

Soil Maps of the United States of America

Eric C. Brevik*

Dep. of Natural Sciences and Agric.
and Technical Studies
Dickinson State Univ.
Dickinson, ND 58601

Alfred E. Hartemink

Univ. of Wisconsin-Madison
Dep. of Soil Science
FD Hole Soils Lab.
1525 Observatory Dr.,
Madison, WI 53706

National soil maps provide an important archive depicting soil science theory and ideas behind the application of soils information at the time the maps were created. A look at soil maps of the USA produced since the beginning of the twentieth century shows a move from a geologic-based concept of soils to a pedologic concept of soils. These maps also show changes from property-based systems to process-based, and then back to property-based, and ideas on diagnostic mapping of soil properties changed over time. The national soil mapping program in the USA was established in 1899. The earliest nation-wide soil map was published by M. Whitney in 1909 consisting of soil provinces that were largely based on geology. In 1912 G.N. Coffey published the first country-wide map based on soil properties; the map showed 22 soil units belonging to 5 divisions based on parent material, color, and drainage. The next national map was produced by C.F. Marbut, H.H. Bennett, J.E. Lapham, and M.H. Lapham in 1913 and showed 13 broad physiographic units that were further subdivided into soil series, soil classes and soil types. In 1935 Marbut drafted a series of maps based on soil properties, but these maps were replaced as official U.S. soil maps in 1938 with the work of M. Baldwin, C.E. Kellogg, and J. Thorp. Modern soil maps appeared in the 1960s with the seventh Approximation and followed with the 1975 and 1999 editions of Agriculture Handbook number 436, Soil Taxonomy.

Soil maps have been generated in the United States since as early as 1820 (McCracken and Helms, 1994). The individuals who mapped soils at this time were often geologists (Helms, 2002; Brevik, 2009, 2010), thus these early maps were essentially surficial geology maps (Beaumont, 1931; Aldrich, 1979; Brevik and Hartemink, 2010). Thomas Chamberlain in 1882 made the first map in the USA to be based on soil properties, a soil map of Wisconsin (Coffey, 1911; Hartemink et al., 2012). Early maps such as these covered relatively small areas, ranging from county- to state-size. There were no national standards to guide the mapping at this time.

A coordinated effort at national soil mapping began in the USA in 1899 (McCracken and Helms, 1994; Brevik, 1999; Durana and Helms, 2002) and was described by Curtis Marbut as follows: “The idea of Soil Survey, so far as it concerned the soils of the United States, originated with Milton Whitney. So far as it concerned differentiation of soils in any considerable detail...it originated with him for the world...” (Marbut, 1928). The mapping effort was national in the sense that it was standardized and overseen at the national level and included work in multiple parts of the country. The areas mapped in the earliest days of the national soil survey were usually counties or topographic features such as valleys (McCracken and Helms, 1994; Helms, 2002). To keep the mapping effort moving along, soil survey crews typically worked in northern locations during the summer months and southern locations through the winter (Lapham, 1949). This led to many individual soil surveyors gaining experience in a wide range of settings and gaining

Soil Sci. Soc. Am. J.
doi:10.2136/sssaj2012.0390
Received 19 Nov. 2012

*Corresponding author (eric.brevik@dickinsonstate.edu).

© Soil Science Society of America, 5585 Guilford Rd., Madison WI 53711 USA

All rights reserved. No part of this periodical may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Permission for printing and for reprinting the material contained herein has been obtained by the publisher.

exposure to a broad assortment of different soils (Lapham, 1949; Brevik, 1999, 2001,; 2010). It was inevitable that these soil surveyors would start to address the issue of broad soil patterns over the national scale (Marbut, 1928).

This paper investigates the development of national-scale soil mapping in the USA. Soil maps provide a view of our thoughts and understanding regarding soils as well as an understanding of the distribution of some level or levels of the classification systems used at the time of mapping. The properties deemed important in our mapping also demonstrate the importance placed by soil experts on various soil uses (Cline, 1977a; Arnold, 1983; Smith, 1986; Arnold, 1996; Durana and Helms, 2002). In addition to the maps, this paper briefly explores the soil taxonomic system behind each map, as soil mapping and soil classification are mutually dependent activities (McCracken and Helms, 1994); the quality of our soil taxonomic systems are closely related to the quality of our soil mapping and vice versa (Cline, 1977a).

The First National-Level Soil Map of the USA

The first national-level soil map of the USA was published by Milton Whitney in 1909 at a scale of 1:7 million (Fig. 1). This map showed 14 soil provinces based on the underlying geology. The soil map by Marbut et al. (1913) bears a strong resemblance to the map by Whitney (1909), but neither resembles the other USA soil maps that would follow. Marbut would later refer to Whitney's map as a "so-called province map" (Marbut, 1928). Examples of criticism Marbut leveled at Whitney's 1909 map

included (i) the map was based almost entirely on geology, with practically no regard to soil properties, (ii) the soil province approach had a negative influence on the study of soils in the field, as it had soil scientists looking at the bottom of their excavations to identify geologic materials rather than at the top of their excavations where the actual soil was, and (iii) it misdirected U.S. efforts at understanding the soil in general (Marbut, 1928). Simonson (1989) pointed out that the same criticisms Marbut (1928) directed at Whitney's 1909 map applied equally to the effort Marbut himself lead 4 yr later (Marbut et al., 1913).

The classification system presented by Whitney (1909) had three levels: (i) soil provinces, (ii) soil series, and (iii) soil type (Table 1). The soil provinces were based on geology and climate (Whitney, 1909), not on soil properties (Marbut, 1928). Soil series were groups of soils having a common origin and similar physical properties, with the exception of texture. The soil type was the soil series with the inclusion of texture (Whitney, 1909). The Bureau of Soils had mapped about 379,708 km² (146,606 square miles) of land between 1899 and 1908, the time covered under the publication (Whitney, 1909). This represented about 3.4% of the conterminous United States. A total of 260 soil series had been identified (Whitney, 1909).

George Nelson Coffey published the first national soil map for the USA that was based on soil properties (Coffey, 1912) (Fig. 2). The map is dated 1911, which would be when the map itself was printed, but the map appeared in USDA Bureau of Soils Bulletin 85, which was published in 1912. Coffey completed the mapping as part of his doctoral coursework at George

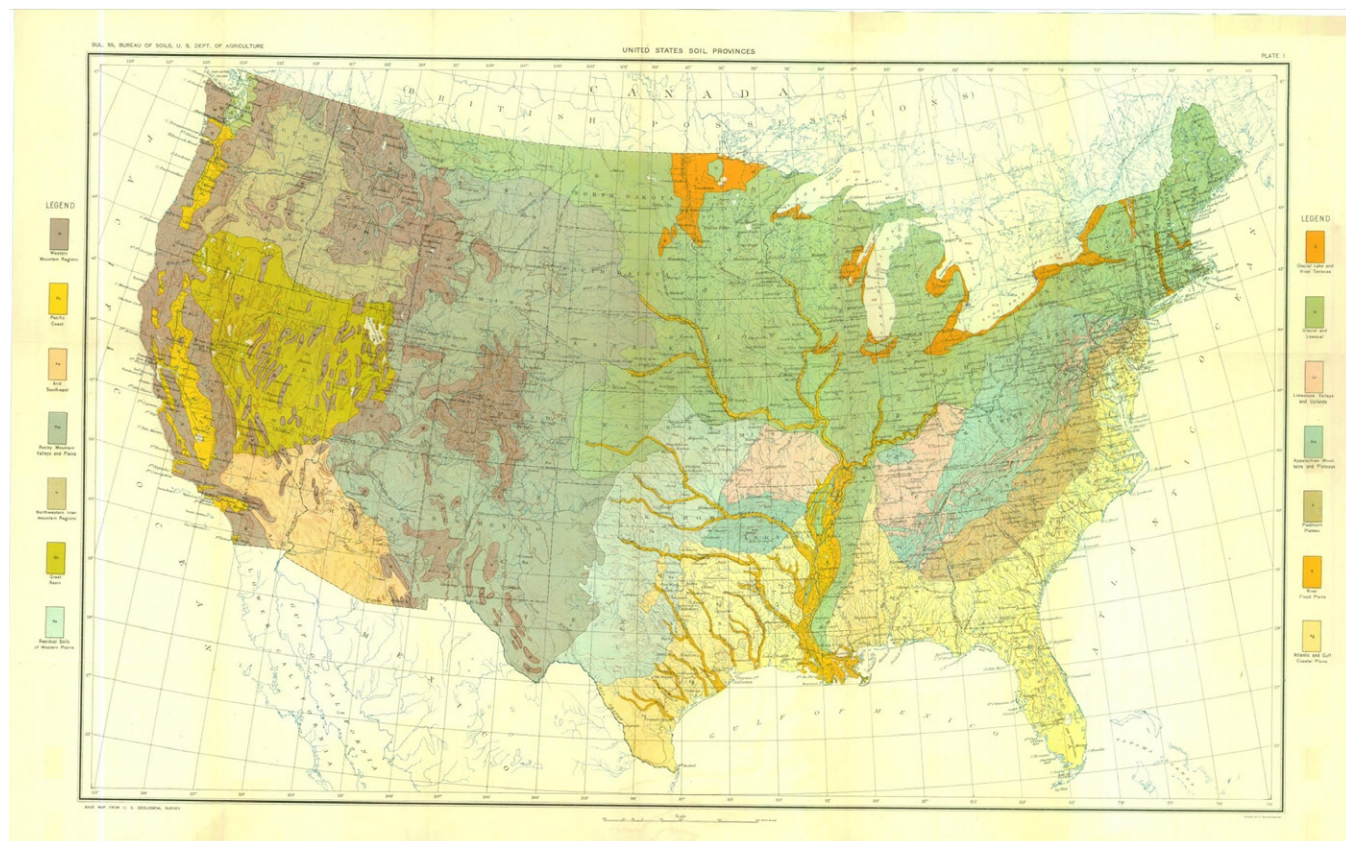


Fig. 1. The soil map from Whitney (1909). This was the first national soil map published for the United States.

Washington University (Brevik, 1999). The map was prepared at 1:7 million scale. Unlike most of the maps that were made at this time, where geology represented the primary determining characteristics, Coffey's map was based primarily on soil properties with geologic attributes having a lower level role in the classification.

Coffey's (1912) soil classification system consisted of three levels: (i) divisions, (ii) subdivisions, and (iii) series (Table 2). There were five divisions based on properties that Coffey deemed to represent significant differences between soils. The subdivisions were based on parent materials, but only for the three mineral-based divisions; there were no established subdivisions for the organic-based soil divisions. The series level was the most specific level of the classification and referred to series already established by the Soil Survey through over a decade of mapping. However, as admitted by Coffey (1912), the series were not well integrated into the overall classification and additional work to figure their proper placement was needed.

Coffey's (1912) map shows his three mineral-based divisions. The organic-based divisions are shown by letters but not colors, as their total area was deemed too small to represent as colored areas on the national map at its scale of 1:7 million. The main spatial patterns on Coffey's (1912) map include light colored "timber soils" roughly east of the Mississippi and along the mountains of the western USA. The dark-colored "prairie soils" extend roughly from the Mississippi River to the western borders of the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. The area west of this was mapped primarily as arid soils, with the previously noted exception of light-colored timber soils in the mountainous regions. Coffey's (1912) map also shows subdivisions and series using a combination of letters. Series were only mapped in places where a single series was deemed to dominate broad portions of the landscape.

The areas mapped by Coffey (1912) as light-colored timber soils roughly correspond to areas mapped as Alfisols and Ultisols today, the dark-colored prairie soils roughly correspond to the area mapped as Mollisols through the central part of the USA, and the arid soils roughly correspond to the areas mapped as Aridisols and Entisols of the American west. Coffey's dark-colored swamp or leached soils high in organic matter and organic or muck and peat soils roughly correspond to modern day Histosols. Areas of these soils were mapped by Coffey (1912) in the Florida Everglades region and the Mississippi Delta of Louisiana, places where extensive Histosols are mapped today. However, Coffey (1912) did not map the organic-rich soils in places like northern Minnesota and the upper peninsula of Michigan that are recognized as Histosols on modern maps.

Table 1. Whitney's (1909) soil classification system.

Soil provinces	Soil series†	Soil type†
Atlantic and Gulf coastal plains	Myatt series	Myatt fine sand Myatt fine sandy loam Myatt clay loam
River flood plains	Congaree series	Congaree fine sandy loam Congaree loam Congaree clay
Piedmont Plateau	Chester series	Chester stony loam Chester fine sandy loam Chester mica loam Chester loam
Appalachian Mountains and plateaus	Fayetteville series	Fayetteville stony loam Fayetteville fine sandy loam Fayetteville loam
Limestone valleys and uplands	Cumberland series	Cumberland gravelly loam Cumberland fine sandy loam Cumberland loam Cumberland clay loam
Glacial and loessial	Williams series	Williams stony loam Williams loam
Glacial lake and river terraces	Williston series	Williston gravelly sandy loam Williston sandy loam
Residual soils of western prairie	Oswego series	Oswego fine sandy loam Oswego silt loam
Great Basin	Elsinore series	Elsinore fine sandy loam Elsinore sand
Northwestern intermountain region	Bridger series	Bridger gravelly loam Bridger loam Bridger clay loam
Rocky Mountain valleys and plains	Laramie series	Laramie gravelly loam Laramie sandy loam
Arid Southwest	Roswell series	Roswell fine sandy loam Roswell loam
Pacific coast	Puget series	Puget fine sandy loam Puget silt loam Puget clay

† Soil series and type entries are too extensive for comprehensive inclusion in this table. Examples are given here to demonstrate how the system worked. Soil series with a small number of soil types have been chosen to keep the table small.

Coffey's (1912) map was not an official map in the sense of being accepted or endorsed by the Bureau of Soils. In his recommendation that Coffey (1912) be published, Milton Whitney, the Chief of the Bureau of Soils, stated:

"I recommend that it be published as Bulletin No. 85 of the series of this bureau. In publishing it, however, the Bureau of Soils does so for the purpose of offering it to the scientific world as a contribution to the subject, without endorsing the scheme of classification proposed and without accepting all the conclusions drawn from the facts cited." (Coffey, 1912)

In short, the Bureau of Soils did not recognize Coffey's work as official Bureau policy as it did not conform to Whitney's ideas regarding soil classification (Brevik, 1999). This was fairly standard procedure for Whitney when his subordinates produced

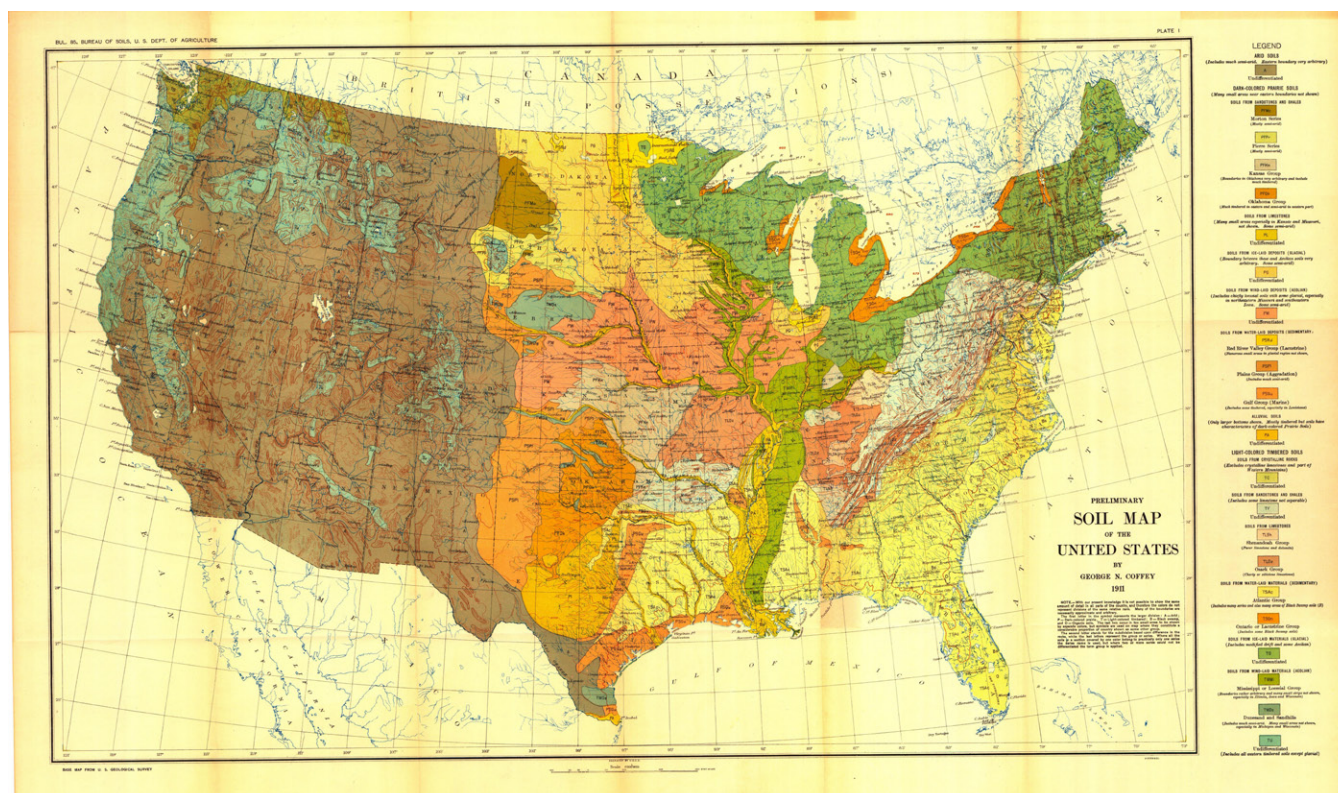


Fig. 2. The U.S. soil map constructed by George N. Coffey in 1911, published in Coffey (1912) and showing his three mineral-based divisions using colors and letters. This was the first national soil map of the United States based on soil properties.

Table 2. Coffey's (1912) classification system.

Divisions	Subdivisions	Series†
Arid or unleached soils, low in humus	soils from crystalline rocks	Not yet established
	soils from sandstones and shales	Not yet established
	soils from limestones	Not yet established
	soils from ice-laid materials	Not yet established
	soils from unconsolidated water-laid material	Not yet established
	soils from aeolian material	Not yet established
	soils from gravity-laid material	Not yet established
Dark-colored Prairie or semileached soils rich in humus	alluvial soils	Not yet established
	soils from crystalline rocks	Not yet established
	soils from sandstones and shales	Morton series
	soils from limestones	Undifferentiated
	soils from ice-laid materials	Undifferentiated
	soils from unconsolidated water-laid material	Red River Valley group
	soils from aeolian material	Undifferentiated
Light-colored Timbered or leached soils low in humus	soils from gravity-laid material	Not yet established
	alluvial soils	Undifferentiated
	soils from crystalline rocks	Undifferentiated
	soils from sandstones and shales	Undifferentiated
	soils from limestones	Ozark group
	soils from ice-laid materials	Undifferentiated
	soils from unconsolidated water-laid material	Atlantic group
Dark-colored Swamp or leached soils high in organic matter	soils from aeolian material	Mississippi group
	soils from gravity-laid material	Not yet established
Organic or muck and peat soils	alluvial soils	Not yet established
		Not yet established

† Series entries are too extensive for comprehensive inclusion on this table. Examples are shown when established to demonstrate their level of standing in the classification system. Coffey had not yet incorporated all established soil series into his system. The exact meaning of "undifferentiated" was not given by Coffey.

work that did not conform to Whitney's ideas, which were the "official" ideas of the Bureau (Simonson, 1986a; Helms, 2002).

The Geological and Pedalfers/Pedocals Period

The next official national soil map of the USA was published at a scale of 1:7 million with Bureau of Soils Bulletin 96 (Marbut et al., 1913) (Fig. 3). This map had 13 units shown on it, as opposed to the 14 units displayed on the Whitney (1909) map, but the two maps were otherwise very similar and bear little resemblance to modern soil maps based on soil taxonomy or to the maps completed by Coffey (1912) or Baldwin et al. (1938). Some researchers have viewed Bulletin 96 as a probable response by the Bureau of Soils to lay out the official Bureau views on soil classification and mapping following Coffey's publication the year before (Simonson, 1989; Brevik, 1999). As with the Whitney (1909) map, the Marbut et al. (1913) map and the classification system it was based on had a strong geologic base, as the subdivisions on the map and the broadest category of classification were based on physiographic provinces rather than soil properties (Fig. 3, Table 3). Thus it closely resembles a physiography (i.e., Henry and Mossa, 1995) or geology (i.e., King and Beikman, 1974) map of the USA. Simonson (1989) put the term soil map in quotes (...soil map...) when discussing the 1913 map by Marbut et al., indicating Simonson himself did not view the Marbut et al. offering as an actual soil map. Even though soils and geology can display strong correlations in some cases (i.e., Lindholm, 1993; Lindholm, 1994; Brevik et al.,

1998; Brevik and Fenton, 1999), it is now widely accepted that soils are not completely dependent on the underlying geology. Despite the fact that Coffey's (1912) classification system and map was rejected by the Bureau of Soils in favor of those presented by Marbut et al. (1913), modern soil science theory is more in line with the ideas of Coffey and Coffey's map more closely resembles modern soil maps. This is manifested in the fact that both Coffey's (1912) system and Soil Taxonomy (Soil Survey Staff, 1975, 1999) start their classification systems based on the properties of soils, rather than on geologic regions. It can also be seen in the fact that soil trends mapped by Coffey (1912) have some resemblance to modern soil mapping, unlike the mapping by Marbut et al. (1913).

The classification system presented by Marbut et al. (1913) had four levels: (i) soil provinces/regions, (ii) soil series, (iii) soil class, and (iv) soil type (Table 3). The difference between soil provinces and soil regions was the degree to which they were understood. More research had gone into establishing soil provinces than soil regions, and it was felt that the soil regions would eventually be divided into two or more soil provinces each with additional study (Marbut et al., 1913). Both soil provinces and soil regions were based on geology and physical geography, and not on soil properties, a fact acknowledged by Marbut et al. (1913). Soil series were groups of soils having the same range in surface soil color, the same character of the subsoil, particularly color and structure, broadly the same type of relief and drainage, and common or similar origins. Soil classes included all

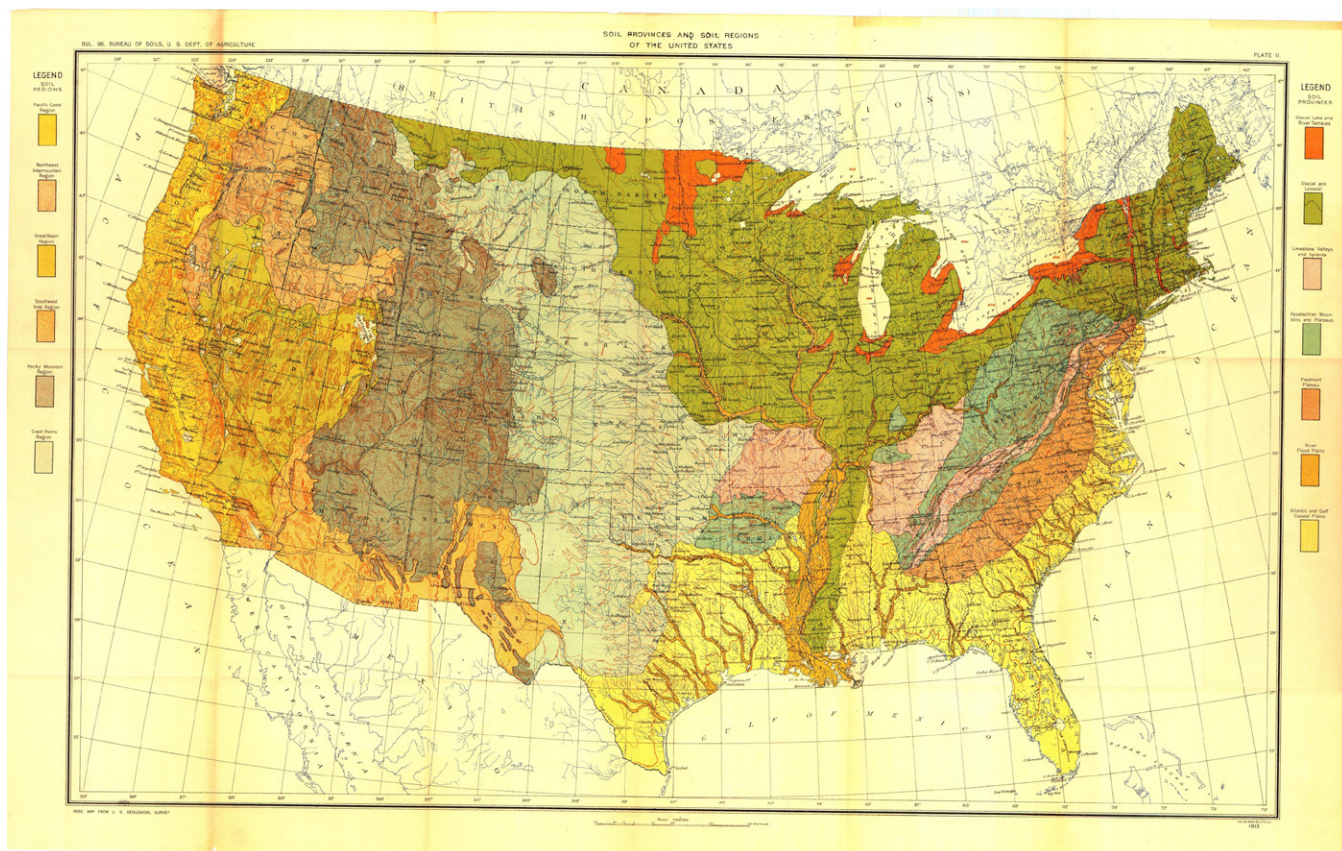


Fig. 3. The soil map from Marbut et al. (1913).

soils that had the same texture and were not limited to a single soil province or region. For example, all the fine sandy loams in Table 3 were part of the same soil class, even though they were found in five different soil provinces or regions. The soil type was the soil individual that included all the features of higher levels of the classification and was limited to a single class, series, and province or region (Marbut et al., 1913). At the time the map and classification system were published the Bureau of Soils had mapped about 1,347,400 km² (520,234 square miles) of land between 1899 and 1912 (Marbut et al., 1913). This represented about 12% of the conterminous USA. A total of 534 soil series had been identified (Marbut et al., 1913).

When Marbut read a publication by the Russian soil scientist K.D. Glinka, his ideas concerning soil classification changed. Marbut started to present his new ideas to the U.S. soil science community with a publication in 1921, followed by additional publications on the topic in 1922 and 1928 (Paton and Humphreys, 2007a). Marbut's seminal work in this area was the 1935 publication "Soils of the United States", which included a comprehensive set of soil maps for the United States presented in a single publication. It marked the first time that an official Bureau of Soils publication on soil classification and soil mapping was done at a national level based first and foremost on the properties of the soil instead of the underlying geology. There were three national soil maps included with three different levels of classification from general to detailed (Fig. 4–6). The first

soil map in Marbut (1935) is a general map showing the locations of Pedalfers and Pedocals (Fig. 4); no map scale was given. This Pedalfers-Pedocals map became a favorite in the U.S. geological community for decades. Although a new official U.S. soil classification was introduced in 1938 by Baldwin et al. that did not use this subdivision at its highest level, many introductory geology textbooks in the USA continued to present the Pedalfers–Pedocals subdivision as envisioned by Marbut in their soils chapters into the 2000s (Brevik, 2002) (Fig. 4). This was followed by a map of soil great groups at a scale of 1:8 million (Fig. 5). The map of soil great groups was considered a soil province map by Marbut, but was wholly different from previous soil province maps in that it was based on soil properties rather than geology (Marbut, 1928), and therefore does not resemble the earlier soil province maps by Whitney (1909) and Marbut et al. (1913). Soil series in the USA were mapped by Marbut (1935) on 12 sheets covering the entire country at a scale of 1:2.5 million (Fig. 6). The soil series distribution map sheets probably represent the most detailed published mapping in the USA at the national level until GIS-based soil maps became widely available through the NRCS in the early 2000s (Soil Survey Staff, 2012). While county soil surveys produced before the early 2000s were more detailed than Marbut's 1938 map, they were assembled at the county level, not at the national level. Furthermore, mapping discrepancies at county borders were not dealt with until the county level maps were entered into national GIS databases,

Table 3. The classification system used by Marbut et al. (1913).

Soil provinces	Soil series†	Soil class	Soil type
Piedmont Plateau	Granville	coarse gravelly loam fine sandy loam gravelly loam	Granville coarse gravelly loam Granville fine sandy loam Granville gravelly loam
Appalachian Mountain and Plateau	Meigs	clay loam	Meigs clay loam
Limestone Valleys and Uplands	Pennington	clay	Pennington clay
Glacial and Loessial	Cossayuna	stony loam fine sandy loam	Cossayuna stony loam Cossayuna fine sandy loam
Glacial Lake and River Terrace	Williston	sandy loam gravelly sandy loam gravelly loam	Williston sandy loam Williston gravelly sandy loam Williston gravelly loam
Atlantic and Gulf Coastal Plains	Tifton	sand sandy loam coarse sandy loam	Tifton sand Tifton sandy loam Tifton coarse sandy loam
River Flood Plains	Rio Grande	silty clay	Rio Grande silty clay
Soil regions			
Great Plains	Killdeer	loam	Killdeer loam
Rocky Mountain Plateau and Plains	Bent	clay	Bent clay
Northwestern Intermountain	Klamath	fine sandy loam loam clay adobe	Klamath fine sandy loam Klamath loam Klamath clay adobe
Great Basin	Redfield	fine sandy loam loam clay loam	Redfield fine sandy loam Redfield loam Redfield clay loam
Arid Southwest	Yuma	sand	Yuma sand
Pacific Coast	Dungeness	fine sandy loam silt loam	Dungeness fine sandy loam Dungeness silt loam

† Soil series entries are too extensive to be listed completely on this table. Examples are given to demonstrate how the system worked. Soil series that did not have very many classes were chosen as examples to reduce the size of the table.

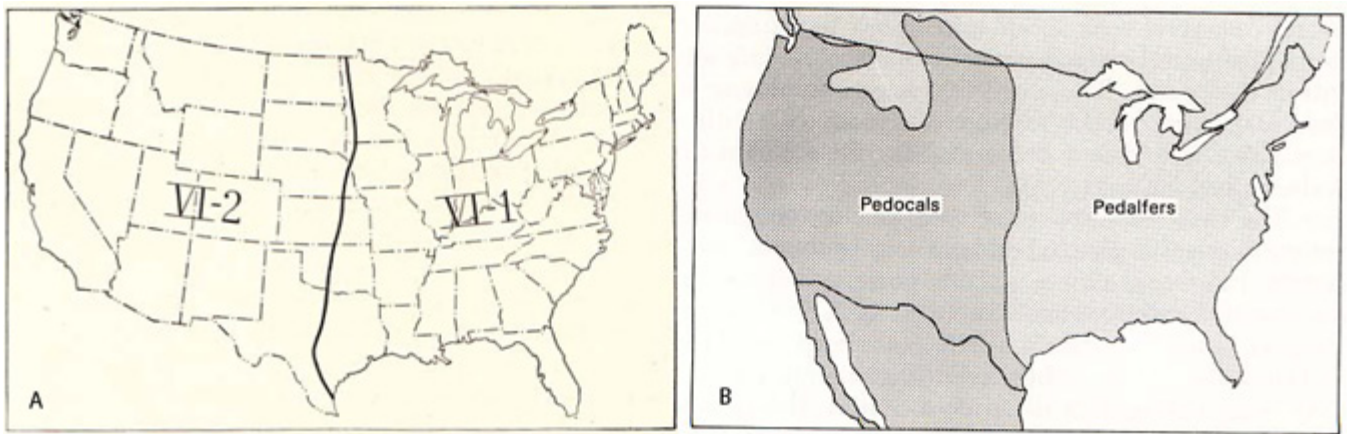


Fig. 4. The broadest category in Marbut's (1935) classification system divided the United States into two regions containing Pedalfers (VI-1) and Pedocals (VI-2). The map on the left is from Marbut (1935), the map on the right is from a late 20th Century geology textbook (Kehew, 1988).

meaning the county level maps in the paper soil surveys did not form a seamless national map. No maps that displayed soils information on a national level beyond general 1:7,500,000 scale maps were made again until GIS-based mapping was introduced, allowing users to display national level soils data at a variety of scales of their choice. In addition to the maps shown in Fig. 4–6, there was also a map that showed which areas of the country had been covered by soil surveys up to January, 1934 and whether the survey was detailed or reconnaissance, and a map showing the distribution of soils without normal profiles.

The classification system was composed of six categories (Tables 4 and 5). The soil series and soil type concepts were preserved from the Marbut et al. (1913) classification but the more general levels of the classification system were revised. At the highest level of the classification there is a two part subdivision based on the presence or absence of carbonates in the soil profile, which Marbut considered the most meaningful subdivision from a pedologic point of view (Marbut, 1935). Categories III–V were determined based on parent materials, color, and presence of salts. The soil series and type concepts

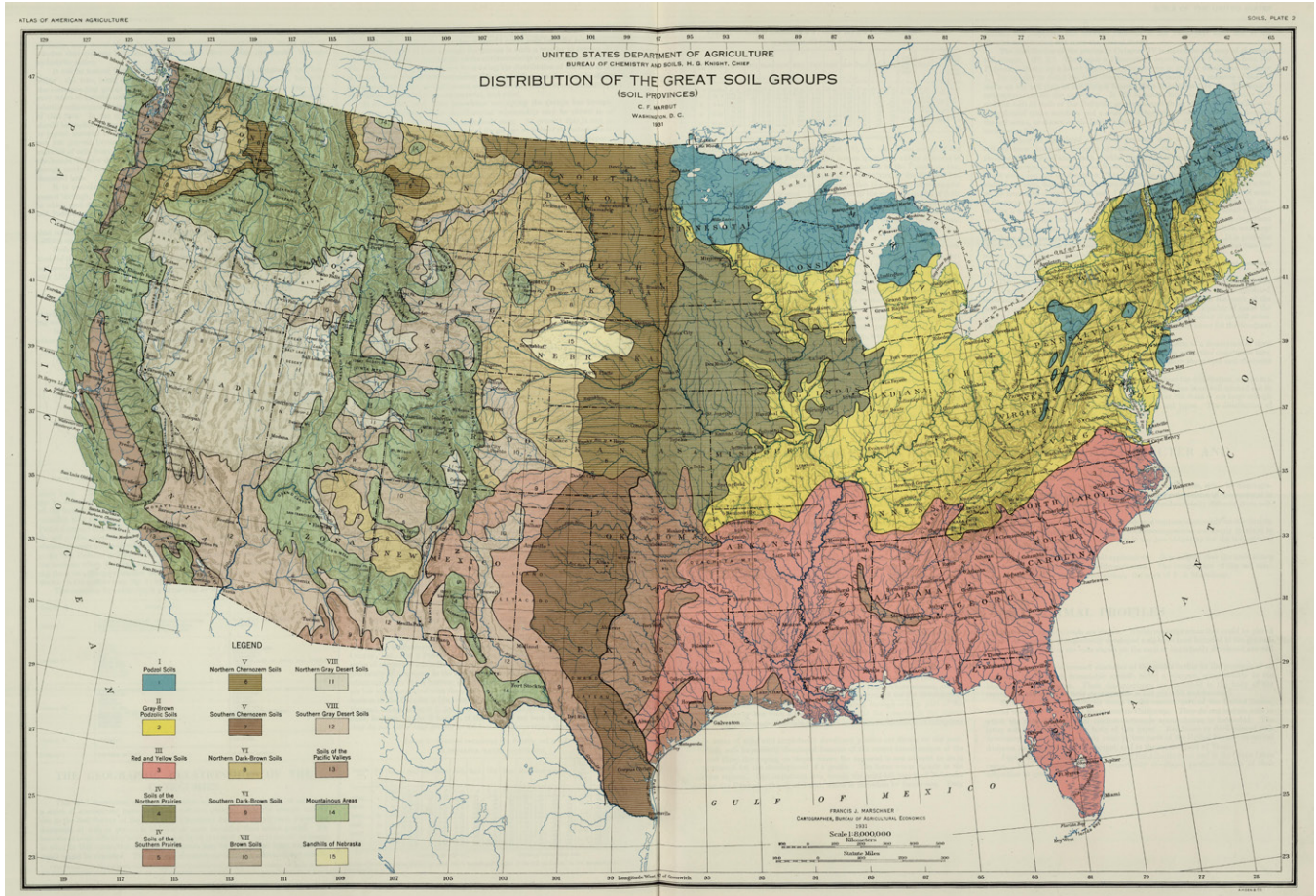


Fig. 5. The map showing the distribution of Great Soil Groups (Category IV level) from Marbut's (1935) soil classification system.

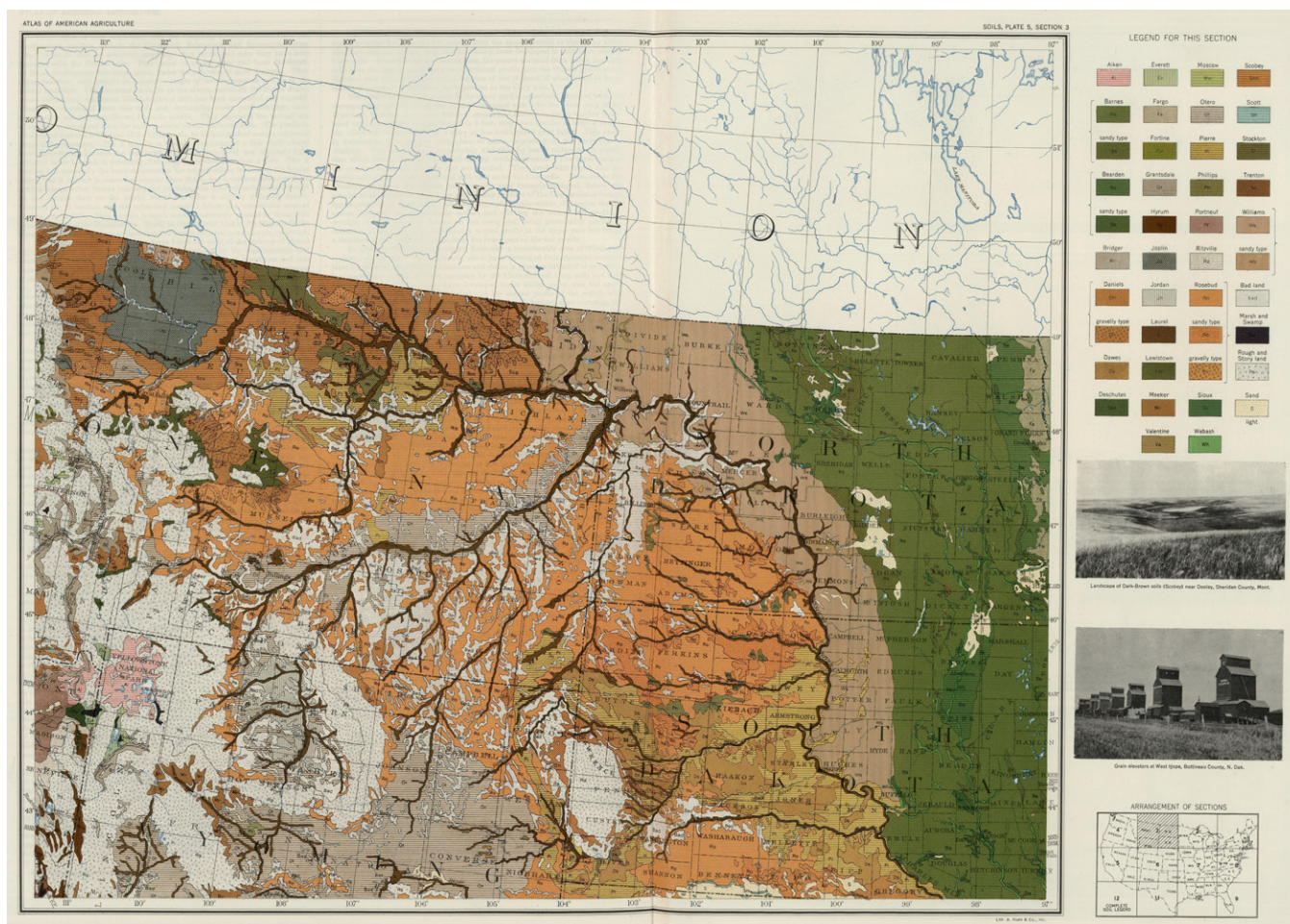


Fig. 6. One of 12 sheets from Marbut (1935) showing soils at the series (Category II) level for the entire conterminous USA. This sheet covers the Northern Plains region of the USA, including all or most of North Dakota, South Dakota, Wyoming, and Montana.

were holdovers from the earliest days of U.S. soil survey, and like Coffey (1912) and Marbut et al. (1913) before, Marbut's 1935 system had a difficult time reconciling all the existing soil series into his great soil groups (Smith, 1986).

Charles Kellogg considered Marbut to be the foremost soils expert in the world at the time of his death, and considered Marbut's 1935 soils atlas to be his most important work

(Kellogg, 1935). There has been some discussion in previous papers concerning whether or not Coffey's work on soil classification influenced Marbut's 1935 classification system (Cline, 1977b; Simonson, 1986b; Arnold, 1999; Brevik, 2001; Paton and Humphreys, 2007a). Simonson (1986b) noted that Marbut opposed Coffey's proposal to set apart the dark-colored soils of the central prairies from the light-colored, leached soils

Table 4. The classification system of Marbut (1935)†.

Category VI	Category V	Category IV	Category III
Pedalfers VI-1	Soils from mechanically comminuted materials	Tundra Podzols Gray-Brown Podzolic soils Red soils Yellow soils Prairie soils Lateritic soils Laterite soils	All Category III soils were subdivided into the following: Groups of mature but related soil series, Swamp soils, Glei soils, Rendzinas, Alluvial soils, Immature soils on slopes, Salty soils, Alkali soils, and Peat soils.
	Soils from siallitic decomposition products Soils from allitic decomposition products		
Pedocals VI-2	Soils from mechanically comminuted materials	Chernozems Dark-Brown soils Brown soils Gray soils Pedocalic soils of Arctic and Tropical regions	All Category III soils were subdivided into the following: Groups of mature but related soil series, Swamp soils, Glei soils, Rendzinas, Alluvial soils, Immature soils on slopes, Salty soils, Alkali soils, and Peat soils.

† Category II (soil series) and category I (soil type) entries are too extensive to show on this table. They formed the most detailed categories in this system.

Table 5. The names for the numbered categories in Marbut's 1935 soil classification system and the information that each level was intended to convey.

Category	Name	Information
VI	Solum Composition Groups	Split soils into two major groups based on the presence or absence of carbonate accumulation in the soil profile.
V	Inorganic Colloid Composition Groups	Broad groups of soils differentiated based on the mineral composition of the parent material, especially the colloids in that parent material.
IV	Broad Environmental Groups (Great Soil Groups)	Groups based on characteristics common to the soils of a large area of the country. These characteristics were determined from the features of well-drained soils developed on relatively flat land surfaces.
III	Local Environmental Groups (Family Groups)	Soils in each group share common pedogenic features developed by local conditions.
II	Soil Series Groups	Defined on the basis of all the characteristics of the soil except the texture of the surface horizon, but including the parent material.
I	Soil Units (or Types)	Subdivisions based on consideration of all soil characteristics including the texture of the surface horizon, designated by the series name and texture description.

of the eastern USA during meetings of the American Society of Agronomy Committee on Soil Classification and Mapping in 1914, but that Marbut later distinguished these two broad groups in his own top category. The areas mapped by Coffey (1912) as dark-colored prairie soils and arid soils closely correspond to the area Marbut (1935) would eventually map as pedocals, while Coffey's light-colored timbered soils closely corresponded to the area Marbut (1935) mapped as pedalfers. Arnold (1999) noted that Marbut was Coffey's supervisor at the Bureau of Soils when Bulletin 85 (Coffey, 1912) was written, and Marbut acknowledged Coffey's paper from 1911 in his soils atlas of the USA (Marbut, 1935). Therefore, Marbut was acquainted with Coffey's ideas, but he makes no reference to Coffey (1912) in his 1935 work or any other works that discuss the classification of soils based on soil properties. This is possibly because Marbut worked under Whitney for many years at the Bureau of Soils and Whitney was known to discourage his employees from pursuing ideas contrary to his own (Simonson, 1989), possibly making Coffey something of an outcast in the Bureau of Soils. It is also possible that Marbut viewed the Russian authors, such as Glinka, whom he did acknowledge in his works, as being a more direct source for the ideas he was seeking to introduce to American soil science.

Zonal Soils, 1938

Mark Baldwin, Charles Kellogg, and James Thorp were charged with developing an official system of soil classification based on soil properties for the 1938 USDA Yearbook of Agriculture (Simonson, 1989). This was done because they recognized there were problems with Marbut's (1935) system that could not be fixed (Smith, 1986). These problems included (i) climate and vegetation were emphasized to the exclusion of other important soil forming factors, (ii) the concept of "mature" and "immature" soils was problematic, in that soils do not follow the same type of life cycle as organisms, and (iii) the Pedalfers/Pedocals subdivision at the highest level of the classification system was problematic (Paton and Humphreys, 2007a).

The Baldwin group was given only 1 yr to put their classification system together (Smith, 1986). They developed a system

with six categories, with the category names being very similar to the modern classification system, Soil Taxonomy (Tables 6 and 7). The influence of the Russian school of soil classification can also be seen in the Baldwin et al. (1938) system, in both the higher level classes chosen (Paton and Humphreys, 2007b) and in the use of Russian terms such as "Chernozems". Baldwin et al. (1938) decided that the Pedalfers/Pedocals subdivision of Marbut (1935) had merit, but only for the soils they termed zonal soils. Therefore, they subdivided their zonal soils order (Category VI) into Pedocals and Pedalfers (Table 6). As with earlier official systems, the soil series and type concepts were preserved in the new system. All categories in the Baldwin et al. (1938) system were based on soil properties (Table 7). However, Baldwin et al. (1938) were very rushed in creating their system due to the pressures imposed on them to meet publication deadlines for the 1938 USDA Yearbook of Agriculture, forcing them to rely on previously done field work and denying them the chance to conduct studies specifically designed to answer questions they had in developing their system (Smith, 1986). The soil map published with Baldwin et al. (1938) displayed associations of series using a combination of letters, numbers, and Roman numerals and great soil groups using color codes at a scale of 1:7,600,000 for the main map, 1:15,200,000 for the Alaska insert, and 1:1,900,000 for the Hawaii, Puerto Rico, and Panama Canal Zone inserts (Fig. 7). This was also the first national soil map of the USA to include Alaska and Hawaii, which were still territories at the time.

In the map by Baldwin et al. (1938) some physiographic regions are visible, such as the Appalachian Mountains in the east and the Basin and Range province in the west, but the map is not a virtual duplicate of a physiography map like the maps by Whitney (1909) and Marbut et al. (1913). This suggests a declining influence of geology on soil classification and mapping from Whitney and Marbut to the next generation of soil survey leaders in men like Baldwin, Kellogg, and Thorp. Baldwin et al. (1938) recognized bog soils that were mapped in areas such as southern Florida and Louisiana where Histosols are mapped today, tundra soils in Alaska that in many respects preceded modern Gelisols, podzolic soils were recognized in many areas mapped as variations of Ultisols on modern maps, and zones of

Table 6. The classification system of Baldwin et al. (1938) †.

Category VI Order		Category V Suborder	Category IV Great soil groups	
Zonal soils	Pedocals	Soils of the cold zone	Tundra soils	
		Light-colored soils of arid regions	Desert soils	
			Red Desert soils	
			Sierozem	
			Brown soils	
			Reddish Brown soils	
	Pedalfers	Dark-colored soils of the semiarid, subhumid, and humid grasslands	Chestnut soils	
			Reddish Chestnut soils	
			Chernozem soils	
			Prairie soils	
			Reddish Prairie soils	
		Soils of the forest-grassland transition	Degraded Chernozem soils	
			Noncalcic Brown or Shantung Brown soils	
			Light-colored podzolized soils of timbered regions	Podzol soils
				Brown Podzolic soils
				Gray-Brown Podzolic soils
Lateritic soils of forested warm-temperate and tropical regions	Yellow Podzolic soils			
	Red Podzolic soils (and Terra Rossa)			
	Yellowish-Brown Lateritic soils			
	Reddish-Brown Lateritic soils			
Intrazonal soils	Halomorphic (saline and alkali soils of imperfectly drained arid regions and littoral deposits)	Solonchak or saline soils		
		Solonetz soils		
		Soloth soils		
	Hydromorphic soils of marshes, swamps, seep areas, and flats	Wiesenböden (Meadow soils)		
		Alpine Meadow soils		
		Bog soils		
		Half Bog soils		
		Planosols		
		Ground-Water Podzol soils		
		Ground-Water Laterite soils		
	Calomorphie	Brown Forest soils (Braunerde)		
		Rendzina soils		
	Azonal soils	Lithosols		
		Alluvial soils		
		Sands (dry)		

† Family, series, and type entries are too extensive to include on this table. They formed the most detailed categories in this system.

prairie soils that covered many areas recognized as Mollisols today. Therefore, there are similarities between the maps created using Baldwin et al.'s (1938) classification and soil taxonomy. This is not surprising given that the central concepts from many

of Baldwin et al.'s (1938) great soil groups became the concepts from which many of the orders and suborders of soil taxonomy were formed (Smith, 1986).

Table 7. The categories in Baldwin et al.'s 1938 soil classification system and the information that each level was intended to convey.

Category	Name	Information
VI	Order	Differentiated based on profile development or lack thereof (azonal) and whether the controlling factors in profile development, if it exists, are local (intrazonal) or broad (zonal).
V	Suborder	The main groupings of great soil groups.
IV	Great soil groups	A group of soils having common internal soil characteristics; includes one or more families of soils. Among the zonal soils each great soil group includes the soils having common internal characteristics developed through the influence of environmental forces of broad geographic significance; among the intrazonal soils each great soil group includes the soils having common internal characteristics developed through the influence of environmental forces of both broad and local significance; among the azonal soils each great soil group includes similar soils that lack developed characteristics owing to the influence of some local condition of parent material or relief.
III	Family	A taxonomic group of soils having similar profiles, composed of one or more distinct soil series.
II	Series	A group of soils having genetic horizons similar as to differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material. A series may include two or more soil types differing from one another in the texture of the surface soils.
I	Type	A group of soils having genetic horizons similar as to differentiating characteristics, including texture and arrangement in the soil profile, and developed from a particular type of parent material.

the modern classification system named Soil Taxonomy (Soil Survey Staff, 1975; 1999). According to Guy D. Smith (1986), Marbut's (1935) classification ideas had little influence on soil taxonomy, while Baldwin et al. (1938) was significantly influential. Smith (1986) makes no mention of George Coffey nor Milton Whitney.

Soil taxonomy was developed through a series of approximations, culminating in the publication of "Soil Classification, A Comprehensive System, seventh Approximation" (Soil Survey Staff, 1960). A modified version of the seventh approximation was adopted as the official classification system of the USDA in 1965 (Simonson, 1989). The seventh approximation was amended several times during the 10 yr following its publication. In 1970, the official title "Soil Taxonomy" was given to the new classification system. It was first published in December 1975 as Agriculture Handbook No. 436 (Soil Survey Staff, 1975). Soil taxonomy was amended 19 times between 1982 and 1998 before publication of the second edition in 1999 (Soil Survey Staff, 1999). At each stage, as the classification system was revised to meet new understanding and thoughts in the field, the small-scale soil maps generated by soil taxonomy were also revised.

The maps produced based on the seventh approximation (Fig. 8) and the first edition of soil taxonomy (Fig. 9) both display the 10 original soil orders. These maps show similar patterns, such as an extensive area of Mollisols through most of the middle portion of the country as well as in eastern Washington and

Oregon, southern Idaho, and running through central Utah into parts of Arizona and New Mexico. The broad swath of Aridisols through the southwestern USA is the same on both maps, as are the areas of Ultisols in the southeast, Alfisols through the Great Lakes states, and the band of Spodosols that runs from New England west into northern Michigan, Wisconsin, and Minnesota. There are some differences between the two maps. For example, an area of Entisols appears around the Salton Sea in southern California on the seventh approximation map that does not appear on the 1975 map. Also, an area of Alfisols that appeared on the seventh approximation map did not appear on the General Soil Map of the United States from the first edition of Soil Taxonomy. There are several small pockets of Histosols mapped along the coast of North Carolina on the seventh approximation map that do not appear on the first edition map. Some of these differences are likely explained by the scale of the mapping. The scale on the seventh approximation map is 1:7.5 million. No ratio scale is given for the first edition map, but it was printed on a 21.5 cm (8.5 in) by 28 cm (11 in) page in a book and therefore would have been at a smaller scale than the seventh approximation map. The bar scale provided with the first edition map indicates an approximate ratio scale of 1:20,780,000.

When the second edition of Soil Taxonomy (Soil Survey Staff, 1999) was published it included a map of the dominant soil orders and suborders of the United States as a pocket insert at a scale of 1:15 million. A more detailed map of the dominate soil



Fig. 8. General soil map of the USA based on the seventh approximation.

orders at a scale of 1:7.5 million was prepared for the online version of Soil Taxonomy (Soil Survey Staff, 1999) (Fig. 10), which is a larger, more detailed scale than the general soil map from the first edition and the same scale as the seventh approximation map. There are more changes between the first and second edition soil taxonomy maps than between the seventh approximation and first edition maps. This is for two primary reasons:

1. Two soil orders (Andisols and Gelisols) were added between 1975 and 1999. This led to the mapping of Andisols in Idaho, Washington, Oregon, California, Alaska, and Hawaii and the mapping of Gelisols in Alaska; and

2. Computer-aided mapping techniques used on the 1999 map make certain features, such as soil changes along major river valleys, within the Basin and Range province of the southwest, or in the ridges and valleys of the Appalachian Mountains much more pronounced and detailed than on the earlier maps. The computer-aided mapping created increased interfingering of map units along boundaries versus the smoother boundaries seen in Fig. 1 through 8.

DISCUSSION AND CONCLUSIONS

Maps represent an intersection between science and art (MacEachren, 1995). The information communicated on a map represents the current state of knowledge in the field, while an artistically pleasing presentation of that information can enhance

its communication. It is possible to lose information if a map is poorly constructed, but a well-designed map can expand knowledge in a field by revealing spatial relationships that were not previously recognized (MacEachren, 1995). In soil survey, there are always minor components that cannot be mapped separately within the delineations that are mapped (Brevik et al., 2003). How these minor components are addressed influences the number of taxonomic units that are developed in the classification system, particularly at the level of the categories that are frequently mapped (Cline, 1977a). In this way, decisions made during soil mapping influence both the information communicated by the maps themselves and which spatial relationships may or may not be recognized as well as what information is communicated by the classification systems (Table 8).

Throughout all the classification changes over time the soil series has been preserved, with every U.S. soil classification system using the soil series at some level within the classification. According to Guy D. Smith (1986), the general concept of the series has undergone very little change between its initial use in the early days of U.S. soil survey and the present, although details behind what constitutes a given series have changed over time as more has been learned about soils and their properties. The number of soil series has also grown considerably as more areas have been mapped and ideas concerning soils have been refined (Fig. 11). When soil taxonomy was developed, there was great re-

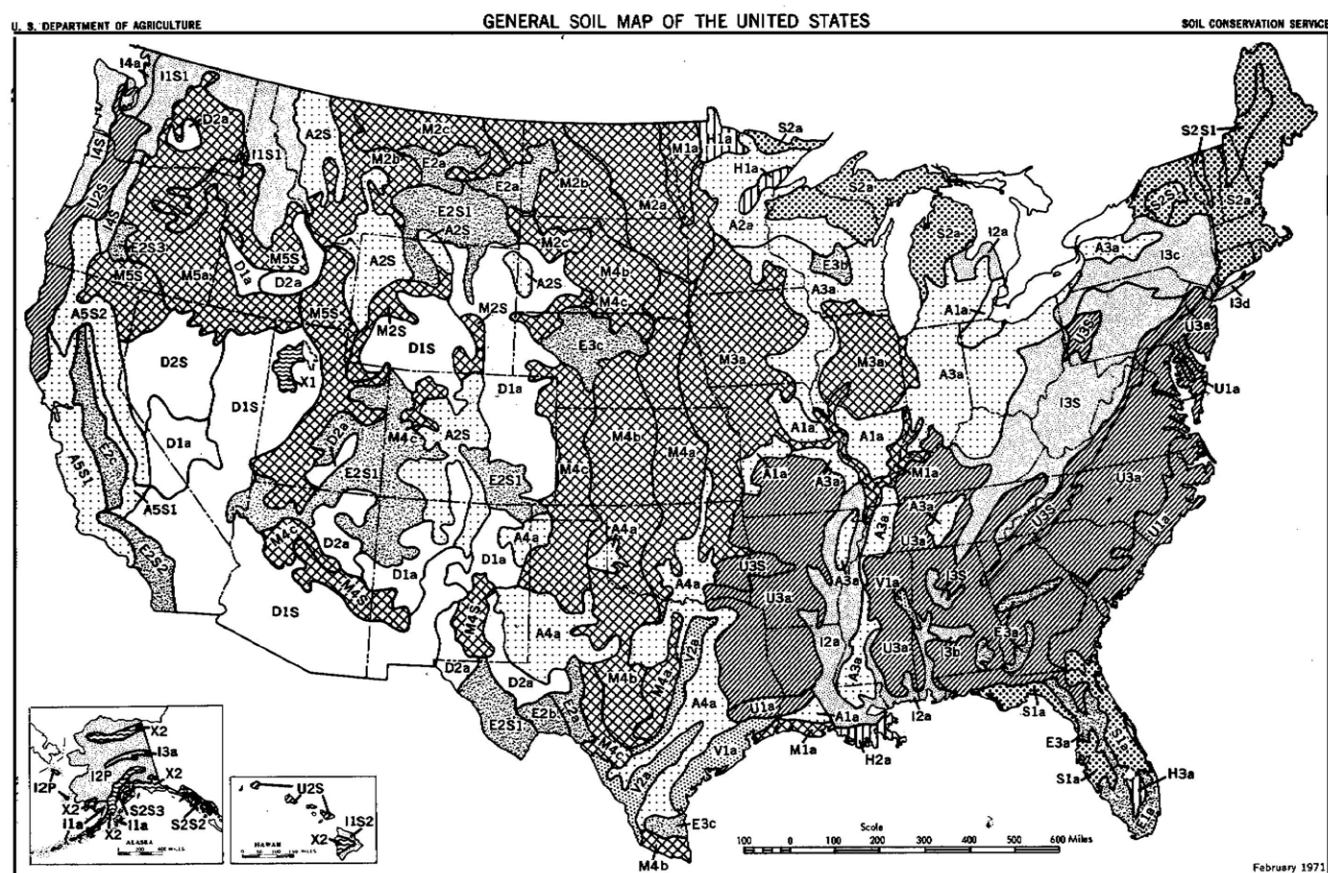


Fig. 9. The soil map of the USA from the first edition of Soil Taxonomy (Soil Survey Staff, 1975). The map contains information to the suborder level. Map symbols that start with an A denote Alfisols, D Aridisols, E Entisols, H Histosols, I Inceptisols, M Mollisols, S Spodosols, U Ultisols, V Vertisols, and X areas with little soil cover (rocks, snow fields and glaciers, etc.).

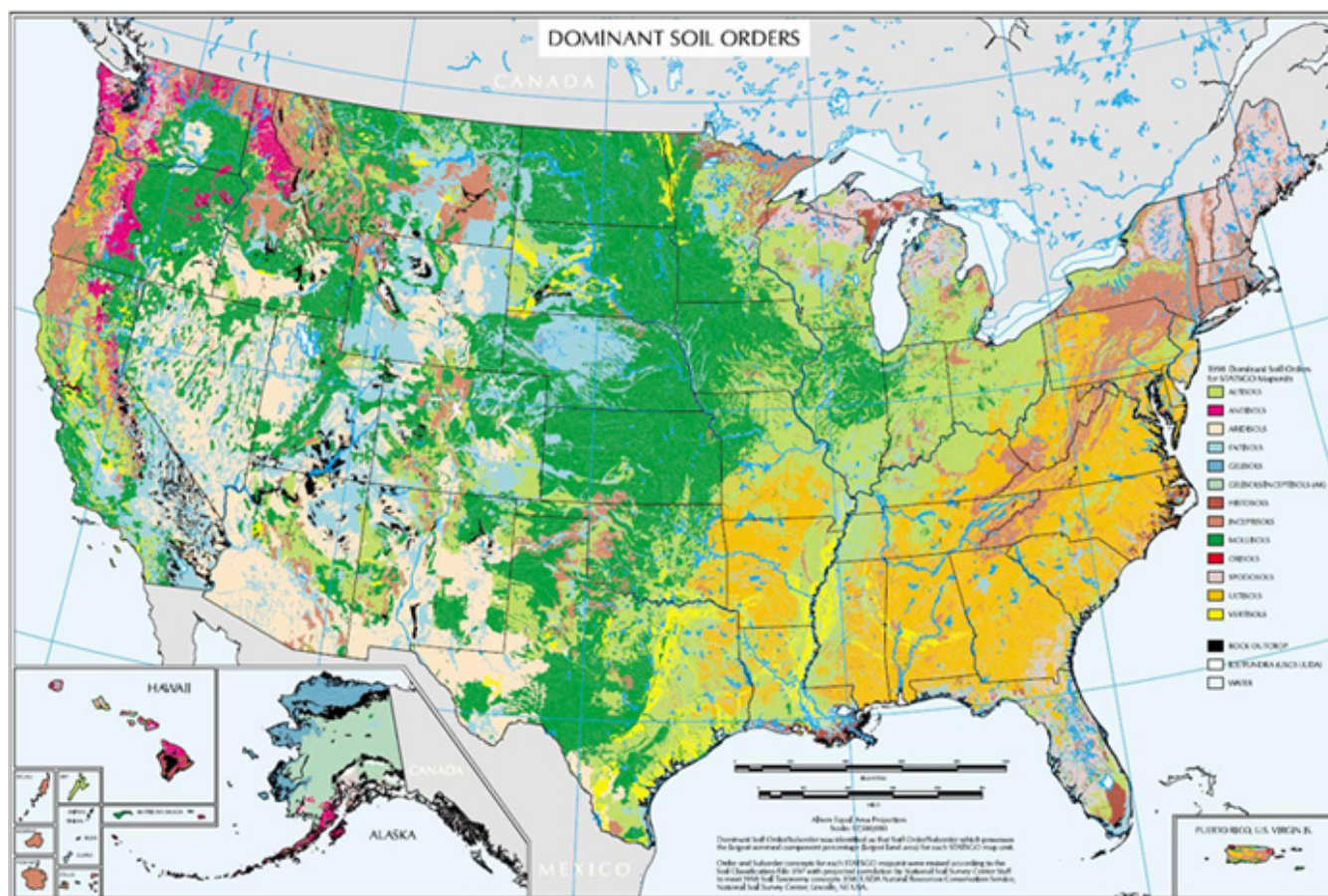


Fig. 10. The dominant soil orders map from the online version of the second edition of Soil Taxonomy (Soil Survey Staff, 1999, map available at ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/maps.pdf). Note the addition of Andisols and Gelisols to the soil orders.

sistance to doing anything that would significantly alter the definitions of the soil series that had already been mapped (Smith, 1986). This resistance was driven by local users such as farmers, tax assessors, and highway engineers who had grown comfortable making local land use interpretations based on the series that had been established in their area (Smith, 1986).

Two main soil classification approaches have been used over the years, systems based on soil morphological properties and systems based on soil-forming processes (Bockheim and Gennadiyev, 2000). The earliest official systems in the USA (Whitney, 1909; Marbut et al., 1913) were based more on geology than on the soil itself, but were considered property-based systems by Bockheim and Gennadiyev (2000). Coffey's

Table 8. A comparison of the main diagnostic properties used to create the primary subdivisions shown on various national soil maps of the USA.

Map	Diagnostic properties
Whitney (1909)	Defined on the basis of physiography, which is a combination of broad regional landform trends and underlying geology.
Coffey (1912)	Soil properties including the degree of leaching, color, and organic matter content.
Marbut et al. (1913)	Defined on the basis of physiography, which is a combination of broad regional landform trends and underlying geology.
Marbut (1935) Category VI map	Based on the presence or absence of carbonate accumulation in the soil profile.
Marbut (1935) Category IV map	Based on characteristics common to the soils of a large area of the country determined from the features of well-drained soils developed on relatively flat land surfaces.
Marbut (1935) Category II map	Defined on the basis of all the characteristics of the soil, including the parent material but excepting the texture of the surface horizon.
Baldwin et al. (1938)	Based on associations of soil series, which were defined as soils that had similar characteristics in their genetic horizons and in the arrangement of the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material.
Soil Survey Staff (1960)	Map subdivisions were based on soil properties that reflect the major controls on soil development (orders), with special emphasis on environmental controls on pedogenesis (suborders).
Soil Survey Staff (1975)	Map subdivisions were based on soil properties that reflect the major controls on soil development (orders), with special emphasis on environmental controls on pedogenesis (suborders).
Soil Survey Staff (1999)	Map subdivisions were based on soil properties that reflect the major controls on soil development (orders).

(1912) system was a combination of property-based and process-based, while the systems of Marbut (1935) and Baldwin et al. (1938) were process-based (Bockheim and Gennadiyev, 2000). Soil taxonomy (Soil Survey Staff, 1960, 1975, 1999) moved back to a property-based system. It is important to understand these shifts in the ideas behind the maps, as they influence the maps created. Discussion of the advantages and disadvantages of the process-based versus property-based systems can be found in Arnold (1983), Smith (1983), and Bockheim and Gennadiyev (2000).

National soil maps provide an important archive depicting soil science theory and ideas behind the application of soils information at the time the maps were created. A look at available soil maps of the United States produced since the beginning of the twentieth century shows a move from a geologic-based concept of soils to a pedologic concept of soils. These maps also show changes from property-based systems to process-based, and then back to property-based. Ideas on diagnostic mapping of soil properties changed over time. It is important to understand the history behind our soil mapping and classification efforts as we move into an age that applies remotely sensed data and computer-aided mapping techniques to our soil survey efforts.

REFERENCES

- Aldrich, M.L. 1979. American state geological surveys, 1820–1845. In: C.J. Schneer, editor, *Two hundred years of geology in America*. Univ. Press of New England, Hanover NH. p. 133–143.
- Arnold, R.W. 1983. Concepts of soils and pedology. In: L.P. Wilding et al., editors, *Pedogenesis and soil taxonomy. I. Concepts and interactions*. Elsevier Science Publishers B.V., Amsterdam, The Netherlands. p. 1–21.
- Arnold, R.W. 1996. Soil survey reliability: Minimizing the consumer's risk. In: W.D. Nettleton, editor, *Data reliability and risk assessment in soil interpretations*. SSSA Spec. Publ. No. 47. SSSA, Madison WI. p. 13–20.
- Arnold, R.W. 1999. Our first centennial, 100 years of soil survey in the USA. *Bull. Int. Union Soil Sci.* 95:40–43.
- Baldwin, M., C.E. Kellogg, and J. Thorp. 1938. Soil classification. In: B.W. Allin, et al., editors, *Soils and men: Yearbook of agriculture 1938*. USDA. U.S. Gov. Print. Office, Washington DC. p. 979–1001.
- Beaumont, A.B. 1931. The oldest soil map? *Agron. J.* 23(3):241–242. doi:10.2134/agronj1931.00021962002300030011x
- Bockheim, J.G., and A.N. Gennadiyev. 2000. The role of soil-forming processes in the definition of taxa in Soil Taxonomy and the World Soil Reference Base. *Geoderma* 95:53–72. doi:10.1016/S0016-7061(99)00083-X
- Brevik, E.C. 1999. George Nelson Coffey: Early American pedologist. *Soil Sci. Soc. Am. J.* 63:1485–1493. doi:10.2136/sssaj1999.6361485x
- Brevik, E.C. 2001. George Nelson Coffey, early soil surveyor. *Soil Surv. Horiz.* 42:122–126.
- Brevik, E.C. 2002. Problems and suggestions related to soil classification as presented in introduction to physical geology textbooks. *J. Geosci. Ed.* 50:539–543.
- Brevik, E.C. 2009. The teaching of soil science in geology, geography, environmental science, and agricultural programs. *Soil Surv. Horiz.* 50:120–123.
- Brevik, E.C. 2010. Collier Cobb and Allen D. Hole: Geologic mentors to early soil scientists. *Phys. Chem. Earth* 35:887–894. doi:10.1016/j.pce.2010.05.006
- Brevik, E.C., and T.E. Fenton. 1999. Improved mapping of the Lake Agassiz Herman strandline by integrating geological and soil maps. *J. Paleolimnol.* 22(3):253–257. doi:10.1023/A:1008050510681
- Brevik, E.C., and A.E. Hartemink. 2010. Early soil knowledge and the birth and development of soil science. *Catena* 83:23–33. doi:10.1016/j.catena.2010.06.011
- Brevik, E.C., T.E. Fenton, and D.B. Jaynes. 2003. Evaluation of the accuracy of a Central Iowa soil survey and implications for precision soil management. *Precis. Agric.* 4:323–334.
- Brevik, E.C., T.E. Fenton, and J.R. Reid. 1998. Soil maps as a tool in mapping poorly preserved landforms: A case study in Grand Forks County, North Dakota. *Soil Surv. Horiz.* 39(3):61–67.
- Cline, M.G. 1977a. The soils we classify and the soils we map. New York Soil Survey conference, Bergamo East. USDA-SCS, U.S. Gov. Print Office, Washington, DC. p. 5–19.
- Cline, M.G. 1977b. Historical highlights in soil genesis, morphology, and classification. *Soil Sci. Soc. Am. J.* 41:250–254. doi:10.2136/sssaj1977.03615995004100020018x
- Coffey, G.N. 1911. The development of soil survey work in the United States with a brief reference to foreign countries. *Proc. Am. Soc. Agron.* 3:115–129. doi:10.2134/agronj1911.00021962000300010017x
- Coffey, G.N. 1912. A study of the soils of the United States. USDA Bureau of Soils Bull. 85. U.S. Gov. Print. Office, Washington DC.
- Durana, P.J., and D. Helms. 2002. Soil survey interpretations: Past, present, and looking to the future. In: D. Helms et al., editors, *Profiles in the history of the U.S. soil survey*. Iowa State Press, Ames IA. p. 275–302.
- Hartemink, A.E., B. Lowery, and C. Wacker. 2012. Soil maps of Wisconsin. *Geoderma* 189–190:451–461. doi:10.1016/j.geoderma.2012.05.025
- Helms, D. 2002. Early leaders of the Soil Survey. In: D. Helms et al., editors, *Profiles in the history of the U.S. soil survey*. Iowa State Press, Ames IA. p. 19–64.
- Henry, J.A., and J. Mossa. 1995. *Natural landscapes of the United States*. Kendall/Hunt Publishing Co., Dubuque, IA.
- Kehew, A.E. 1988. *General geology for engineers*. Prentice Hall, Englewood Cliffs NJ.
- Kellogg, C.E. 1935. Curtis Fletcher Marbut. *Science* 82(2125):268–270. doi:10.1126/science.82.2125.268
- King, P.B., and H.M. Beikman. 1974. *Geologic map of the United States (exclusive of Alaska and Hawaii)*. U.S. Geological Survey, three sheets, scale

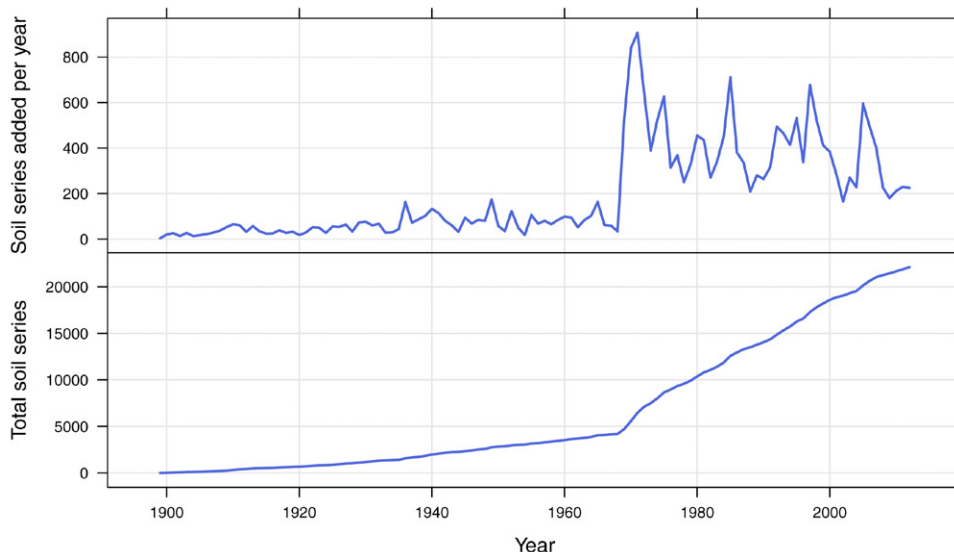


Fig. 11. The growth of soil series mapped in the USA. Note the sudden increase in the number of soil series as Soil Taxonomy was adopted. Figure courtesy of Dylan Beaudette, USDA-NRCS, California Soil Resource Lab.

- 1:2,500,000. Reston, VA, USA.
- Lapham, M.H. 1949. Crisscross trails: Narrative of a soil surveyor. Willis E. Berg Publishers, Berkeley CA.
- Lindholm, R.C. 1993. Soil maps as an aid to making geologic maps, with an example from the Culpeper Basin, Virginia. *J. Geol. Educ.* 41:352–357.
- Lindholm, R.C. 1994. Information derived from soil maps: Areal distribution of bedrock landslide distribution and slope steepness. *Environ. Geol.* 23:271–275.
- MacEachren, A.M. 1995. *How maps work*. The Guilford Press, New York.
- Marbut, C.F. 1928. History of soil survey ideas. In: G.A. Weber, editor, *The Bureau of Chemistry and Soils: Its history, activities, and organization*. Brookings Institution Institute for Government Research, Washington DC. p. 91–98.
- Marbut, C.F. 1935. Soils of the United States. In: O.E. Baker, editor, *Atlas of American agriculture*. USDA Bureau of Chemistry and Soils, U.S. Gov. Print. Office, Washington DC. p. 1–98.
- Marbut, C.F., H.H. Bennett, J.E. Lapham, and M.H. Lapham. 1913. *Soils of the United States*. USDA Bureau of Soils Bull. 96. U.S. Gov. Print. Office, Washington DC.
- McCracken, R.J., and D. Helms. 1994. Soil surveys and maps. In: P. McDonald, editor, *The literature of soil science*. Cornell Univ. Press, Ithaca NY. p. 275–311.
- Paton, T.R., and G.S. Humphreys. 2007a. A critical evaluation of the zonalistic foundations of soil science in the United States. Part I: The beginning of soil classification. *Geoderma* 139(3–4):257–267. doi:10.1016/j.geoderma.2007.01.020
- Paton, T.R., and G.S. Humphreys. 2007b. A critical evaluation of the zonalistic foundations of soil science in the United States. Part II: The pragmatism of Charles Kellogg. *Geoderma* 139(3–4):268–276. doi:10.1016/j.geoderma.2007.01.013
- Simonson, R.W. 1986a. Historical aspects of soil survey and classification. Part I. 1899–1910. *Soil Surv. Horiz.* 27(1):3–11.
- Simonson, R.W. 1986b. Historical aspects of soil survey and soil classification. Part 111. 1921–1930. *Soil Surv. Horiz.* 27(2):3–9.
- Simonson, R.W. 1989. Historical highlights of soil survey and soil classification with emphasis on the United States, 1899–1970. *International Soil Reference and Information Centre Technical Paper 18*. Wageningen, The Netherlands. 83p.
- Smith, G.D. 1983. Historical development of soil taxonomy– background. In: L.P. Wilding, editor, *Pedogenesis and soil taxonomy: I. Concepts and interactions*. Elsevier, Amsterdam. p. 23–49.
- Smith, G.D. 1986. The Guy Smith interviews: Rationale for concepts in soil taxonomy. In: T.R. Forbes, editor, *New York State College of Agriculture and Life Sciences*. Cornell University, Ithaca NY.
- Soil Survey Staff. 2012. Soil survey geographic (SSURGO) database. <http://soils.usda.gov/survey/geography/ssurgo/>. Accessed 29 June 2012.
- Soil Survey Staff. 1960. *Soil classification, a comprehensive system*. 7th approximation. U.S. Gov. Print Office, Washington DC.
- Soil Survey Staff. 1975. *Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys*. U.S. Government Print Office, Washington DC.
- Soil Survey Staff. 1999. *Soil taxonomy. A basic system of soil classification for making and interpreting soil surveys*. 2nd ed. U.S. Government Print Office, Washington DC.
- Whitney, M. 1909. *Soils of the United States*. Bureau of Soils Bull. No. 55, U.S. Dep. of Agric.. U.S. Gov. Print Office, Washington DC.