and Nemecek using *Parse OSD* scripts, https://github.com/dylanbeaudette/parse-osd

(4) Export Component table and convert CompName to all upper case.

(5) Join new table to Component table and osd_colors table.

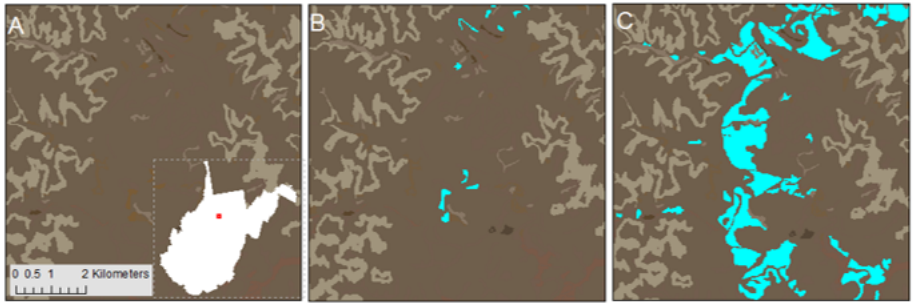
(6) Identify the dominant soil series within each map unit.



6. Example Use

A user can select map units with a specified *Munsell color, Munsell parameter* (just hue for example) or *range of colors*.

SSURGO map units for a portion of West Virginia (A), are selected for having a *typical* moist soil color of 10YR 4/4 at 5 cm depth blue in (B) by a query of the dominant component. (C) shows the same query for ANY constituent component within the map units.



7. Forensic Applications

- **Non-native soils** recovered as forensic evidence often have colors notably distinct from the native soils at the crime scene and within the surrounding regions.
  - Maps of soil color can substantiate the rareness of such soils in the area of interest. (Real world example is soil from a baseball field as evidence)
- **Geographic extent of soil of specific color** could help a forensic examiner explain to jurists that while soil on an item of evidence shares similar properties with soil from a crime scene (color, mineralogy, texture) it is likely that soils with similar characteristics might be found over a wider area.
- **Provenance estimations** aim to provide an investigative lead regarding the more likely source areas of trace soil. These investigations rely on comparisons to reference data. Queryable soil color spatial data will enable soil color to by used for probabilistic geographic attribution modelling of forensic soils, along with other case-pertinent information..
  - Could be applied for sourcing of pigments in archaeological investigations.

8. Limitations

1. To compare laboratory acquired soil color data with field data, lighting and soil moisture conditions should aim to match. Use D65 illumination.
2. Soil surveys are interpretations and interpolations with commensurate uncertainties in soil properties and location.
3. The map units in the NRCS Soil Surveys often consist of more than one soil series, and soil series components in the same map unit may differ in color at a specified depth.
4. The colors parsed from the OSDs are the "typical" colors of the soil horizons for the soil series, not the full range of expected colors for that series at the specified depth.
5. Series that did not have both wet and dry typical colors listed in their OSDs required calculation of the Munsell color for the missing moisture condition using a supervised classification algorithm (soil moisture decreases value by as much as 2.0 units and increases hue by as much as 0.3).
6. The downloadable CSV files are provided for specified discrete depths, which may or may not be appropriate for all specific applications.

There are non-trivial uncertainties associated with the creation and use of soil color maps, but provided the users of these maps understand the nature of these uncertainties, this approach might have utility in forensic soil reports or other applications.

References

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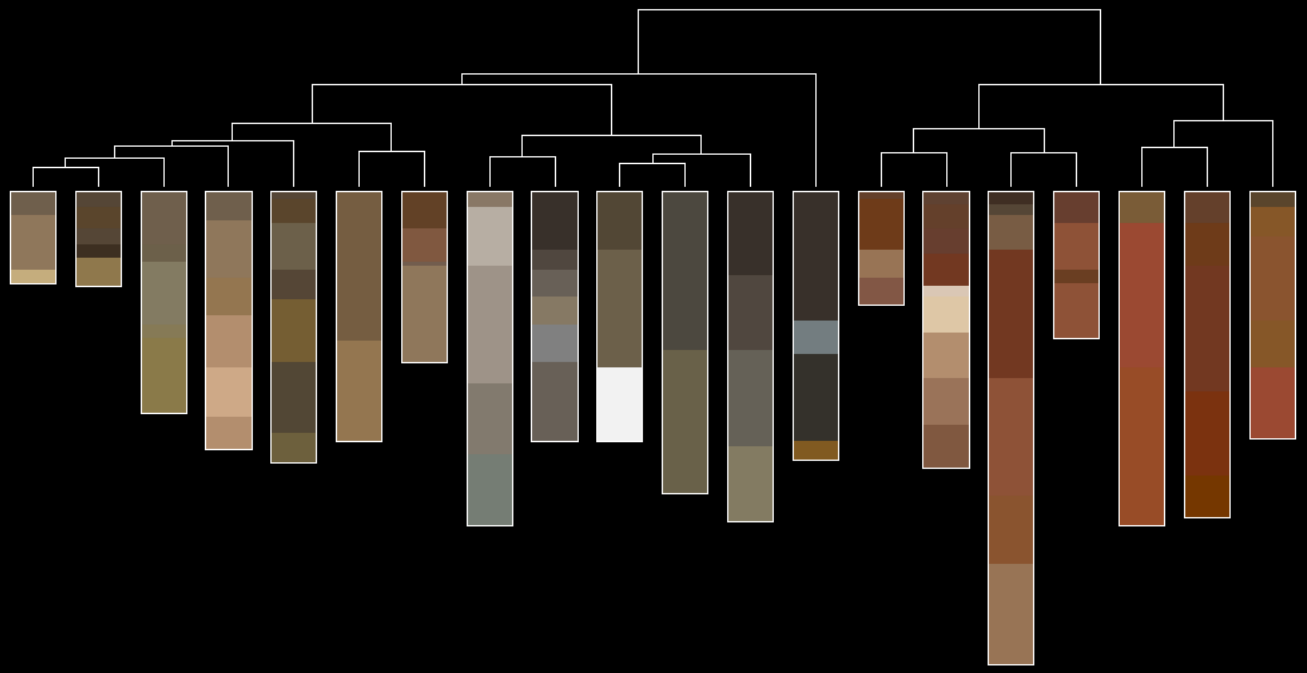
- Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for the Conterminous United States. USDA NRCS. Available online at https://gdg.sc.egov.usda.gov/
- Beaudette, D. (2018), Parse OSD, https://github.com/dylanbeaudette/parse-osd
- National Cooperative Soil Survey (2018) Soil Color Book, https://github.com/ncss-tech/soil-color-book/tree/master/data
- *Soil Data Development Toolbox for ArcGIS™* https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd362254&ext=zip
- Beaudette, D., C. Ferguson, J.Nemecek and Soil Survey Staff "Soil Colors of the Continental United States" https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcseprd1423827 https://nrcs.app.box.com/v/soils/folder/53525984812

Disclaimers/Acknowledgements

The opinions expressed here are those of the authors and not necessarily those of the FBI Laboratory or the USDA-NRCS. Names of commercial products are provided for identification only and inclusion does not imply endorsement by the FBI Laboratory or the USDA-NRCS. Christine Dong participated in this research through the FBI Laboratory Visiting Scientist Program administered by the Oak Ridge Institute for Science and Education.

Coming Soon

- Version 2.0: component-specific colors (linked pedons)
- HI, AK, US territories
- Soil Color database:
  - OSD colors
  - Curated pedon data, by soil series
  - Quantitative RIC via CIE LAB coordinates
- Color-based queries and similarity



Thank You

Soil Colors of the Continental United States
https://goo.gl/kpL8LV

Exploring Soil Colors (WI State Parks)
https://goo.gl/1hBMux

AQP Website
http://ncss-tech.github.io/AQP/

Soil Color in R (KSSL + morphologic data)
https://goo.gl/uWQBah

Help Test SoilWeb for Android Devices

https://goo.gl/WvrV8Y