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HISTORICAL HIGHLIGHTS OF SOIL SURVEY AND SOIL CLASSIFICATION WITH EMPHASIS ON THE UNITED STATES, 1899-1970

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INTRODUCTION

Over the centuries, thought must have been given from time to time to differences in the soil mantle from place to place, but systematic efforts to recognize kinds and to classify and map them are largely a 20th century phenomenon. In the United States prior to 1899, maps purporting to show kinds of soils had been prepared for several areas a few hundred square kilometers in size, for some states, and for the Cotton Belt (Simonson, 1968). These showed surface geology except for the last which outlined areas of native vegetation. Comparable efforts had been made in other countries and those "soil maps" also showed surface geology with one notable exception (Coffey, 1912a). The exception, completed in Russia during the last quarter of the 19th century, remained little known outside of that country through the first decades of the 20th century (Simonson, 1985).

The onset of efforts to classify and map soils of entire countries can be marked by the first report of "Field Operations of the Division of Soils, 1899" of the U.S. Department of Agriculture, referred to later as USDA. That report records the results of soil surveys of four areas by "three well-organized parties... equipped with the most modern methods for surveying, investigation, and mapping of soils..." (Whitney, 1900). The four surveys were the modest beginning of a program that has since produced more than 2,000.

This bulletin presents highlights in the development of soil survey and soil classification under six headings: (1) soil survey programs, (2) field operations, (3) map units, (4) standards and terminology, (5) soil classification, and (6) applications of soil surveys. Major attention is given to the work done in the United States. Some information is included to illustrate activities in other countries but comprehensive coverage has not been attempted.

SOIL SURVEY PROGRAMS

Before the American program is described, special mention will be made of a pre-1899 program in Russia because of its ultimate effect on soil science as a whole and eventually on all soil surveys and classification. The purpose of the soil survey conducted by Dokuchaiev and his colleagues in the Zemstvo of Nizhni-Novgorod little more than 100 years ago was to improve the basis for assessment and equalization of taxes (Yarilov, 1927). At the outset Dokuchaiev divided the task into two parts, namely: (a) the establishment of a natural classification of soils and (b) the grading of soils according to their agricultural potentials. Yarilov (1927) quotes Dokuchaiev as follows: "First of all, it is necessary to determine the soil as a natural body, in its relation to man and conditions of time; it would thus be required to analyze the contents of the soil, and to ascertain its physical characteristics and relations to the subsoil, which knowledge would provide the only basis for subsequent determination of the relative value of soils". This is an early argument (1876) for recognition of soils as natural bodies, tangled though the sentence may be. A prime reason why Dokuchaiev was asked to prepare a land classification of Nizhni-Novgorod had been his study of Chernozems, now available in an English translation (Dokuchaiev, 1967). The original monograph, "Russki Chernozem", was published in 1883.

Portrait of V.V. Dokuchaiev. His monograph on Russian chernozems in 1883 marks the birth of modern pedology with all consequences to soil survey and soil classification

The approach followed in Nizhni-Novgorod of describing and mapping the soils, gathering data on yields of major crops on the different kinds, and assigning productivity ratings to those kinds (Yarilov, 1927) was basically what we did 50 years later in McKenzie Country, North Dakota (Kellogg, 1933), where the results were also subsequently used for the assessment and equalization of taxes (Simonson, 1980). As a student assistant mapping soils in my first field season, I had not heard of the Russian work and thought we were doing something brand-new.

United States

The soil survey program launched in the United States in 1899 was begun without prior knowledge of work already done in Russia. "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, 1928a). Where Whitney got the idea for soil surveys cannot be learned now. While on the staff of the Maryland Agricultural Experiment Station, he had travelled widely in the United States in the early 1890's to collect 1,500 soil samples for the U.S. Department of Agriculture (Whitney, 1893). Thus, he had an opportunity to see many kinds of soils, although within the framework of that day his primary attention would have been focused on underlying rock rather than soil characteristics. Even so, the experience may have opened his mind to the idea of maps showing the distribution of different kinds of soils. Correspondence during preparations for the 50th anniversary of the American soil survey program in 1949 included the information that Clarence A. Dorsey and Thomas H. Means made a trial soil map of part of the Hagerstown Valley of Maryland in the summer of 1898. Whitney visited the men several times and was highly enthusiastic about the work. The map prepared that summer was never published and apparently has been lost. What the full background may have been for launching the soil survey program remains clearly out of our reach.

The first congressional authorization for soil surveys was for the mapping of "tobacco lands" (Whitney, 1901). Presentations must have been made to the Congress to obtain that authorization and the subsequent appropriation. Milton Whitney was greatly interested in tobacco and loved cigars. A clerk who had worked in Whitney's office told me that the man was rarely if ever without a cigar in his mouth. A more intriguing story was related to me by a soil surveyor who had worked for the Bureau of Soils in its early years.

According to that tale, Whitney claimed that when he smoked a cigar he could identify the soil type on which the tobacco had been grown. I could never verify that. Whatever the facts may have been about the tastes of cigars the first federal appropriation for soil surveys in the United States was made for the mapping of "tobacco lands."

The American survey program expanded rapidly during its first few years. A total of 1,125 square miles (ca 2,900 sq km) was mapped the first season. During the next two, an additional 14,745 square miles (ca 38,000 sq km) were mapped. In the 1902 season alone, however, the total was 17,996 square miles (ca 46,600 sq km) (Whitney, 1903). Some surveys were made cooperatively with state agricultural experiment stations from the beginning of the program.

"There is probably no type of agricultural work which has had a more rapid development within the last decade than the mapping and classification of soils." That remark was made by George N. Coffey (1912a) at the annual meetings of the American Society of Agronomy in 1911. By 1910, detailed and reconnaissance soil surveys had been made of 214,000 square miles (ca 554,000 sq km) and 210,000 square miles (ca 544,000 sq km), respectively. The total had been expanded to 563,000 square miles (ca 1,458,000 sq km) and 517,000 square miles (ca 1,339,000 sq km), respectively, by 1920, all from the 1,125 square miles (ca 2,900 sq km) mapped in 1899. The "rapid development" was primarily in number of soil surveys and in area covered.

Ten years after Coffey made his remark, only a few soil surveys were underway in the United States. The program came to a virtual stop when the country went to war in 1918. Afterward, surveys were resumed but on a much reduced scale. Moreover, the number in progress increased slowly and remained small throughout the twenties (Miller, 1949).

Gradual expansion continued in the early thirties. A news release from USDA in April 1932 reported that 60 men had in the preceding fiscal year made detailed soil surveys of 28,530 square miles (ca 74,000 sq km) in 30 states, Puerto Rico, and the Virgin Islands plus reconnaissance surveys of 14,014 square miles (ca 36,300 sq km) in five states.

In 1920, virtually all surveys were being made cooperatively by the Bureau of Soils, USDA, and the state agricultural experiment stations. Additional agencies cooperated in some surveys.

Great changes in the program occurred in the thirties. A New Deal agency, the Soil Erosion Service, set up in the Department of Interior but later transferred to the Department of Agriculture and re-named the Soil Conservation Service (called SCS in the remainder of this bulletin), started a large program of surveys (Miller, 1949). That program was in addition to the modest one already underway. Both the older and smaller organization, the Divisions of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE) and the newer and larger organization, the Soil Conservation Surveys Division, SCS, conducted surveys in cooperation with state agencies. For each soil survey BPISAE had in progress, SCS had a dozen or more. Funds and staff differed in the same proportions. USDA thus had a pair of competing survey organizations. Serious controversy followed from basic differences in the philosophy of soil survey, which will be discussed in a later section on map units.

After having had two soil survey organizations for almost 20 years, USDA merged them in the early fifties. Memorandum No. 1318, issued by Secretary of Agriculture Charles F. Brannan, ordered that effective 15 November 1951, "All soil survey activities of the Department of Agriculture shall be conducted by the Soil Conservation Service." At that time, Robert M. Salter was chief of SCS. Charles E. Kellogg and senior staff members of the former Division of Soil Survey, BPISAE (W.H. Allaway, Roy W. Simonson, and Guy D. Smith) together with Roy D. Hockensmith, who was already on the SCS staff, were assigned responsibility for the combined program.

What might follow from consolidation of all USDA soil surveys within SCS was of great concern to the land-grant universities. Soon after the merger was announced, representatives of five agricultural experiment stations from as many sections of the country met with USDA staff members to express their concerns and urge full consideration of needs they considered important. A prime concern, voiced by Richard Bradfield, was that the excellent international reputation of the American soil survey not be jeopardized. The representatives of the land-grant universities urged strongly that nothing be done to damage the standing of the soil survey.

Moreover, the men feared that basic soil surveys would be slighted under the new arrangement with consequent loss to soil science as a whole. What would eventually follow could not be foreseen at the time.

A period of much adjustment followed the merging of the two survey organizations. Participants in bitter controversies needed time to reach common ground. Moreover, the political party in power in the government changed, bringing in a new Secretary of Agriculture (Ezra Taft Benson) who undertook additional reorganization. One step was to abolish SCS regional offices, which necessitated further adjustments. Working out new relations thus continued for several years. Reflecting on that period of change, I have concluded that reorganizations have a life and momentum of their own. Started for certain objectives, reorganizations once underway spin their own webs, as Leo Tolstoy remarked about wars in his great novel, "War and Peace."

Soon after the merger, programs were launched within SCS to improve the backgrounds of field soil scientists. A two-week workshop for 15-20 men was held annually in each of several parts of the country. Lectures, discussions, and exercises were conducted on topics such as the concept of soil, logic of classifications systems, theories of soil genesis, preparation of mapping legends, making field reviews, and completing correlations of soils of survey areas. I took part in most of the workshops for several years and remember a pair of them especially well. I lectured for about 7 hours on each of Monday and Tuesday at one workshop, flew to another part of the country on Wednesday, and repeated the performance on Thursday and Friday. Then I went home exhausted. I did not try that again. The workshops or training sessions were strenuous, however, for all participants.

Additional efforts toward improvement of backgrounds included lectures and discussions for field scientists at state-wide meetings, joint field trips in which soil profiles were examined and described, an annual 6-week course for about 20 men on a university campus, and the distribution of publications and bibliographies to all field men.

Improvements in the backgrounds of field men were reflected in better descriptions of soil profiles and map units. The improvements were gradual and continued for more than a decade. Previously, records of profile characteristics and of the nature of map units had been kept in few surveys. Changes in habits of thought were therefore required for the improvements, and those take time. Furthermore, committing ideas or information to paper -- the act of writing -- is hard for most people. Croce (1909) argued that thoughts are at first poorly formed and hazy in the mind, as anyone can learn by putting them on paper. The rather hazy thoughts must be sharpened and clarified, even made more complete than they were originally, if they are to be effective when spelled out. Many a soil surveyor has found that out for himself when setting out to prepare a descriptive legend or a manuscript for publication. Three centuries ago Francis Bacon expressed the idea of difficulty of English composition in another way -- "Writing maketh an exact man." Gains in the form of improved records of the nature of units shown on the soil maps continued for a long while.

As might have been expected, the expanded soil survey program in the fifties experienced growing pains. Various approaches to the classification and mapping of soils were proposed and tried with much attendant controversy (Cline, 1977). Full agreement on an approach or approaches was unlikely with so many individuals taking part in the program. By the early sixties, slightly more than 1,000 individuals were participating. The number was almost half again as large in the seventies. Approximately 40 million acres (ca 19 million ha) were mapped per year during the sixties and approximately 57 million acres (ca 26 million ha) per year during the seventies.

Examples from Other Countries

Soil survey programs were started in many countries during the present century. Among those programs some drew on American experience and some did not. Thus, William Ogg of Great Britain visited the United States in 1920 and took home information about the new approach of describing and mapping soils according to their profiles (Muir, 1961). Marbut (1924) gave a report on the American soil survey program to an international conference in Rome in the mid-twenties. Reports were also given on cartography of soils in other countries but systematic programs were still to be started in many of them.

Growing attention to American surveys can be illustrated by a report on some surveys in India and by a pair of exchanges between men in the Netherlands East Indies and the United States. Pendleton (1947) made soil surveys of several small areas in Gwalior State of India in the mid-twenties to demonstrate the American approach. Criticisms of American soil surveys by two Dutch geologists, published in the Netherlands East Indies, drew responses from C.F. Marbut and C.F. Shaw. Marbut (1934) published a paper in Spanish in a Cuban journal responding to criticism of the report on soils of Cuba by Bennett and Allison (1928). I have seen the English manuscript as well as the published Spanish version of the response but not the initial criticism. Written in Dutch, it would have been out of my reach. Correspondence in the old soil survey files show that Marbut first sent his manuscript to the journal that had published the criticism. The journal rejected his response. I presume that Marbut then decided to publish the manuscript in Spanish in Cuba because the criticisms were about a soil survey of that country. The tone of the response by Marbut (1934) shows that he was irritated. Some items in the response seem overly strong, as can happen when a person is angry, whereas other items seem to be valid arguments. The initial criticism could have included its share of overstatements, too.

One year earlier a rebuttal by Shaw (1933) to criticisms of American soil surveys in general by E.C.J. Mohr was published in English in a journal in the Netherlands East Indies. I have not seen those criticisms, either, but to judge from the rebuttal one criticism was lack of adequate attention to geology. That seems farfetched now, given the attention accorded surface geology in the first few decades of the American program. The statements by Shaw were more restrained than later ones by Marbut. The two responses -- and what they indicate of the original criticisms -- illustrate how different a given subject may appear, according to the point of view of the observer. To a large degree our situation in soil survey and classification parallels that of the six blind men of the Hindu parable who went to see the elephant. Each of us can place the hands of his intellect on but a small part of the entire creature.

To illustrate soil survey programs outside of the United States, those in Australia, Canada, China, Great Britain, the Netherlands, and the Soviet Union will be described briefly.

The first detailed survey in Australia was completed during the twenties (Taylor and England, 1929) although other types of investigations had been in progress for some time (Wells and Prescott, 1983). During the thirties and forties, soil surveys were largely restricted to areas already under or proposed for irrigation, as summarized by Prescott and Taylor (1949) and later by Stephens (1962). After 1950, surveys were still being made of irrigated areas and proposed projects but were also being extended to other districts, especially where agriculture was rainfed but the rain was on the short side. A few examples of surveys are from New South Wales (Butler and Brewer, 1953). Queensland (Hubble and Thompson, 1953), and

South Australia (Blackburn and Baker, 1952).

The history of soil surveys in Canada from their beginnings in 1914 until 1975 has been reported in some detail by McKeague and Stobbe (1978). Limited information will therefore be given here.

The first soil survey in the country was started in 1914 when A.J. Galbraith began to map soils in southwestern Ontario (Ruhnke, 1926). G.N. Coffey, formerly of the Bureau of Soils, USDA, spent a month in the field with Galbraith at the outset of the work. The survey was suspended shortly because of the outbreak of war in Europe.

Soil surveys were resumed in Ontario after the war and were also started in other provinces during the twenties. Modest beginnings were made in the prairie provinces of Alberta, Manitoba, and Saskatchewan. Interest in surveys had been stimulated by the failures of veterans who had homesteaded crown lands after the war. Many homesteads were abandoned because of poor soils, indicating a need for better information on soil resources (Hawkins, 1922). The survey program expanded gradually but not without its troubles. The vicissitudes of soil surveys in Alberta, including complete suspension for a period in the thirties, were described by Bowser (1969) in a report on the first half century of the program in the province.

By 1950, soil surveys were in progress in all parts of Canada. Detailed surveys were concentrated in regions with well-established rainfed farming and in irrigation projects. Mapping on a reconnaissance scale had been completed during the thirties in the major agricultural sections of Saskatchewan (Joel et al., 1936). Reconnaissance surveys were extended into the northern part of the province and also into areas such as the Peace River district of Alberta. Such areas were being considered for possible settlement. Thus, during the fifties and later, surveys on either of both of detailed and reconnaissance bases were being made in all provinces. A beginning had also been made in the Northwest Territories (McKeague and Stobbe, 1978).

Soil mapping was started in 1931 by the Soils Division of the National Geological Survey of China. The program consisted of reconnaissance surveys, for the most part, but detailed maps were made of a few widely separated areas. The American approach was followed in the program (Thorp, 1936). I have seen a dozen individual survey reports, all of which were in both Chinese and English. One cover and one half would be in the first and the other cover and the other half in the second language.

The earliest soil surveys in Great Britain were made during the second decade of the century. In his first report as Director, Soil Survey of England and Wales, G.W. Robinson (1947) remarked that those surveys were based on the assumption "that each geological formation gave rise to it own kind of soil... and that a map of surface geology could be translated, with due interpretation, into a soil map." He added that earlier surveyors had not realized that more then one kind of soil could be formed from one kind of parent material.

More activity in soil surveys began in the twenties and continued afterward. Late in the twenties, Robinson initiated soil surveys in Wales patterned after the approach in the United States (Muir, 1961). In 1930, a Soil Correlation Committee was set up in Great britain to standardize approaches in the soil surveys in progress (Robinson, 1947). The Soil Survey of England and Wales was then established in 1939 with G.W. Robinson as its director. Work was suspended shortly, however, because of the outbreak of war. Later reports of the progress of soil surveys in Great Britain were published by Robinson (1947) and by Muir (1947) who became director of the Soil Survey of England and Wales when the headquarters were moved from Bangor to Rothamsted in 1946. Mapping progress was slow. Scotland had a separate soil survey organization with its headquarters at the Macaulay Institute for Soil Research in Aberdeen (Muir, 1961).

The first detailed soil survey in the Netherlands was started in 1943 in the river clay area of the Rhine and Meuse Rivers by a group of students under the direction of C.H. Edelman as the men were hiding from the German occupation. The Netherlands Soil Survey Institute (Stichting voor Bodemkartering) was established two years later (J. Schelling, personal communication, 1984). Seven years later, the soils of the country were described in a report (Edelman, 1950) for distribution to all participants in the Fourth International Congress of Soil Science held that year in Amsterdam.

During the fifties, the pattern of isolated soil surveys in the Netherlands was terminated in favor of systematic and complete coverage. The total number of surveys was also increased during that decade and later. Soil surveys were being made of all areas of land reallocations schemes (J. Schelling, personal communication, 1984).

Mapping of soils in Russia, beginning with the program in Nizhni-Novgorod in the last quarter of the 19th century, was continued in a large effort started in Siberia in 1908 under the direction of K.D. Glinka (Yarilov, 1927). About 3,000,000 sq km were mapped at a scale of approximately 1:350,000 by 100 field parties in six years. The program was stopped by war in 1914.

Soil mapping was resumed in the USSR after the war. Within the first decade, soil surveys had been completed of all of European Russia south of the tundra and northern forest zones. The maps were not published but were being used to compile a general map at a scale of 1:1,000,000 of the southern part of European Russia (Tulaikov, 1923).

During the thirties, soil surveys were being extended widely within the USSR. This is indicated in a comparison of approaches in the Soviet Union and other countries by Prasalov (1937) in a report focused primarily on a general soil map of the world completed the preceding year. Maps were also being prepared of small areas such as experiment stations, illustrated by a report for the North Chernozem Experiment Station (Lebediantzev et al., 1932).

The soil survey program continued with some changes from 1940 to 1970 in the USSR. Soil surveys were being made especially of state and collective farms, all for internal use. Most but not all such farms had been mapped before 1960 (Kellogg, 1959). Mapping of the remainder was progressing rapidly at that time. Further information on the general nature of the program in the Soviet Union is provided by a soil survey manual available in English translation (Tyurin et al., 1965). The contents demonstrate continued interest in broad-scale representations of the soil mantle, which seems reasonable for a very large country. Instructions are included, however, for detailed investigations of soils.

FIELD OPERATIONS

Some operations have remained the same from the beginning, whereas others have been changed. Examining soils in place and plotting boundaries of field sheets have been parts of all surveys. Modes of transportation, base maps, and field equipment have changed, either much or little, as have other survey elements. These last will be discussed in later sections, whereas the evolution of field operations in the United States from 1899 to 1970 is traced in this section.

A story of early field work in soil surveys, covering experiences that range from the absurd to the hazardous, is well told in a book, "Criss-Cross Trails," by Macy H. Lapham (1948). Macy was hired as a scientific aide by the Division of Soils, USDA in 1899. For the next 45 years he continued to work for the federal soil survey organization His accounts of surveys and of people encountered during his work are good fun in addition to being first-hand descriptions by a man who was there.

During the first field season in 1899, three parties, each consisting of two men, completed mapping of Cecil County, Maryland; Connecticut Valley, Connecticut and Massachusetts; Pecos Valley, New Mexico; and Salt Lake Valley, Utah. The surveys of the first two areas were made by the same two men, whereas the third area was mapped by another pair. One of those men then mapped the fourth area with the help of an assistant from the Utah Agricultural Experiment Station. Three of the five men in those original field parties were alive at the time of the 50th anniversary of the soil survey in 1949. As mentioned in an earlier section of this report, two of those men had made a trial survey of the Hagerstown Valley, Washington County, Maryland, during the summer of 1898 but the results were never published.

Equipment

Although the crews used the "most modern methods" (Whitney, 1900), little information is included about their equipment. Each pair of men had a horse and wagon for local transportation. Each pair must also have had one or more soil augers to make borings "as necessary to examine the soils." The report of field operations further states that camping outfits were not needed by any crew.

Some items of equipment are listed in a paper in the 1901 Yearbook of Agriculture (Whitney, 1901). For each pair of men, these are a horse and buggy, a compass, an odometer, a soil auger, and extra pipe to permit occasional borings to depths of 15 to 18 feet (ca 4.5 to 5.5 m). A few crews would also need plane tables and men working the western part of the country where "alkali" was encountered were to be furnished a "trunkful" of equipment.

Specimen field operations in soil surveys in the United States in 1914. One man is reading the odometer next to the right front wheel of the buggy while the other is prepared to sight back along the road segment just traversed and then mark the new location on the field sheet as soon as he gets the distance covered. The photograph also illustrates the common plane table plus acceptable field clothes of the period. USDA photograph.

A more complete list of equipment is given in the earliest manual I have found, prepared for the fourth field season (Bureau of Soils, 1902). Every "field outfit" was to include a soil auger with a 40-inch (1 m) handle,geologist's hammer, notebooks, compass or plane table, odometer, chain scale, colored pencils, base maps, sacks and tags for soil samples, and cards for recording samples. Some crews would also need an "alkali outfit," extension auger and pipe wrenches, filter pump, and a metallic tape 50 feet (ca 15 meters) long.

The 1902 manual provided detailed instructions on a variety of topics. One set covered the mounting of an odometer on a buggy or wagon. The usual place for the odometer was on the front axle next to the right wheel, as illustrated in a photograph from about 1914.A formula is provided for making those corrections. Odometers operating from the right front wheel were long used to measure distances in mapping soils, first on buggies and wagons and later on motor vehicles (Carter et al., 1919; Bushnell, 1921).

Truck with probe to withdraw cylindrical cores of soil about 5 cm in diameter and 1.5 m long. The probe is forced into the soil and withdrawn by a hydraulic pump powered by the truck motor. Power probes are of various lengths with most between 1 and 2 m. USDA photograph.

The "field outfits" listed in the books of instructions issued in the 5th, 6th, and 8th field seasons (Bureau of Soils, 1903; Bureau of Soils, 1904; Bureau of Soils, 1906) are the same as the one for 1902. The same "field outfit" is again given in a book issued in the 16th season (Bureau of Soils, 1914) with the addition of litmus paper and dilute acid. That outfit also included an electrolytic bridge to be added for areas where "alkali" might be encountered.

The "shakedown cruise" of the American program seems to have been completed in 1906. A further book of instructions was not issued again for another 8 years (Bureau of Soils, 1914). Moreover, that book was not labeled for a given field season but rather as a "field book." The instructions seem to have been meant to stand for a number of years, which they did, not being superseded by another manual for 23 years.

Some items listed in the first "field outfits" are still used in mapping soils but some are not. Horses and buggies have dropped out of the picture, as has litmus paper. Boring with an auger or digging with a posthole spade -- a "sharpshooter" in the Great Plains -- remains the primary method of examining profiles to identify the soil bodies to be shown on maps. Power probes mounted on small trucks can be used to withdraw cylindrical cores of soils if they are not gravelly or stony. Backhoes are also hired to dig occasional trenches so that cross sections of soils several meters long can be studied. These provide some measure of small-scale lateral differences and thus extend the point observations possible with auger, spade, or power probe.

Base Maps and Map Scales

The first base maps used for plotting soil boundaries were topographic sheets published by the U.S. Geological Survey. Such maps were to be used wherever they were available, according to the early instructions (Bureau of Soils, 1902). The policy of using topographic maps to the extent possible remained in effect for many years.

Because of the rapid expansion in the mapping program between 1900 and 1910, soil surveys had to be made in areas without topographic maps. Surveyors were therefore instructed to prepare their own planimetric maps in such areas. The importance attached to preparation of base maps is clearly shown by the space given to the subject in the 1914 book of instructions. The section on construction of base maps (37 p.) is half again as long as the next biggest one. Moreover, the instructions are detailed. Those outlined in 1914 were still followed 18 years later during my first field season in a soil survey in western North Dakota. One departure from the 1914 instructions was that our odometers were mounted on pickup trucks rather than wagons or buggies. The odometer itself was attached to the lower edge of the dash inside the cab and connected with a flexible cable to a driving gear on the right front wheel. Calibration of odometers was performed along a mile of country road that had been measured with a standard chain scale. Coarse adjustments were made by substituting a larger of smaller gear at the driving end of the flexible cable. Fine adjustments were made by changing the pressure of the right front tire.

Planimetric maps were used in the field work and also for publication of all soil maps through 1930 and for a great majority of them through 1940. Aerial photographs came into limited use as field sheets during the thirties. Widespread use followed in the next decade (Baldwin et al., 1947).

The earliest proposal known to me for use of aerial photographs as field sheets in soil surveys was made by Cobb (1923) who tried them in Louisiana. He did not expect the photographs to be useful in areas with a grid of roads at 1-mile intervals and much land in cultivation. On the other hand, he thought they should be useful in areas with much forest and limited networks of roads. Cobb (1923) obtained aerial photographs for an area of about 400 square miles (ca 1,000 sq km) in Louisiana at costs of $360 for film and prints at a scale of 1:7,000 and of $500 for flying.

Six years later, Bushnell (1929) argued at the annual meeting of the American Soil Survey Association that aerial photographs made current field methods obsolete. Plotting of boundaries would be more economical and their accuracy would also be greatly improved. The views were expressed with vehemence but comparisons of costs, rates of progress, and accuracy were not offered. Data were probably not available at the time. In 1929, the replacement of planimetric maps by aerial photographs in soil surveys was still several years in the future. Three years after the remarks by Bushnell (1929), we constructed our own base maps in McKenzie County, North Dakota. About that time, however, aerial photographs were being used on an experimental basis in a county soil survey in the state of Indiana (Bushnell, 1932).

My first experience in mapping soils on aerial photographs came in 1935 when I took part in appraising lands to be flooded by the Fort Peck Dam along the Missouri River in Montana. Made for our use, the photographs were at a scale of about 1,000 feet per inch (1:12,000). I found the photographs useful indeed, both in maintaining location and in plotting boundaries. My experiences along the Missouri River were out of the ordinary for soil surveys at the time but would not touch those of Macy Lapham (1949) early in the American program.


Soil surveyor sketching soil boundaries on an aerial photograph in the early years of their use as field sheets, just prior to World War II. Photographs were first mounted on plane tables as planimetric maps had been previously, but that practice was dropped in a few years. USDA photograph.

The appraisal crew lived in a boat on the river much of the time and traveled along its banks and into the bordering Badlands by whatever means might work best.

General adoption of aerial photographs as field sheets in soil surveys occurred during the 1940's (Baldwin et al., 1947). By that time, the cost of the photographs had become relatively small for a survey area because much of the country had been flown for programs to adjust crop acreage (Miller, 1949). By 1960, aerial photographs were being used as field sheets in virtually all surveys. A proposed survey would be postponed until photography became available.

By that time, too, detailed soil maps were being published on photomosaics. An enthusiastic manual on the use of aerial photographs in soil surveys was published in the United States in the sixties (Soil Survey Staff, 1966).

Interest in aerial photography for soil surveys was widespread in the world by 1960. The American Society of Photogrammetry published a manual on photointerpretation which included a chapter on its use in soil surveys (Buringh, 1960). An International Training Centre for Aerial Survey was established in the Netherlands. The Food and Agriculture Organization (FAO) published a bulletin on the use of aerial photographs in mapping soils (Goosen, 1967) and the Commonwealth Bureau of Soils (1969) issued a bibliography on aerial photography, radar, etc.
The use of aerial photographs in soil surveys was reported from the Soviet Union (Andronikov, 1967) and East Germany (Reinhold und Asmus, 1968). These are but a few examples of the numerous reports on use of aerial photography in mapping soils. Enthusiasm was initially very high because of expectations that examination of photographs could replace much of the field work in soil surveys. Those expectations were not realized even though the photographs did facilitate mapping and improve accuracy. Field operations continued to be necessary. To put this in another way, soils still had to be examined in their natural habitats. Some 40 years earlier, Marbut (1921) had called Soil Survey an institution for the study of soils in their natural habitats.

The scale chosen for field work in the first areas in 1899 became standard and was used in both mapping and publication for the next 40 years with few exceptions. One inch per mile (1:63,360) was initially considered a large scale but it would make the published maps "easy to read" (Whitney, 1900). Because of the scale, the smallest area to be shown on the maps at first was roughly 1/4 mile (0.4 km) in diameter or 40 acres (ca 18 ha) in size. Within the first few years, however, the minimum area to be shown was first reduced to 20 acres (ca 9 ha) and then to 10 acres (ca 4,5 ha). Experience had demonstrated that areas smaller than 40 and even smaller than 20 acres could be important to crop production.

Departures from the standard scale of 1 inch per mile (1:63,360) were allowed in some surveys, as for example those of irrigation projects and the reconnaissance mapping of large areas. Field scales could be two or three times the "standard" for surveys of irrigation projects. Scales were much smaller, mostly about 6 miles per inch (1:380,160), in reconnaissance surveys such as those of western South Dakota (Coffey and party, 1912a) and northwestern Texas (Carter et al., 1925). Similar small scales (1:350,000) were also adopted for reconnaissance surveys in Siberia under the direction of K.D. Glinka (Yarilov, 1927). Mapping legends for the reconnaissance surveys in the two countries differed greatly.

By 1930, the 31st year of the American program, quite a few soil surveys were being made at field scales larger than 1 inch per mile (1:63,360). Furthermore, larger scales were no longer restricted to irrigation projects. More information than could be shown at the "standard" scale was found necessary in a number of places. Larger scales were therefore being adopted. For example, mapping in McKenzie County, North Dakota (Edwards and Ableiter, 1942), in the early thirties was at a scale of 2 inches per mile (1:31,680). The survey data were to be used in tax assessment and equalization (Kellogg, 1933).

Further enlargement of field mapping scales followed when SCS launched its program of soil surveys in the thirties. Most surveys were made at field scales of 4 inches per mile (1:15,840) but some were at 8 inches per mile (1:7,920) (Fuller, 1936; Norton, 1939). Planimetric maps were used for field work in the first years of the program but those were being replaced by aerial photographs by the end of the decade.

After aerial photographs came into general use as field sheets in soil surveys, most scales were either approximately 3.2 inches per mile (1:20,000) or 4 inches per mile (1:15,840). Surveys made by SCS were mostly at the larger scale and those of BPISAE mostly at the smaller scale. After the two agencies were combined in 1951, progressively more of the field work was done at the smaller scale as the years passed. Available aerial photography in the United States was predominantly at a scale of 1:20,000 and that scale was found to be adequate with but few exceptions.

Traverses and Soil Examination

Instructions in the first manuals were detailed and explicit on most subjects. Thus, for example, instructions are included on hiring a horse and buggy from a livery stable and on getting laundry done. In contrast, the guide on required traverses is far from explicit, and none is provided on the frequency with which soils should be examined during the traverses.

Intervals between traverses have become smaller over the years. The first manuals called for traverses with a horse and wagon along all roads in a survey area. By 1914, traverses were to be made on foot between roads as necessary so that the interval would be no more than a half mile (0.8 km). That interval was the principal one in surveys for at least 30 years, although departures were allowed in some situations. For example, intervals were more than one-half mile in the cutover country of the Lake States and smaller in irrigated projects. The traverse intervals remained the same for a decade or two after motor vehicles replaced horses and wagons. Eventually, however, traverse intervals were reduced below one-half mile in detailed surveys, generally, and widened in reconnaissance surveys.

Prior to the advent of aerial photographs, field sheets in many surveys consisted of heavy, cloth-backed paper which could be mounted on a plane table. Common practice in mapping on such sheets was to mark each stop of a traverse with a pinhole. The distance traversed from one stop to the next would be measured from the last pinhole and a new one made for the very next stop. Such pinholes were used to mark stops in traverses for construction of the base map and also in traverses on foot for the plotting of soil boundaries. After the work on a sheet had been completed, it could be removed from the plane table and held up against the light to find the pinholes showing the pattern of traverses. I have heard stories that men pricked pinholes in the sheets without making the traverses, using those pinholes to support soil boundaries plotted without actual examinations of the soils. I did not encounter any of those myself.

Making traverses more or less on a regular grid with fixed intervals became both less important and less common after aerial photographs were introduced as field sheets. Traverses to examine soils could then be related to patterns on the photographs, once a person had gained enough experience with the landscapes of a survey area.

How frequently soils should be examined during the traverses has been left to the discretion of field men from the beginning. "Periodic borings' are mentioned in the first report of field operations (Whitney, 1900). The manual issued in the 16th year of the program (Bureau of Soils, 1914) provides essentially that same information. A section of 3½ pages is headed "Identification and mapping of soils." This calls for examination of soil sections to depths of 3 feet (90 cm) and 6 feet (180 cm) in humid and arid regions, respectively. Following that statement comes this "...in starting on the survey, the field man, through a sufficient number of borings, becomes acquainted with the character of the soil type and proceeds with caution and judgment until the character of the soil materials changes to another soil type...." Field men were thus urged to exercise good judgment, which seems appropriate. During the 20 years in which I supervised soil correlation and classification in the United States, I wished many a time that I would be able to prepare some brief and effective instructions on how to exercise good judgment. Exhortation rather than instruction was possible in 1914 and still is.

From the onset of soil surveys to the present, the hallmark of an effective surveyor has been his ability to devise a theory for the distribution of the local kinds of soils in his area. Once that theory has been worked out, the surveyor makes periodic examinations of soils to check predictions as to what the soil is on the next slope. Without such a theory, the surveyor can make borings by the score and still be lost. I have known such men. Hard-working as can be imagined, they would make dozens of borings without being able to get a picture of the soil pattern. For the man who has worked out a theory, even his predictions fail on occasion. Then, a modification of the theory is needed to accommodate new facts not considered previously. The best soil maps are made by individuals who have grasped the distribution patterns of the soils in their survey areas and make their soil examinations to test a theory of soil distribution.

Rates of Progress and Costs

Rates of progress in field mapping decreased gradually over the years as the numbers of traverses and soil examinations were increased per unit area. Complexities of soil patterns also had their effects.

The survey crews in 1899 completed their field mapping in seasons of 6 to 8 months. The survey areas ranged in size from 250 square miles (ca 650 sq km) in each of the Pecos Valley, New Mexico, and Salt Lake Valley, Utah, to 375 square miles (ca 970 sq km) in Cecil County, Maryland, up to 400 square miles (ca 1,000 sq km) in the Connecticut Valley, Connecticut and Massachusetts (Whitney, 1900). Rates of progress in square miles per day, with square kilometers in parentheses, ranged from 5 (13) in Cecil County to 1.1 (2.8) in Pecos Valley. Slower progress in the latter area was attributed to the "more complex problems in arid regions of the West" (Whitney, 1900). Twenty years later, a crew of two men normally mapped the soils of a county of 400 square miles (ca 1,000 sq km) in Iowa in 9 months. The rate of progress in such counties was a bit slower than it had been in Cecil County, Maryland, in 1899.

Costs of field work per square mile in 1899, with costs per square kilometer in parentheses, were $1.70 (66c) in Cecil County, $2 (77c) in Connecticut Valley, $6 ($2.32) in Salt Lake Valley, and $12 ($4.63) in Pecos Valley. The cost in Salt Lake Valley was considered reasonable, but that for

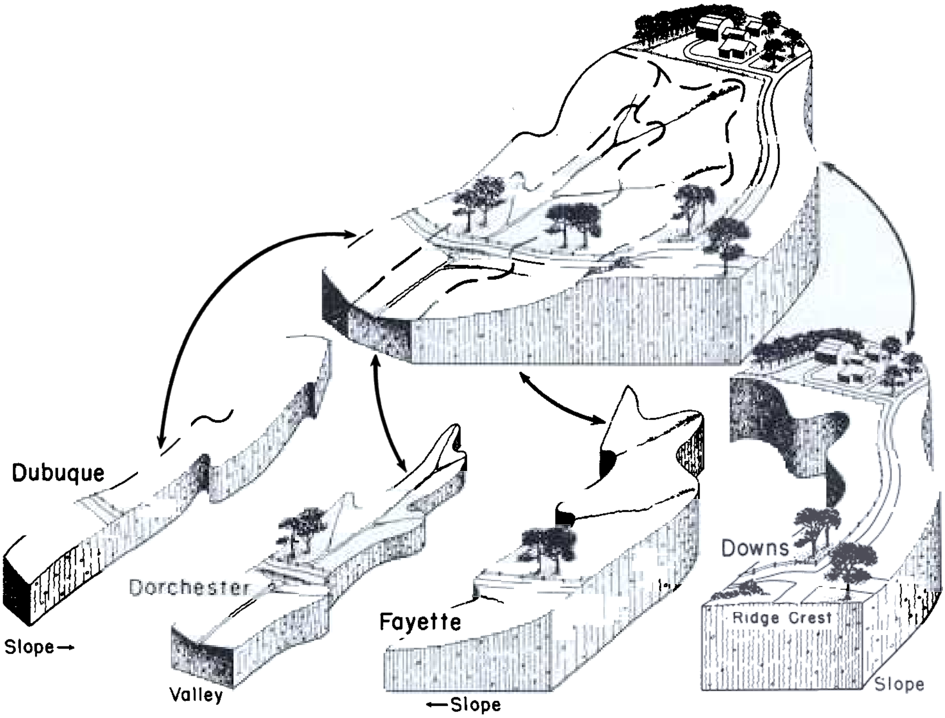
Pecos Valley was thought to be high. Reduction of costs should be possible, however, with more experience (Whitney, 1900). One explanation for the higher costs in western areas was the greater distance from Washington, D.C., with the consequently higher travel expenses. That remark is an illuminating aside on relative costs of the different elements of a soil survey in 1899.

Information is also available on costs of soil surveys at three later dates. In 1902, the cost per square mile, with cost per square kilometer in parentheses, ranged from 89c (34c) in Clinton County, Illinois, to $6.75 ($2.61) in the Imperial Valley of California (Whitney, 1903). The average cost was $1.93 (74c) for surveys underway in 25 states and Puerto Rico. These costs are exclusively for field work. An average of $1.93 (74c) in 1902 compares to a range from $12 ($4.63) to $20 ($7.92) in 1932, according to a news release from USDA. Eighteen years later, in 1950, costs per square mile and square kilometer were summarized for field work at three levels of detail. These were $70 ($27.02) for irrigated areas, $35 ($13.50) in rainfed parts of the eastern Great Plains, and $7 ($2.70) for grazing lands.

The gradually increasing costs reflect the greater amounts of time and effort being allocated to the examination of soils and to the greater detail being recorded on the field sheets. Changes over time had required more information on the nature and distribution of soils within survey areas.

MAP UNITS

The nature of map units set apart in soil surveys has changed greatly since the early days of the American program. By map unit is meant the set of soil bodies represented as delineations identified by one symbol on the map of an area, however large or small the area may be.



Sketch to indicate how a small segment of landscape in northeastern Iowa would be subdivided into four soil bodies in a soil survey. Each represents a different map unit. Each delineated body would be part of a phase of one series but only series names are listed for brevity. Soils of the locality are dominantly Hapludalfs (Alfisols).

In the first surveys, map units were few and had wide ranges as compared to those in current detailed surveys. Thus, 10 kinds of "soil" were set apart in 1899 in Connecticut Valley, Connecticut and Massachusetts, with its area of 400 square miles (ca 1,000 sq km) (Simonson, 1964). In the 1904 field season, five map units were enough for 710 square miles (ca 1,840 sq km) in Tama County, Iowa (Ely et al., 1905). Thirty-five years later, 50 map units were needed in Tama County (Aandahl and Simonson, 1950), 10 times the number of 1904. A similar ratio held for Grainger County, Tennessee, where 14 map units were enough in 1906 and 128 were needed in 1942 (Simonson, 1952a).

Another sign of change can be taken from Tama County, Iowa. A.R. Aandahl and I prepared a small general soil map (4x6 inches or 10x15 cm) of the county to be reproduced on a single page of the soil survey report. Our map was based on the field work completed at a scale of 4 inches per mile (1:15,840) in 1938. Once our map was done, we compared it with the inch-per-mile (1:63,360) "detailed" map prepared in 1904. Had we but known, the earlier crew had done part of our work for us. The boundaries of three of the five "soil types" mapped in 1904 were closely similar to those of as many of our broad soil groups. On our map, we did subdivide the most extensive "soil type" mapped in 1904, labeled Marshall silt loam at the time. We also passed up two of the "soil types" of 1904 because of their limited extent. Those map units can be identified, however, on the detailed map compiled after 1938 (Aandahl and Simonson, 1950).

In the first American surveys, a map unit was considered a **class**. Moreover, each class was also considered a **soil type** and given its own name. Examples of names of "soil types" in the first four surveys are Connecticut swamp, Holyoke stony loam, Jordan sandy loam, Pecos conglomerate soil, and Windsor sand (Whitney, 1900). Three years later, Riverwash and Coral sand were added as "soil types" in Puerto Rico (Dorsey et al., 1903). Names were being assigned on an ad hoc basis at that stage. Even so, the mode of construction of some names has persisted and is still being followed.

Problems in naming map units have also persisted. Early examples of those problems are provided by a pair of reconnaissance surveys of the Canal Zone in Panama. Ten map units were set apart in the first survey (Bennett and Taylor, 1912). The two most extensive map units in the 450 square miles (ca 1,160 sq km) were called "Steep hill land" and "Red clay." Only two map units were named as soil types with the combined place names and texture terms. Each of those was minor.

Some incidental observations on the soils in 1912 were marked departures from the conventional wisdom of their day, viz.:

> Two important and interesting facts in connection with the soils of the Canal Zone are the little surface accumulation of vegetable mold and the strong resistance to erosion.... The range in organic matter was 1.7 to 8.3% with few below 3%. The high average is rather surprising....
>
> There are a number of factors that combine to explain the

remarkable resistance to erosion offered by the soils of the Canal Zone... (Bennett and Taylor, 1912).

Several factors were then listed as responsible for the "remarkable resistance." The list is all the more interesting because it was prepared by H.H. Bennett, widely known later for what he said and wrote about the evils of soil erosion.

Seventeen years after the first survey, a second was made of the Canal Zone plus contiguous territory (Bennett, 1929). Twenty-one map units were then set apart in 855 square miles (ca 2,215 sq km). Ten were listed as soil types, seven as phases, and four as miscellaneous land types. Soil types were named in conventional fashion, e.g., Gatun loam. Six of the seven phases were identified by a descriptive phrase, "low and less broken areas," in the next line below the name of a soil type in the map legend. The seventh phase was called "San Jose phase" from the locality in which it was mapped. The naming of mapping units was thus somewhat more orderly in the second survey than in the first but was still largely ad hoc and also on something of a catch-as-catch-can basis.

During the first 30 years of the American program, map units were mostly named as soil types (place names plus texture terms) although a few were called phases. The status of phases in relation to soil types was rather uncertain in both detailed and reconnaissance surveys. Moreover, the nomenclature was essentially the same in both types of surveys. Many names assigned to map units in reconnaissance surveys would sound familiar today, as for example Pierre clay in western South Dakota (Coffey and party, 1912a) and Victoria clay in southern Texas (Coffey and party, 1912b). One map unit in southern Texas was called a shallow phase of Neuces fine sand. Information about that phase consisted of one short paragraph in the description of Neuces fine sand. Furthermore, the map unit considered the shallow phase was not given a separate symbol but was shown by crosshatching of some delineations of Neuces fine sand.

Another reconnaissance survey made in Texas in 1919 had four map units called phases (Carter et al., 1925). One phase was keyed to each of color, erosion, stoniness, and landform. Information about the phases was again included in the descriptions of the soil types under which the phases were listed in the map legend, which also suggests that the phases had lower status as map units.

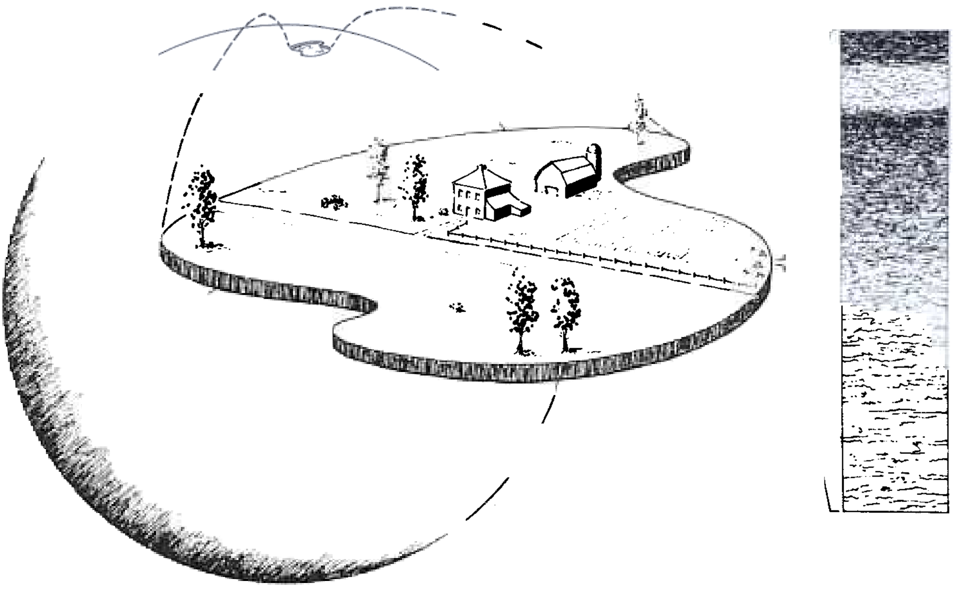
Ten years later, three of 30 units were called phases in a detailed survey of Marion County, Iowa (Orrben and Leighty, 1936). The other 27 map units were named as soil types. One phase was keyed to slope, one to soil depth, and one to source of regolith. As had been done earlier, phases were listed by means of descriptive phrases under soil type names. Information about the phases was included in the descriptions of the soil types under which they were listed. Thus, phases continued to have lower standing than soil types for many years.

Naming map units as phases became more common after 1930. Moreover, phases were accorded more status than previously. Thus, 21 of 58 map units were labeled as phases in the survey of McKenzie County, North Dakota, in the early thirties (Edwards and Ableiter, 1942).
In that county, 18 phases were keyed to topography, two to drainage, and one to color.
Each phase was assigned a name consisting of a soil type name plus an additional phrase, e.g, Williams loam, rolling phase. Individual phases were not described separately, however; the description of a soil type included some remarks about the related phases. Nonetheless, the approach in McKenzie County indicates a transition in the status of phases.

Marked departures from past practice in the design and definition of map units followed the launching of a large survey program by SCS in the mid-thirties. The departures are evident from a comparison of three handbooks published during the decade. The first was called "Procedures for Making Soil Conservation Surveys" "(Fuller, 1936), the second "Soil Survey Manual" (Kellogg, 1937), and the third." "Soil Conservation Survey Handbook" (Norton, 1939). The first and last were published by SCS and the second by the Division of Soil Survey, Bureau of Chemistry and Soils. That Division was transferred shortly afterward to the Bureau of Plant Industry which later became the Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE).

Concepts of map units, basic to the philosophy of soil surveys, were greatly different and became a source of bitter controversy between BPISAE and SCS (Cline, 1977). The underlying concept in BPISAE surveys was that a map unit represented a set of soil bodies that could be defined and described in terms of their profiles, slopes if any, degree of truncation if any, stoniness if apropos, and so on. A soil body, as illustrated by a sketch, had various attributes and all should be considered, both in defining and using it.

The underlying concept in SCS surveys was that soil, slope, and erosion were separate entities that could be mapped individually. Legends for mapping thus had three parts, one for soil, one for slope, and one for erosion. Each had significance unto itself.



Sketch to indicate how a single body of soil is related to the rind of the earth and to a profile. The soil body would be represented as one delineation on a detailed soil map. A set of such bodies identified by the same symbol would constitute a map unit. That unit would be described in terms of a typical profile and the ranges in characteristics among other profiles in the unit plus information on topography, stoniness if any, wetness if any, and so on.

This was a logical consequence of the basis for establishing the SCS. The justification for the organization had been soil erosion. Consequently, erosion was given primary attention and great emphasis. Mapping erosion as a separate entity in soil surveys was one means of emphasizing it.

The differences in underlying philosophies were brought home to me repeatedly. From 1938 to 1943 I was soil survey leader for the Iowa Agricultural Experiment Station. During those years I took part in the preparation of legends in several dozen counties as those became soil conservation districts. Differences in concepts of map units were beyond discussion and possible resolution. The men with whom I worked had their instructions and were not allowed to discuss basic philosophy. That had come down from headquarters and was firmly fixed. The difficulties encountered during my years in Iowa, however, paled in comparison with those that were to follow.

Officials of the U.S. Department of Agriculture were concerned about the controversy and possible duplication of effort by its two soil survey agencies. Consequently, the Secretary of Agriculture obtained recommendations from a committee of soil scientists in 1942 and subsequently decided that legends for all soil surveys should be prepared by staff members of BPISAE. The hope was that all surveys would have the same kinds of map units and be of the same caliber.

The hope did not materialize; the controversy continued. The SCS, with E.A. Norton in charge of surveys, turned to what were called "utilitarian" surveys, proposing that BPISAE restrict itself to "scientific" surveys for the improvement of soil classification. One group of surveys would be useful and the other scientific.

Map units in "utilitarian" surveys were set apart on the basis of a difference in any of a pre-selected set of characteristics thought to be important to soil use and erosion control. The expression of each characteristic was to be recognized by classes, numbering from four to six. Examples of characteristics considered important were texture of the surface layer, texture of some deeper layer, permeability of a limiting layer, and depth of rooting zone. Given the permutations for a list of a dozen characteristics, each broken down into four or more classes, the resulting number of map units within a survey area could run into the thousands and often did (Cline, 1977).

After joining the BPISAE staff in 1943, I examined the field work in some of the "utilitarian" surveys in the southeastern USA. I found that boundaries were being placed on the field sheets on various bases, not necessarily those indicated in the system. The field men used differences in landform. differences in vegetation, and concepts of soil types not yet forgotten, among other things. Moreover, no record was kept of the bases for separations. Humorous twists did grow out of the approach, as for example the proposal by a pair of men in northeastern Mississippi. They had concluded that the only distinctions needed in their work area to permit recommendations for erosion control were in the texture and acidity of the surface layers. All other characteristics could be disregarded. The men lost the argument although their proposal seemed the ultimate step in considering **only** the characteristics important to soil use and erosion control in a locality.

A further change was made by USDA in 1945 in arrangements for the construction of legends in soil surveys. BPISAE staff members were no longer to prepare legends for SCS "farm planning surveys." Those would have local legends with map units designed by the field man when he mapped the soils of a farm. The soil map was to serve in preparation of a plan for the given farm by SCS staff and nothing more. The farm maps would be expendable, not expected to contribute to a picture of the soil resources of the country. The number of immediate conflicts was thus reduced but the differences in philosophy did not disappear.

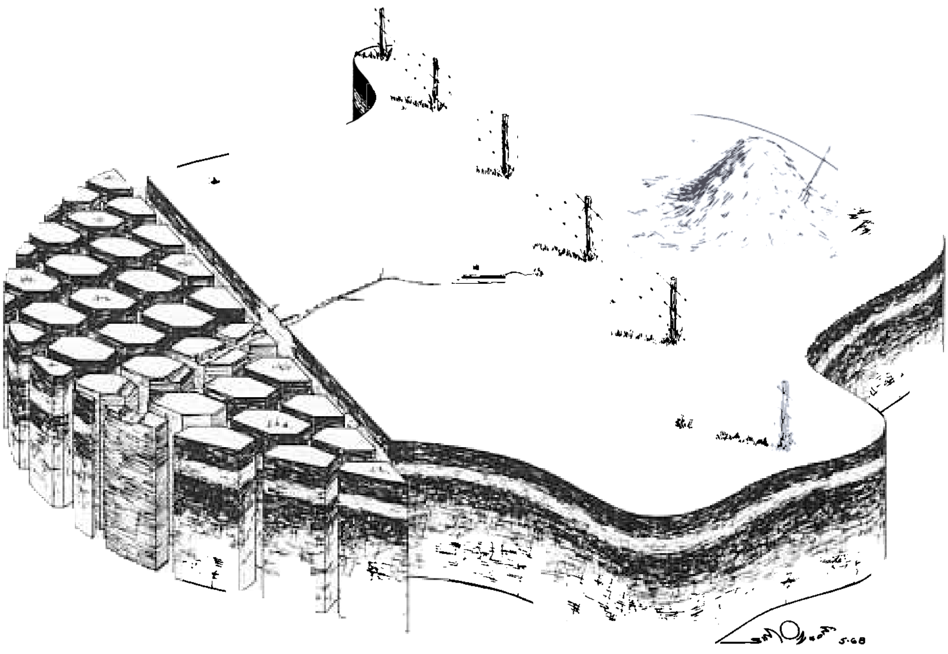
After the two survey agencies were combined in 1951, evaluation of existing surveys, partially of entirely completed, was undertaken and continued for several years. Special attention was given to the nature of map units. Eventually, many of the maps prepared of individual farms and those growing out of "utilitarian" surveys were written off as no longer useful. During the same period of years, there was a gradual shift as well to the philosophy that all characteristics of soil bodies should be considered, both in the design of map units and in the use of soils.

Increasing attention was given during the sixties to the nature and proportions of component kinds of soils in map units, once the adjustments required by reorganization had been completed. Attention was focused especially on the "purity" of map units named as single phases of soil series. The latest manual (Soil Survey Staff, 1951) specified that no more than 15% of the soils of a map unit could be outside the range of the series providing the name. The extraneous soils were called "inclusions". By 1960, enough evidence had accumulated to show that more than 15% of many individual map units named as single phases of series consisted of inclusions. Consequently, a sliding scale was being used for soil correlation in the United States (Simonson, 1963). As little as 5% would be recognized in the name of a map unit if the contrast between an inclusion and the dominant soil were large. At the other extreme, as much as 30% of inclusions would be allowed if those closely resembled the dominant soil, especially in behaviour.

The character and proportions of inclusions were studied in several places but only three examples will be cited. Powell and Springer (1965) used transects to estimate proportions of inclusions in several map units in Walton County, Georgia. They found a majority of the map units had more than the specified 15%. With few exceptions, however, the inclusions behaved in the same ways as the dominant soils.

Transects were also made in Dawes County, Nebraska, to determine proportions of inclusions in two map units (personal communication, Larry Ragon and James R. Culver, 1985). Total length of the transects for each map unit was 2.25 km with observations made at approximate intervals of

30m. In the four transects across delineations of Keith silt loam, 1 to 3% slopes (an Aridic Argiustoll), proportions of inclusions were 18, 27, 36 and 43% with an average of 31%. In the three transects across delineations of Pierre silty clay, 5 to 30% slopes (a Typic Torrert), the proportions of inclusions were 8, 18 and 35% with an average of 26%. Thus, for both map units the proportions of inclusions exceeded 15%. Differences in behavior between the dominant soils and the inclusions were small, for the most part.



Sketch to show how a soil body that would be represented as one delineation on a detailed soil map could consist predominantly of one kind of soil and have a minor proportion of a second kind. The latter is too small to be set apart at the map scale and is therefore not delineated but is considered an "inclusion".

McCormack and Wilding (1969) used point-counting to characterize map units correlated with six series in northwestern Ohio. Out of 220 profiles, 37% were classified correctly as to series. The mapping of profiles with and without IIB horizons, however, had been beset by problems. Such horizons were present in 78% of the profiles expected to have them but also in 55% of those that should not. Some inclusions differed appreciably from the dominant soils and others did not.

Two examples will be cited from other countries of attention given to components of map units. Protz et al. (1968) described a method of establishing modal profiles and then separating the inclusions in map units in Ontario, Canada. Fridland (1974, 1976) reported that map units in detailed surveys in the Soviet Union were largely combinations of "elementary soil areals" the primary constituents of the soil mantle. Each "elementary soil areal" was "soil that belongs to some classification unit of lowest rank." Although the name for that unit in the translations from Russian was "elementary soil areal," C.C. Nikiforoff told me at the time that a more accurate translation would have been "basic soil space unit." I have used the phrase from the translations, however, to minimize chances for confusion. The examples from Canada and the Soviet Union show that the nature of map units in detailed surveys was also being considered more carefully in countries other than the United States than it had been in the past.

As would be expected, soil surveys made over the years in various parts of the world have given rise to variety in the nature of map units. Thus, in Canada, soil associations were mapped in Manitoba (Ellis, 1932) and Saskatchewan (Joel et al., 1936), whereas soil types were being mapped in British Columbia (Kelley and Spilsbury, 1939). In Manitoba, an association consisted of all soils formed from the same parent material within a physiographic region (Ellis, 1932). The three component soils of an association were called the oromorphic, phytomorphic, and hydromorphic associates. In East Africa, reconnaissance soil surveys, made largely by meh from Great Britain, recorded map units for which the term "catena" was coined (Milne, 1935). Possible alternative meanings for the term were mentioned in the original paper and the word acquired more as its use spread in the world. In the Soviet Union, fairly broad groups of soils constituted the map units in the soil surveys of state and collective farms (Kellogg, 1959).

STANDARDS AND TERMINOLOGY

The standards and terms used in soil descriptions today reflect substantial evolution from those of the first soil surveys. Guides were not available to the men who mapped soils in the four areas in 1899. As Marbut (1928b) remarked about the soil surveyor "He had been placed unwittingly in a virgin field..."

As might be expected, the descriptions of the soils mapped in 1899 provide little information. Mostly, color and texture were reported for a layer or two. One printed page carried the full information about Hartford sandy loam in the Connecticut Valley (Dorsey and Bonsteel, 1900). The page has but one sentence about the soil itself: "The soil is red, brown, or yellow medium-grained sandy loam, about 12 inches deep, underlaid by yellow sands, containing little or no organic matter." Mechanical analyses are also given for five samples, probably of surface layers from as many locations, but sources are not specified.

Whitney (1900) offered some explanation in that first report of what was being attempted. Only such features of the soils could be considered as were "apparent in the field." Examples were texture, amount of gravel, depth of soil, conditions of drainage, native vegetation, and conditions of crops. All of these were apparently considered for Hartford sandy loam; much more information is provided on the setting, geology, conditions of crops, and native vegetation than on the soil itself. The balance struck in the first reports among kinds of information persisted for many years.

Descriptions of all soil types mapped to date in the United States were included in the books of instructions printed for the field seasons of 1902, 1903, 1904, and 1906. In 1902, descriptions were mostly about 50 words long, but they had been expanded to an average of 120 with a range of 60 to 200 words by 1906. Whereas the very first descriptions simply listed color and texture for a layer or two, some of those six years later reported one or more of structure, consistence, concretions, and hardpans.

Seven years later a monograph was published to describe all the soils of the country and still more characteristics were then covered (Marbut et al., 1913). The number of characteristics being recorded in a soil description continued to grow as the years passed.

Early Efforts at Standardization

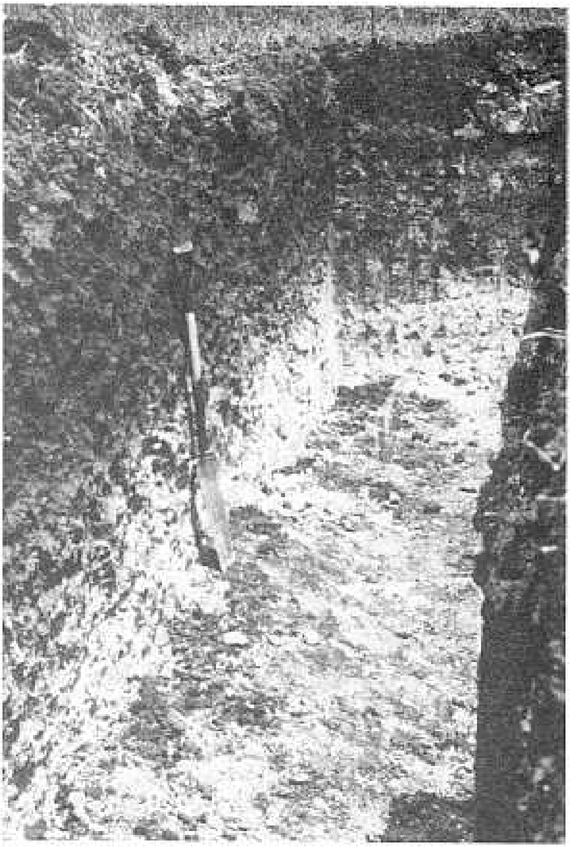
One of the first steps toward uniform standards and names was an attempt to fix names for soil colors. This step was taken in the 16th year of the American program. The field book issued that year (Bureau of Soils, 1914) listed 22 names for general use. Those names had been given in the monograph published the preceding year (Marbut et al., 1913). The 1914 field book called for exclusive use of the names in the list unless circumstances were clearly exceptional.

Interest in soil color names was widespread within the United States by 1920. The standards and names for soil colors were among eight topics covered at the first annual meeting of the American Association of Soil Survey Workers (later re-named the American Soil Survey Association) at the University of Chicago in December 1920. I have heard that a primary objective in founding the organization was to counteract the growing influence of C.F. Marbut. As a former state soil survey leader, I have no trouble accepting that statement of purpose.

At that first meeting, J.G. Hutton (1921) of South Dakota made a plea for internationally accepted standards and names for soil colors. He proposed that the Bureau of Soils approach soil survey organizations in other countries and work out some agreement that could be adopted worldwide. He mentioned as a possibility the "Color Standards and Color Nomenclature" developed and printed privately by Robert Ridgeway in 1912. Those were still available for $12 each. If it were impractical to find names for all soil colors, a "numerical system" could be developed. To read the one-page statement by Prof. Hutton now is to be reminded of how long it can take to establish standards and names.

The American Soil Survey Association was concerned throughout its 16-year existence with standards and terms for describing soil characteristics. No annual program was without one or both of committee reports and individual papers on one or both of the topics. The possibility that less attention could be given to such topics in the new organization made many members of the soil survey group lukewarm to the founding of the Soil Science Society of America in 1936. Some soil surveyors felt that they would lose their forum. Several years earlier, a complaint had been made (Bushnell, 1929) that the share of the annual program devoted to soil surveys was too small. Soil science as a whole was the camel that had been allowed to put its head in the tent and it had largely pushed soil surveys out.

Four papers on soil color were offered at the First International Congress of Soil Science in Washington, D.C., in 1927. Hutton (1928) reported that "practically all soil colors" could be reproduced with four color disks obtainable from the Munsell Color Company. Bushnell (1928) had tried both Munsell and Ridgeway systems to some extent in field identification of colors. A third report from the Soviet Union showed that soil color could be recorded in the Ostwald system (Arkhangelsky, 1927). Origins of soil colors and their significance were discussed by Zakharov (1927) in one of 15 bulletins published in English by the USSR Academy of Sciences for the 1927 Congress.


Trench about 10 m long to study small-scale lateral differences in a Typic Pellustert (Vertisol) with marked contrast between the dark solum and the underlying calcareous materials. The spade is 105 cm long.

More striking than his discussion of color is the report by Zakharov (1927) on the descriptions of structure, consistence, porosity, and "new growths and intrusions" -- these last being concretions and similar features. Names given to the main types of soil structure, for example, are cube-like, prism-like, and plate-like. The names as well as the photographs of specimens look familiar. Parallel discussions without illustrations are offered on consistence and porosity. Circulation of the bulletin by Zakharov was limited in the United States, but the standards and terms for structure and consistence spread slowly among soil scientists.

The concept of the soil profile and its horizons had been introduced to C.F. Marbut and others little more than 10 years prior to the 1927 Congress from the book by K.D. Glinka (1914). Two copies of the volume reached the library of the U.S. Department of Agriculture shortly before World War I broke out (Marbut, 1928a). The book appealed greatly to Marbut who eventually translated it from German into English (Glinka, 1927). The book also caught the attention of others; a reference to it for information on soils of Finland is cited in the report of a reconnaissance survey of some areas in Alaska (Bennett and Rice, 1915).

The concept of soil profiles as consisting of genetically related horizons, accepted by Marbut and then promoted by him, was a marked departure from ideas prevalent in the country around 1920. "Soil sections" had been recognized from the earliest soil surveys. These were subdivided into surface soil or "soil," subsoil, and substratum, mostly with a priori depths of 0-6 inches (0-15 cm), 6-20 inches (15-50 cm), and 20-40 inches (50-100 cm).

Few people recognized the importance of the concept of the soil profile with its related horizons. One exception was R.S. Smith of Illinois who wrote about the consequences of the "new concept of soil as a natural body made of parts. The new concept requires that soils be studied, classified, correlated, and described on the basis of soil characteristics..." (Smith, 1926). Changes would be needed in the modus operandi of soil surveyors to capitalize on the new opportunity.

The A-B-C notation for horizons was introduced with the concept of the profile. The notation had been proposed by Dokuchaiev for Chernozems (Mollisols) in Russia to record the sequence of horizons from the surface downward (Nikiforoff, 1931). The A horizon was the dark surface layer, the B horizon was next below it, and the C horizon deepest of the three. When introduced into the United States, the A-B-C notation was used in a variety of ways. The letters were simply used to record horizon sequences in many profiles. With the passing of time, however, efforts were made to give the letters genetic significance. Those efforts gradually took control.

Correspondence between C.F. Shaw and C.F. Marbut in the fall of 1928 illustrate the effort to give genetic meanings to the letters. In a reply to Marbut, Shaw takes exception to the opinion that "true B horizons" are restricted to soils formed under forest in humid regions. Studies in California and Mexico had provided evidence of the downward migration of clay even in some soils not fully leached of lime. Furthermore, Shaw believed that such downward migration was of "almost universal occurrence," provided only that soils were old enough and that water supplies were sufficient.

After a lapse of 23 years without publication of a soil survey manual in the United States, a new one was finally issued (Kellogg, 1937). An important share of the 135 pages in the book consists of guides on the preparation of base maps and on field operations in soil surveys. One section of 15 pages, however, covers "Description of the soil profile." A diagram of a hypothetical soil profile with labeled horizons plus general definitions opens the section which includes guides on the identification of parent materials, organic matter and root distribution, horizons, texture, structure, special formations, porosity, consistence, color, reaction, and present land use. Ten terms are given for the "important" types of structure" with general definitions, e.g., "Prismatic -- blocky structure with the vertical axis longer than the horizontal, as in the B horizons of Chestnut soils." Several of the listed terms remain in use. General guides are given for describing porosity and consistence. A list of 28 names is provided for soil colors and those **are to be used** except in unusual circumstances. The 28 names are defined in terms of the color disks of the Munsell system. Most of the 28 names are in use today. Reaction was to be recorded in nine classes for which ranges in pH are given.

The guides in the 1937 Manual grew out of a combination of experience, proposals for standard terms, and a widespread desire to standardize soil descriptions so that those would have the same meanings to all soil scientists. When the book first became available, I found the guides easy to follow. Most were already part of my working knowledge from undergraduate courses taught by Charles E. Kellogg and from working in soil surveys supervised by Thomas D. Rice. Both men had their major experience in the midwestern United States, which was my work area at the time. The ease with which I could accept and follow the guides did not turn out to be general experience, although some gains were made.

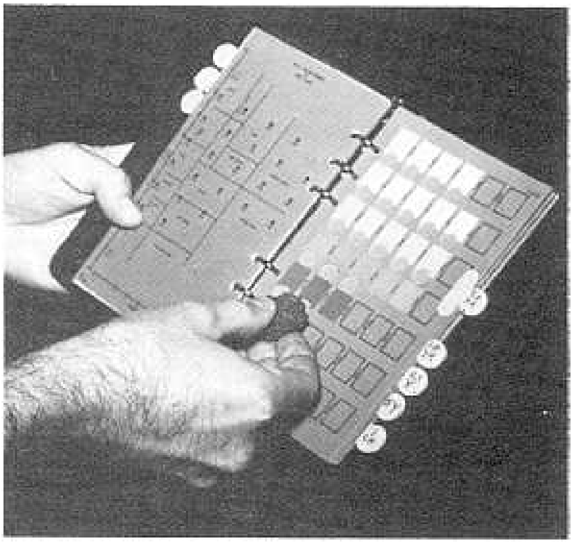
That guides do not necessarily turn out as expected can be illustrated by the consequences of a form developed in the fifties for profile descriptions. About 4x7 inches (ca 10x18 cm) in size so that it would fit into a field notebook, the form had columns for recording horizons, their depths, and their properties. Spaces were also provided for information about the site or setting of a profile. Our objective was to ensure that a minimum of information would be recorded whenever a profile was described. That objective was largely met. At the same time, an unforeseen result was that the information called for by the form turned out to be the maximum as well as the minimum recorded with but few exceptions. To place a ceiling on the amount of information recorded had been no part of our purpose.

Later Efforts at Standardization

Efforts to improve the characterization of soils gathered momentum during the forties despite the energy dissipated in controversy within the United States.

Early in the decade, Rice et al. (1941) published a bulletin "Preliminary Color Standards and Color Names for Soils." This was a more ambitious attempt and went farther toward meeting needs than had any earlier effort. The bulletin included six charts for field use. Each chart was similar in design to those in the present soil color books, i.e., arranged for comparisons of small soil specimens with standard color chips. Names for the individual chips were picked from those proposed by the Intersociety Color Council and the National Bureau of Standards (ISCC-NBS names).

The charts were used to a limited extent both before and during World War II. For example, I found that the charts worked quite well in Iowa, the soils being mostly Mollisols and Alfisols. That may have reflected the long experience of Thomas D. Rice with soils in the great Plains and Midwest. My later experience with the charts in describing Ultisols in the southeastern fourth of the country did not turn out as well. I also found that men were generally reluctant to try the new charts. Consequently, those were not widely used even though they were a big step in the right direction.



Identifying the color of a soil specimen by comparison with chips on the 7.5YR chart of Munsell soil color book.

Beginning after the end of World War II in 1945, the Division of Soil Survey, BPISAE, held annual conferences of senior staff members to develop better standards and terms for describing soils and to improve their classification. After the first year or two, representatives of land-grant universities and of several federal agencies took part in the conferences. Separate committees considered properties of horizons such as color, texture, structure, consistence, and boundaries as well as the nomenclature for horizons. Primary attention was given to properties of soils in the early years and to horizon nomenclature and to soil classification in later years. Operations of the committees can be illustrated by the work of those on standards and terms for soil color, texture, and structure.

The 1945 committee on soil color began its deliberations by considering the possibility of recommending the bulletin by Rice et al. (1941) for general use. Before long, however, the committee agreed that more distinctions were needed than had been provided in the 1941 bulletin. Attention was then turned to the standard Munsell charts with hues, chromas, and values recorded as numeral-letter combinations plus numeral fractions. After trials of those charts for more than a year, the committee recommended that the ISCC-NBS names be dropped in favor of vernacular names. The committee believed that the Munsell notations would soon become the "names" to soil scientists and that vernacular names would convey more information to the public. Several annual conferences were then required to arrive at a set of names, "to hammer out agreement on the anvil of argument," as put by Lord Bryce (1888). The charts and names in the present Munsell soil color books grew out of the discussions (arguments?) and field trials conducted between 1945 and 1950. E.H. Templin was chairman of the committee throughout its deliberations. As a member of the committees, I took an active part in the discussions and trials. Some years later, the color book was expanded by addition as an optional sheet of a "Color Chart for Gley" to cover very wet soils.

Like the committee on soil color, the one on soil texture started from the status quo in 1945. More complete guides had been worked out earlier for texture than for color. Early in the century, size limits had been adopted for eight soil separates. Origins of the size limits were reported by Truog et al. (1936) and Whiteside (1967). The original size limits remain in force today except that 0.005 mm has been replaced by 0.002 mm as the limit between the silt and clay separates (Knight, 1937). Proportions of the various separates for texture classes such as loamy sand, fine sandy loam, silt loam, and silty clay loam were first specified in the guide issued in the seventh year of the program (Bureau of Soils, 1906). Some changes were made later, as for example, those specified by Davis and Bennett (1927). The committee recommended no changes in the size limits but did suggest a few in existing but unpublished guides on proportions of separates. The proposed guides were then tested for the next two years and their adoption recommended in 1947.

The committee on soil structure began by considering the terms for structural units in the latest previous Soil Survey Manual (Kellogg, 1937) together with a proposal by Nikiforoff (1941). He had suggested that structural units be described in terms of shape, size, and distinctness under the words type, class, and grade, respectively. Earlier proposals were not reviewed by Nikiforoff but much of what he offered was foreshadowed in the bulletin by Zakharov (1927), distributed at the First Congress in 1927. Minor changes were made in the Nikiforoff outline, after which the proposal was tested for two years and then recommended for adoption in 1948.

The approaches followed in developing standards and terminology for color, texture, and structure were applied to other soil properties. A similar approach was also followed in revising horizon definitions and nomenclature. Definitions in the last previous Soil Survey Manual (Kellogg, 1937) were modified and expanded. Some changes were made in nomenclature as well.

Before the newly developed standards and nomenclature were published, they were put to use, partly for additional testing. Most ambitious of these tests, as well as an expansion of prior approaches in study of soil profiles, were a pair of projects in as many parts of the country. One was mostly for soils near the Canadian border and the other in the southern states. Sixty-nine profiles were described and sampled near the Canadian border, mostly from Michigan westward. All of these profiles were characterized further by laboratory analyses of horizon samples. The profiles represented the great soil groups of Podzols, Brown Podzolic soils, Brown Forest soils, and Gray Wooded soils, as recognized at the time. Fifty-six profiles were described and sampled later from Texas through Georgia, mostly to represent the Red-Yellow Podzolic group. I took part in the first stage of the second project in describing and sampling of profiles from central Texas through Louisiana. The weather was hot and the chiggers must have been notified of our coming; they greeted us in swarms. Never before nor since have I served as food for so many creatures. All of the horizon samples collected in the second project were also characterized further by laboratory analyses.

The morphological data from the profile descriptions and the laboratory data from the analyses of horizon samples were published for each of the two projects so as to make the original findings widely available. All data for one profile were grouped together. The data were published in two reports, one for each project. The first report covered 69 profiles representing four great soil groups (Soil Survey Staff, 1952) and the second 56 profiles, mostly representing one great soil group (Soil Survey Staff, 1954). Not evident at the time they were published, the two bulletins were precursors of a string of reports of Soil Survey Investigations that were to follow in the sixties and seventies.

The modified definitions and designations of horizons and the complete set of standards and terms for describing soils were pulled together by Charles E. Kellogg for a revised and much larger Soil Survey Manual (Soil Survey Staff, 1951). Thus, the work done to hammer out better standards and terminology reached the "sugaring off" stage. Completion of the revised version of the manual was a big step toward standardization of soil descriptions. The importance of the 1951 Manual was pointed up 10 years later by Cline (1961) -- "Development and publication of the Soil Survey Manual... was probably the most significant accomplishment for our day-to-day work during the past 22 years." Looking back from the present, I consider the 1951 Manual a major contribution to accurate and complete characterizations of soils in their natural habitats.

An unexpected but welcome response to the standards and terms of the 1951 Manual came at the end of an excursion prior to Seventh International Congress of Soil Science in Madison in 1960. Having made the trip from New York to Madison, a pair of men from Great Britain told me that they had been impressed by our knowledge of American soils but even more so by the system we had worked out for describing soil profiles. After reading the descriptions and seeing the first few profiles in the state of New York, the men decided that they could read a description in the tour guide and tell in advance what they were going to see as the next soil -- except for the fragipans! Need for improvement on other items has also become apparent since then but those deficiencies do not reduce the importance of the contribution made 36 years ago.

Changes were made during the sixties (Soil Survey Staff, 1962) in the designations and definitions of soil horizons published in the 1951 Manual. The definitions of the A, B, and C horizons were made more explicit and complete, the G horizon and the D layer were dropped, and the letter R was added for consolidated rock (not considered a soil horizon). Notations such as A&B were introduced for interpenetrating horizons. Subscript numerals and letters were replaced by suffixes, and the number of lowercase letters for subordinate properties of horizons was increased. Those designations and definitions were carried through the decade into the seventies and were used in the monograph describing the new classification system (Soil Survey Staff, 1975). Further revisions of horizon designations and definitions have been made during the last decade (Guthrie and Witty, 1982).

SOIL CLASSIFICATION

Soils must be classified in some way before they can be mapped. Before kinds of soils can be shown on maps, kinds of some sort must be recognized. At the outset of the program to map the soils of Nizhni-Novgorod, Doukuchaiev listed the first step as classification of the soils (Yarilov, 1927). That requirement has not changed.

Early Efforts in Classification

Initial efforts in the American program to classify and name soils were made without looking beyond the boundaries of a survey area. Each survey area was a universe unto itself. Even so, the possibility of correlating soils of one area with those of another was considered in 1900. The report of field operations for the first season includes a statement that no attempt will be made to correlate "a loam soil in the Connecticut Valley with a loam in the Susquehanna Valley of Pennsylvania unless the two are clearly identical in origin, in character, in relation to crops, and under essentially the same climatic condition" (Whitney, 1900). For a period of four years, the soil survey program was thus using an ad hoc system of soil classification consisting of a single category, the **soil type**.

The possibility of relating soils of one survey area to those of another did not lie fallow long. What was done is brought out in successive books of instructions for soil surveys published in 1902, 1903, 1904, and 1906. The first of those books, published in the fourth year of the program (Bureau of Soils, 1902), includes a list of the 192 soil types recognized by that time. The book published in the fifth year (Bureau of Soils, 1903), however, introduced the soil series for the purpose of showing how soil types of one area were related to those of another. The concept of the series in the 1903 book (Simonson, 1952b) is indirect but nonetheless clear:

> When Norfolk sand is being deposited the conditions somewhere in the area will undoubtedly be favorable to the deposition of gravel, of fine sand, of silt, of loam, and of clay, and whenever material of these characters is encountered, presumably coming from the same source and being deposited essentially at the same time, they should be given this distinctive name so as to show their relation to one another. Knowing as we do the processes of soil formation, either from the

disintegration of rock in place or of its transportation by wind or water, we should expect that materials from the same source would differ in their texture. The relationship of the derived soils should be shown by the use of a common name..." (Bureau of Soils, 1903).

Thus, by the fifth year of the survey program, the system of soil classification consisted of two categories -- the **soil series** and the **soil type**. The system continued to be ad hoc rather than formal. Furthermore, efforts were made for a few years to "complete" soil series so that each would include the full range of textures from sand to clay, inclusive. The book of instructions issued in the sixth year (Bureau of Soils, 1904) reports much progress in "completing series" but admits that much remains to be done. The effort must have been dropped soon afterward, however, because no mention is made of completing series in the book of instructions published two years later (Bureau of Soils, 1906).

Portrait of Milton Whitney. He was chief of the Bureau of Soils, U.S.D.A. In charge of a Division of Soils, Whitney initiated a soil survey program in 1899 intended to cover the entire country. USDA photograph.

The philosophy underlying the classification of soils in the American survey program as of 1904 is given in a statement by Whitney (1905) to introduce the report of field operations for the year. One section has the heading "Classification of soils," part of which follows:

> The classification of soils in the United States must take into account both the relationship between soils of limited areas and those which concern the entire country. Thus, while a classification founded chiefly upon texture and upon local conditions may be satisfactory over limited areas, the general classification must rely upon the basis of geological origin, the method of formation, and the topographic similarity....

> In making the classification there are four main groups of factors which are found to occupy a position of special prominence. The first of these is soil texture.....
>
> The second point... is the structure of the soil -- that is, the arrangement in space or the condition of aggregation of the soil particles...
>
> The texture, structure, and organic matter content of the soil concern the characteristics of the soil body itself and are nearly as pronounced in the isolated sample as in the mass of the soil under field conditions. There are, however, soil characteristics which are dependent upon the location, the altitude, the surface configuration, and the relationship of the soil body to other surrounding materials. These peculiarities of the soil are grouped under the general term of the physiographic relationship....

Examples of such "peculiarities" are then listed as surface topography, depth to impervious clay or rock, stoniness, and landforms such as level, rolling, and hilly.

> All of these groups of soil characteristics are taken into consideration in the classification and naming of the soil type....

The place of the "physiographic relationship" mentioned by Whitney (1905) is brought out more clearly in the book of instructions published in the eighth year of the program (Bureau of Soils, 1906). Those instructions show that a third category had been added to the _ad hoc_ system since 1904. No instructions were published in 1905 so far as I have been able to learn. The 1906 book listed soil types by series and soil series by physiographic provinces, 10 of which were recognized in the United States by that time. Three years later, the total was 14 and they were then called "great soil provinces" (Whitney, 1909). Examples of the names assigned to provinces are Atlantic and Gulf Coastal Plains, Piedmont Plateau, Limestone Valleys, and Glacial and Loessial Province.

The three-category system continued to be _ad hoc_ rather than formal and was never described in a publication as a system of soil classification. Yet it continued to be the primary frame of reference for construction of mapping legends and for the correlation of soils among survey areas for half a century. Furthermore, the system was a good reflection of the prevailing theory of soils genesis, namely, that rock weathering was also soil formation. That theory was well expressed in the initial statement about the nature of the soil series (Bureau of Soils, 1903). Prevailing theories of soil genesis are strongly reflected in all systems of soil classification (Simonson, 1980).

Even though the main frame of reference for soil classification and correlation remained the same for many years, series criteria were gradually modified and expanded in number almost as soon as the category was first recognized. Summaries of such changes were not published. Changes can be found only if soil survey reports published in different years are compared. Thus, for example, thick and dark A horizons (not so designated) were added to the list of series criteria in the Glacial and Loessial Province by 1904. In that year, the Marshall and Miami series were both recognized in Tama County, Iowa (Ely et al., 1905). The soils are described as formed in identical loess but the Marshall soils had thick, dark surface layers and the Miami soils did not. Prior to 1904, the Miami series had been mapped throughout the region which extended from Maine to Mississippi to Montana. Thus, at the same time that Miami loam was mapped in New York and Ohio, Miami black loam was mapped in North Dakota. Even at that stage, however, a distinction was being made at the "soil type" level by insertion of "black" into the name in one instance. Beginning in 1904, the Miami series was restricted to soils with thin A horizons and evident E horizons (mostly Alfisols), whereas the soils with thick A horizons (mostly Mollisols) were set apart as the Marshall series. Many changes in series criteria were made over the years (Simonson, 1964).

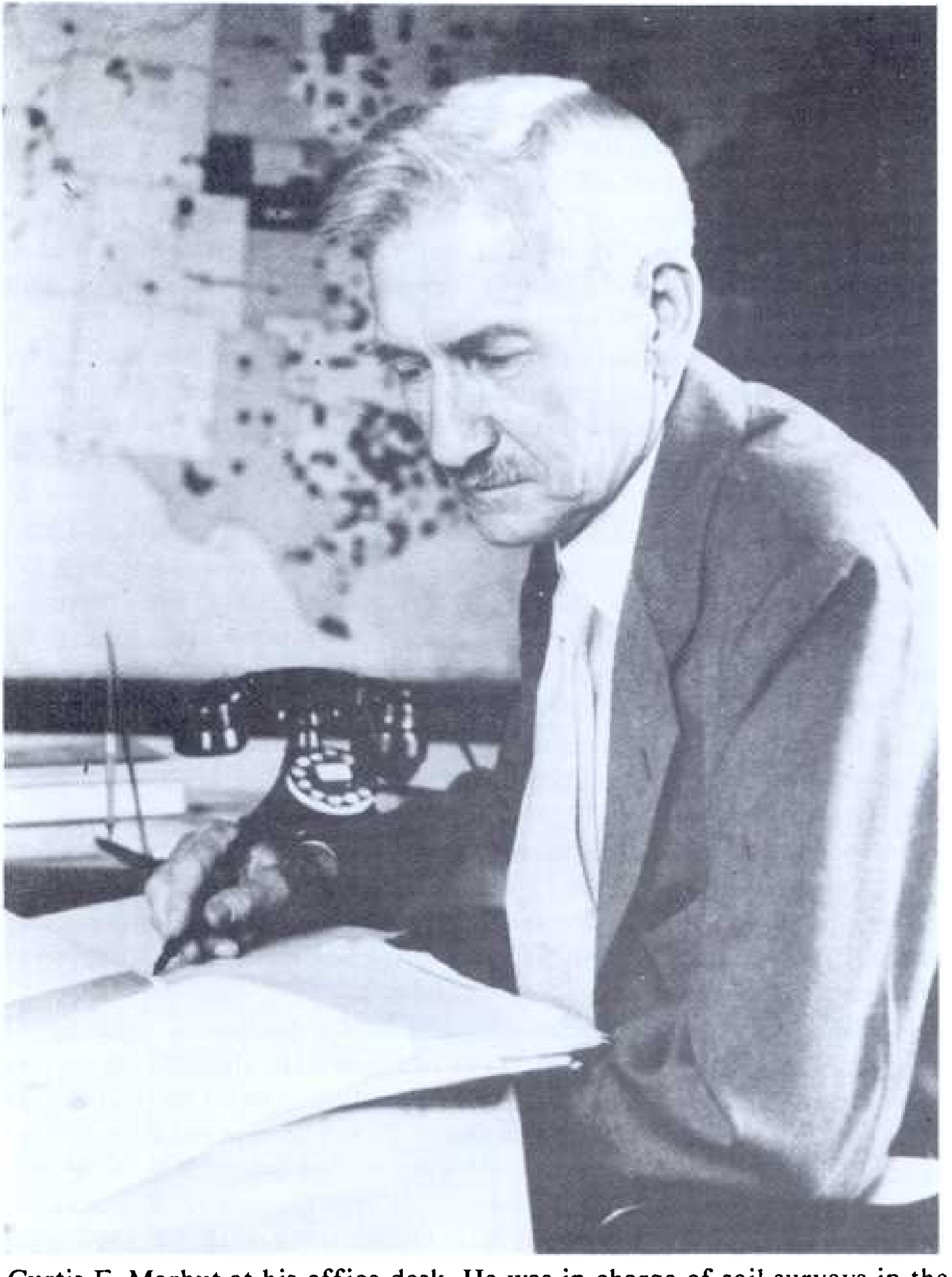
Approaches followed in the few efforts in soil survey and soil classification underway in other countries at the turn of the century were in part like those in the United States and in part different. Soils were classified on the basis of geology generally, as pointed out by Coffey (1912a). The one exception was the program in Russia, mentioned earlier.

The concept of soil and the approach to classification developed in Russia during the last quarter of the 19th century remained largely unknown in other countries through all of the first and part of the second decades of the 20th century (Simonson, 1985). Few individuals heard of it prior to the second decade. Sibirtsev had presented the ideas of the Dokuchaiev school to the Seventh International Geological Congress in St. Petersburg, Russia, in 1897 (Coffey, 1912b). Although published in French (Boulaine, 1984), the paper largely escaped notice. A translation and condensation by Peter Fireman of the 1897 paper was published in the United States four years after it had been presented originally (Sibirtsev, 1901a, 1901b) but that failed to register. Looking at the translation now, I think it was good. Yet it made little or no impression on American soil scientists. Even the identity of Peter Fireman is now a mystery. Americans missed a second chance to learn about the Russian work from a report published in Great Britain a bit later (Tulaikov, 1908). It had no more impact than did the earlier papers by Sibirtsev. The items were probably read by few American soil scientists.

The prevailing American approach to soil classification during the first twenty years of the century and some indicators of coming changes are illustrated by three maps published by the Bureau of Soils within a 4-year span. These were the first efforts to present a general picture of soil resources of the United States. All of the maps were at a scale of 1:7,000,000. Published just prior to 1910 the first map had the title "United States Soil Provinces" (Whitney, 1909). Fourteen map units were used to show the soils of the country. Almost 20 years later Marbut (1928a) wrote of the map "...A so-called province map was constructed in 1907 or 1908 on the basis almost entirely of geological characteristics with practically no reference whatever to soil characteristics and for several years thereafter the soils were related to one another on the basis of geological features as outlined in that so-called province map...."

The second map carried a 1911 date and the title "Preliminary Soil Map of the United States" (Coffey, 1912b). It had 22 map units, some with the same boundaries as those of the 1909 map but many with different boundaries and names. Two big differences between the maps prepared a few years apart and published by the same organization were (a) recognition by Coffey of a large region of "Arid soils, undifferentiated" in the western part of the country and (b) splitting the eastern part into 11 units of dark-colored prairie soils and 10 units of light-colored timbered soils. The map was in a bulletin released in 1912 (Coffey, 1912b). In his letter of transmittal recommending publication of the manuscript by Coffey, Whitney wrote that the author had begun working for the Bureau of Soils in 1900 and had held all positions from the lowest to the highest. After a few more complimentary remarks, the letter repudiated the manuscript because it did not represent the view of the Bureau.

When I first read that letter of transmittal a number of years ago, I thought it strange indeed for Whitney to recommend publication, on the one hand, and repudiate the manuscript, on the other. Later I learned that in 1903 Whitney had approved publication of three and rejected three manuscripts from the Division of Soil Management, of which F.H. King was Chief. Thereupon King resigned and went to the University of Wisconsin. Moreover, he published the second three papers privately (King, 1904) with the approval of the Secretary of Agriculture. The papers reported that yields of corn were increased continuously by progressively larger applications of manure on plots at Goldsboro, North Carolina; Upper Marlboro, Maryland;



Curtis F. Marbut at his office desk. He was in charge of soil surveys in the United States from 1910 until his retirement in 1934.

and Janesville, Wisconsin. Increases were marked on the poorer soils. Moreover, the amounts of nutrient elements soluble in water also increased as manure applications were increased. Such findings were in direct conflict with the thesis offered by Whitney and Cameron (1903), namely, that all soils contain enough nutrients for plant growth and that amendments of various kind improve conditions of temperature and moisture rather than nutrient status. From this bit of history, I inferred that Whitney decided to recommend publication of the Coffey manuscript with a disclaimer rather than reject it and risk the possibility of later private publication. The first alternative must have seemed the lesser evil. By the time the manuscript was published, Coffey had left the Bureau, working later in both Ohio and Illinois.

The third "soil map" of the United States, published in 1913, had the title "Soil Provinces and Soil Regions of the United States" (Marbut et al., 1913). That map had 13 units, one less than the 1909 map. Ironically, the one map unit in the 1909 legend that had included the word soils -- "Residual soils of western prairies"-- had been dropped by 1913. Many names in the 1913 legend are those used for physiographic provinces today, e.g., Great Plains, Piedmont Plateau, and Great Basin. Although the 1913 map is not mentioned in the criticisms by Marbut (1928a) of the 1909 map, those apply with equal force to both. Perhaps Marbut did not want to criticize his own efforts. Being senior author of the bulletin that carried the map, however, Marbut must have had major responsibility for it. Having been State Geologist in Missouri prior to joining the Bureau of Soils to take charge of soil surveys in 1910 (Kellogg, 1974), Marbut was apparently satisfied with the ad hoc three-category system through the early part of the decade. The combination of the text in Bulletin 96 and the general "soil map" provides good evidence that changes in the viewpoint of Marbut had not yet occurred. Those changes might have followed his encounter with the book by Glinka (1914).

In addition to providing a general soil map of the country, Bulletin 96 seems to have been meant to serve as a Domesday Book for the American soil survey program up to that time. The volume is massive, with a total of 791 pages (Marbut et al., 1913). All soil series and types that had been recognized are listed in the volume by provinces or regions. Brief descriptions are given of the active series plus keys for their identification. Inactive series, those that were established but later dropped, are also listed together with current placements of such soils in active series. In other words, re-correlations of a number of soils are reported, which are indications of changes in progress. The text materials and their organization clearly show that the ad hoc system of classification consisting of three informal categories of physiographic provinces, soil series, and soil types was the frame of reference for the soil survey program.

Furthermore, the approach in Bulletin 96 also demonstrates that the concept of soil and the theory of soil genesis remained what they had been in the previous decade without showing any effect of the ideas presented by Coffey (1912b) the preceding year. Those ideas seem both eloquent and valid today, as for example:

> ...Although the soil consists largely of degenerated rock, not all unconsolidated rock can be considered as soil. This material must be acted upon by life in some form before it becomes a true soil. Until this action has taken place it is best to think of it as unconsolidated rock, although it may be readily converted into soil by the influence of organic agencies... The soil is an independent, natural body, a biogeological formation, differing essentially from the rock which underlies it, although closely related to it. It is the one great formation in which the organic and inorganic kingdoms meet and derived its distinctive character from this union.

Supposedly, the bulletin by Coffey (1912b) was based on his Ph.D. thesis, submitted to George Washington University. The opening page carries a footnote of thanks to Dr. Merrill for "many helpful suggestions and kindly criticisms," which is especially intriguing. Differences in concepts of soil and in theories of soil formation expressed by Coffey (1912b) and Merrill (1913) are striking. In all three editions of his book, Merrill clearly considers (a) soil to be the mantle of loose and weathered rock and (b) soil formation to be "rock weathering in its fullest sense." Coffey was obviously marching to his own drum despite those sounding all around him.

Although Coffey left the Bureau of Soils at the beginning of the second decade, he did not lose interest in soil classification for several years. He served as chairman of a "Committee on Soil Classification and Mapping" for the American Society of Agronomy (Coffey, 1914). The committee had two members from Canada, one from each of 10 states, two from the state of Ohio, and one from the Bureau of Soils. Among the group, three that were active in soil surveys for long periods were G.N. Coffey, C.F. Marbut, and A.R. Whitson. Checking the list as a matter of curiosity, I found that I had met five of the members, had heard of another five, and did not know of the remaining five.

The Committee prepared a progress report (Coffey, 1914) in which a system of classification was proposed. This had five categories, i.e., I. Precipitation and humidity -- Soil regions; II. Dynamic agencies -- Soil provinces; III. Lithology -- Soil groups; IV. Specific characters and conditions -- Soil series; and V. Texture -- Soil class. Classes listed for Category I are humid, semi-arid, and arid soil regions. Classes are not listed for Category II but the "dynamic agencies" are given as weathering, biological, water, atmosphere, and glaciation. How these might be used as class criteria for soil provinces is not explained or illustrated. Classes are not given for Category III, but four rock types are listed as criteria, namely, (a) Acid crystalline rocks; (b) Basic crystalline rocks; (c) Sandstones, quartzites, shales, and slates; and (d) "Lime rocks, including marl, limestone, and marble." A few remarks are made about Categories IV and V, the series and class, but full explanations are not given and may have been thought unnecessary. The scheme was a skeleton rather than complete system.

Discussions recorded in the report show that agreement was not reached within the committee. Several members offered criticisms but few changes were actually suggested. Coffey offered a pair of criticisms plus a proposal for a change in Category I. He suggested that too much emphasis was being given to agencies of soil formation and not enough to properties of the soils themselves. Hence, he suggested that "dark-colored prairie soils (chernozems)", and "light-colored timbered soils" be set apart in the highest category. That step would bring the proposed system more into harmony with "work in other countries, especially Russia." That suggestion was rejected by the committee. Members seemingly shared the view expressed by Milton Whitney in his letter transmitting the manuscript for the bulletin by Coffey (1912b): "The primary grouping is based upon the origin and processes of formation rather than upon the characteristics of the soils themselves." The logic behind that statement is a far cry from current ideas in the United States. It resembles those in the Soviet Union where genesis of soils is considered the proper basis for their classification (Gerasimov and Ivanova, 1959). Current Russian understanding of soil genesis, however, differs greatly from that of Milton Whitney in 1912.

Coffey also objected to the list of "dynamic agencies" because they were not all of equal rank. Most could and should be included under the first one -- weathering. That suggestion was also rejected by the committee.

One item in the report, seemingly without a clear purpose, consists of remarks about the decision made by an International Commission for Mechanical and Physical Examination of Soil in 1913 (Lyon, 1914). The

Commission had decided that size limits of soil separates should be those proposed by Atterberg (1908) in steps down from 2.0 mm, namely, 2.0-0.2, 0.2-0.02, 0.02-0.002, and less than 0.002 mm. Perhaps Lyon thought that those size limits could be adopted for use in defining soil classes (Category V).

I have never found a second report of the Committee on Soil Classification and Mapping. Consequently, I presume that the committee was unable to make further headway in its efforts. Moreover, the proposed system was not put into practice anywhere as far as I have been able to learn. Instead of adopting the proposal, the survey program continued to use the ad hoc system with three informal categories as the primary framework. Changes were being made in the concepts of soil series, as had been true from the beginning. In reporting on trends of the time Coffey (1916) wrote that the tendency was to classify on the basis of "**actual differences in the character of the soil itself** rather than upon a dissimilarity in the method of formation, the kind of rock from which it was derived, or some other basis..."

Intermediate Efforts in Classification

Harbingers of coming change in the United States are provided by a pair of papers published by C.F. Marbut in the early twenties although the primary framework for correlation and naming of soils remained as it had been since the early part of the century. Soils were still classified into series and types within physiographic provinces with major emphasis on geology. For example, in a survey of the Panama Canal Zone and contiguous territory, Bennett (1929) set one soil type apart from two others because the underlying rocks were different, not that the soils themselves were known to be.

By 1920, Marbut had been in charge of soil surveys in the Bureau of Soils for about 10 years, with the opportunity to examine soils in all parts of the country. His universe had been greatly enlarged from that of his native Missouri, where he first became interested in soils. Moreover, he had read "Die Typen der Bodenbildung: Ihre Klassifikation und geographische Verbreitung" by K.D. Glinka (1914). Acquaintance with a much larger universe of soils and with the Russian ideas must have changed his outlook. The change is strikingly illustrated by the contrast between ideas expressed in the two papers and his actions as a member of the Committee on Soil Classification and Mapping less than 10 years earlier (Coffey, 1914). At that earlier time, Marbut opposed a proposal by Coffey to set apart at a high level the dark-colored soils of the central prairies from the light-colored, leached soils of the eastern United States. Seven years later, Marbut (1921) distinguished these two broad groups in his top category (a category is a set of classes of the same rank).

In both papers Marbut (1921, 1922) outlines the beginnings of a classification system for soils east of the Rocky Mountains. That outline was a major part of the 1921 paper but only one of three in the 1922 paper. The system was a first approximation of the scheme presented in more complete form to the First International Congress of Soil Science in Washington, D.C. (Marbut, 1928b) and in the final form in the Atlas of American Agriculture (Marbut, 1935). Three elements of the final scheme were already embodied in the first two papers.

The three elements that persisted from the beginning are (a) splitting all soils into two classes in the top category, (b) geography as a class criterion, and (c) the concept of soil "maturity."

Marbut (1921) first divided the soils east of the Rockies into a pair of broad groups by a line running south and a little west from northwestern Minnesota to the Texas-Mexico border. West of the line the soils were said to be dark and east to be light in color. Six years later, Marbut (1928b) coined the terms Pedocals for soils west and Pedalfers for soils east of the line. From the evidence available then, he believed that calcium carbonate accumulated in soils west but not east of the line. Aluminum and iron were believed to accumulate in soils east of the line. Accumulations of carbonates, on the one hand, and of sesquioxides, on the other, were also thought to be mutually exclusive (Marbut, 1928b).

A second element of the 1921 paper that persisted through all of the draft schemes prepared by Marbut was the use of geography as a basis for differentiating classes of soils. The two broad groups east of the Rockies were set apart first on the basis of a geographic boundary rather than specified soil characteristics. The belief that geography and characteristics of soils coincided fully is implicit in the separation.

A third element in the 1921 paper that was carried through all later draft schemes consists of the concept of soil "maturity." Marbut (1921) proposed that the broad groups of soils east of his north-south boundary be subdivided into east-west belts of gray, brown, and yellow soils from the Canadian border to the Gulf of Mexico. The southernmost belt is labeled "yellow soils" because Marbut considered them the "mature" specimens in the region. Soils with red colors in their deeper profiles were common, but those were not considered "mature." Marbut (1921) argued then and later that classification should be based on "mature" specimens of soils as was done for animals and plants.

Despite the emphasis on "mature" soils in 1921 and later (Marbut, 1926, 1928b, 1935), what he had in mind for them is not clear. The names of some groups of "mature" soils of dry regions are listed in a paper on the classification of "arid soils" (Marbut, 1926). First, soils of the word are subdivided into a pair of classes, viz.:

I. Soils developed or developing under the influence of normal good drainage.

II. Soils developed or developing under the influence of excessive moisture.

In the remainder of the paper, only those soils in the first group (I) which qualify as "arid soils" are considered. Such soils are said to be those that in a "mature" stage have a zone of salt accumulation, usually calcium carbonate, in some horizon of the profile. Four sets of soils are then listed in outline form, presumably with mature, immature, and post-mature specimens in each. In the first are black, grayish black, and very dark brown soils; in the second are chestnut or dark brown soils; in the third brown soils; and in the fourth gray desert soils. Post-mature soils are said to be rare and no indications are included as to how they can be recognized. Possible bases for recognition of immature soils are listed as thickness and color of the A and B horizons but no limits are specified.

From the various papers by Marbut, the best I can do is to guess what he might have had in mind for "mature" soils. My guess is that those were formed (a) in undulating uplands which had been stable for extended intervals, (b) in deep regoliths of intermediate physical constitution and chemical composition, and (c) with deep water tables. Because this is an interpretation, it may be in error.

The initial steps taken by Marbut (1921) in his first paper were repeated in part as the last three major sections of the paper published the next year (Marbut, 1922) and also in the paper given three years later (Marbut, 1926). These several efforts were partial approximations of the scheme of soil classification presented at the 1927 Congress in Washington, D.C. (Marbut, 1928b).

The first two major parts of the paper on soil classification (Marbut, 1922), however, break new ground of major importance, which is why I think of it as an American classic. The first major part includes a few remarks on the concept of soil and then spells out 10 principles for classification of soils as natural objects, with a strong flavor of the logic of John Stuart Mill (1874). The first of the principles begins "The soil is a natural body, developed by natural forces acting through natural processes on natural materials." That emphasis prevails throughout the paper.

The second major part consists of a list and discussion of 10 items that should be covered in the examination and description of a soil profile. The list is much more detailed and complete than any offered earlier in this country, as far as I know. Thirty years later, Whiteside (1954) found that the list largely remained valid although a few additions, deletions, and refinements had been made.

Although they cannot now be fully known, the circumstances of presentation and publication of the paper on soil classification (Marbut, 1922) are intriguing. The paper was published is the report of the second meeting of a decidedly informal organization, the American Association of Soil Survey Workers. The program for the meeting lists a paper by Marbut comparing soils of southern Europe with those of the United States. No item on soil classification <u>per se</u> is in the program, and nothing on the soils of southern Europe appears in the published report. Marbut may have abandoned that topic for one he considered more important, program or no program. The report of the meeting consists of mimeographed pages stapled together without covers, a reasonable approach against annual dues of $2. Those mimeographed sheets are becoming brittle after 60 years. Fortunately for future American pedologists who may be interested in ideas of their predecessors, the paper on soil classification as well as others by Marbut were reprinted later (Krusekopf, 1942).

Criticisms by Marbut (1922) of past practice in the classification and naming of soils -- criticisms which applied directly to what he himself had been doing -- were repeated more completely later (Marbut, 1926). Those reflect the state of knowledge in the soil science of their day.

> Soil science is probably the only one of the sciences which continues to use terms from some other science and which refers to the characteristics of bodies treated entirely in terms of those sciences with only an incidental relation to the soil. The science until recently has been encumbered with a great number of terms, and in common parlance and even in much literature that claims to be scientific many of

> those terms are still used. Some pedologists however have discarded many of those terms, such for example as those referring to geological features or agricultural crops, **granite soil** and **wheat soil** serving as illustrations of my meaning. Because, probably, of the close relation shown to exist, by the work of the last few years, between the soil and the climate under which it was developed there seems little tendency to discontinue the use of climatic terms in soil literature.
>
> Those are, however, just as objectionable as those derived from geology or agriculture even though recent work has shown that the character of the soil is dependent at maturity to a much greater extent on the influence of climate than on that of the parent rock.

The two preceding paragraphs are from a paper entitled "The classification of arid soils". Thus, while he was criticizing others for using climatic terms in the names of soils, he did that himself for some reason. No explanation for that is available now.

The three papers on soil classification published by Marbut from 1921 through 1926 were preludes to the one presented to the First International Congress of Soil Science held in Washington, D.C., in 1927 (Marbut, 1928b). That scheme was subsequently revised for publication in the Atlas of American Agriculture (Marbut, 1935). The final version had six categories. Those had been numbered and given names from the bottom to the top as follows: I. Soil units (soils types); II. Soil series groups; III. Local environmental groups (family groups); IV. Broad environmental groups (great soil groups); V. Inorganic colloid composition groups; and VI. Solum composition groups.

The top category (VI) consisted of two classes, Pedalfers and Pedocals. The former was subdivided into three classes in Category V and these were called Soils from mechanically comminuted materials, Soils from siallitic decomposition products, and Soils from sallitic decomposition products. Only one class, Soils from mechanically comminuted materials, was recognized in Category V for the Pedocals.

In Category IV, eight great soil groups are listed for the Pedalfers and four plus "Pedocalcic soils of arctic and tropical regions" for the Pedocals. Those of Pedalfers are Tundra, Podzols, Gray-Brown Podzolic soils, Red soils, Yellow soils, Prairie soils, Lateritic soils, and Laterites. Those named for the Pedocals are Chernozems, Dark Brown soils, Brown soils, and Gray soils.

How the three classes of Pedalfers set apart in Category V were to be subdivided into the eight great soil groups in Category IV was not indicated. I presume that each of the three classes would not include all eight great soil groups. Some distribution of the eight among the three at the next higher level must have been intended though none is specified.

Recognition of Red soils and Yellow soils as separate great soil groups indicates a change from ideas held earlier by Marbut. He had previously considered the "yellow" soils but not the "red" ones to be "mature" (Marbut, 1921). If the principle that classification should be based exclusively on "mature" soils were to be followed, a great soil group of Red soils was not justified. Those might have been set apart from the yellow soils at the level of family groups (Category III).

In the final outline of his scheme, Marbut (1935) lists a number of kinds of soils that should be recognized as "family groups" in Category III. The lists of names are identical for the Pedalfers and Pedocals, viz.: Groups of mature but related soils, Swamp soils, Glei soils, Rendzinas, Alluvial soils, Immature soils on slopes, Salty soils, Alkali soils, and Peat soils. The above list suggests that all kinds of soils associated with the "mature" soil or soils were to be part of a family group with the latter. Like his earlier publications, however, the monograph on soils of the United States (Marbut, 1935) is not explicit as to what "mature" does mean despite the importance given the term.

Previously, Marbut (1922) had pointed out that animals and plants were classified on the basis of mature specimens exclusively. Neither the old nor the young were part of the bases for scientific classifications of fauna and flora. Moreover, Marbut argued that the approach in soil classification should parallel those for animals and plants. Marbut must not have considered the large differences in the life spans of animals and plants, on the one hand, and the time-spans for the existence of kinds of soils, on the other, as important. Yet the greatly different time-scales certainly undercut the validity of the analogy.

Marbut was unable to complete his system. Even the final version remains unfinished. What he might have done had he had more time we cannot know. He had retired from the post of Chief, Division of Soil Survey, Bureau of Chemistry and Soils, USDA, in 1934 and been succeeded by Charles E. Kellogg. Marbut thus put the final touches on his scheme after he had retired. He then went to England in 1935 to attend the Third International Congress of Soil Science and left it bound for China, traveling part of the way on the Trans-Siberian Railroad. During the journey, he contracted pneumonia and then died in Harbin, Manchuria, on August 23, 1935 (Krusekopf, 1942).

By that time, Marbut had been a major figure in soil survey and soil classification in the United States for 25 years. Special recognition was accorded him by the American Soil Survey Association at its annual meeting in Washington in the fall of 1934. On behalf of the Association, A.R. Whitson of Wisconsin presented a gold watch to Marbut at a banquet one evening. Much as he appreciated the gesture on the part of the Association, Marbut was about to attend the sessions the following day without wearing the watch until he was reminded of it. Then he did get the watch out of the desk and took it with him, although it seemed unimportant to him compared to the approval of his fellows.

Several gaps persisted in his system of soil classification. Marbut did not group classes in the lowest category into those in progressively higher categories. Soil types were being placed into series, but that was apart from the proposed system. Some series were listed as examples of great soil groups (IV) and of solum composition groups (VI). Categories III and V, however, remained shadow rather than substance. Those categories were not used.

Looking at the proposal by Marbut (1935) now, we can see that the system had serious flaws but was still a big step forward. The system was one of the first, if not the first, with a formal hierarchy of categories meant to have many classes at the bottom and few at the top, thus being adapted to universes differing greatly in size. The system was also an effort to define classes on the basis of soil characteristics.

The importance of basing their classification on characteristics of soils had been stressed by Marbut for some years, beginning in the early twenties (Marbut, 1922). One of his better statements was made, of all places, to a meeting of sugar technologists in Cuba (Marbut, 1932a). An excerpt follows:

> The bases of classification selected in former years have been fundamentally inapplicable to soils mainly because of the lack of soil knowledge. Soils are natural bodies and their classification must recognize that fact. They must be classified as natural bodies. Until a knowledge of their characteristics as natural bodies had been accumulated, a classification as natural bodies was, of course, impossible. Although it is a fact that the soil is one of the great fundamental resourcesof the world which has been utilized by man as long as any other yet it has been almost the last one to receive any direct study. Until soils are studied as soils, knowledge of soils as soils, of course, cannot be obtained. The study of soils as soils can take place in one

place only, and that is in the place where the soil lies. Soils lie in the open on the surface of the earth and must be studied in the place were they occur....

What then is a rational basis for soil classification? The answer is so simple that it seems almost childish to state it. The real basis consists of the characteristics of the soils themselves....

Prevailing viewpoints on soil classification in the early thirties are illustrated in the introductory remarks by Marbut (1932b) and subsequent comments by pedologists from western Europe and the USSR during one session of the Second International Congress of Soil Science in Moscow in 1930. All remarks are centered on the relationships between broad soil groups and their environments. The remarks clearly indicate the extent to which theories of soil genesis shape efforts in soil classification. The remarks also demonstrate how much the ideas of a soil scientist are shaped by the universe within which he works.

Shortly after the final version of the classification system by Marbut (1935) was published, a new formal guide for making soil surveys was also issued (Kellogg, 1937). This manual included a major change in the definition of the soil series. The 1937 definition follows:

A series is a group of soils having genetic horizons similar as to differentiating characteristics and arrangement in the soil profile and developed from a particular parent material....

Approximately 1½ pages of text are then used to explain the definition. Emphasis on the profile, its horizons, and their characteristics is a marked departure from definitions of the soil series in the early field guides. In those, the series was to consist of a set of soils differing in texture but formed in regoliths deposited or otherwise accumulated at the same time and supposedly having the same composition.

The 1937 series definition reflected and summarized gradual changes that had been in progress from the early years of the soil survey program. Recognition of profiles as bases for the study of soils had been proposed almost 20 years earlier (Marbut, 1922). That profiles should get more attention had been gaining wider and wider acceptance. Several years earlier Rice (1929) had discussed the concept of the series and its place in soil classification at a meeting of the American Soil Survey Association. He offered a series concept centered on the profile and its horizons -- their arrangement, morphology, and composition.

Publication of the modified series definition in the 1937 Manual was not followed by an immediate change in the framework for recognizing soil series. The old framework continued to be important. Patterns of thought once widely accepted and followed tend to persist for a long while; they have a momentum of their own (Simonson, 1980). Even so, that changes were underway and gaining strength is demonstrated by modifications in the classification of the soils originally included in the Sassafras series, recognized first in 1900 in the Coastal Plain of Maryland. Prior to 1931, two additional series had been split from the original Sassafras series. During the thirties, however, 10 more series were recognized among soils once included in the Sassafras series (Lyford and Quackenbush, 1956). The additional series were recognized because of two developments. First, the redefinition of the series category called for classes with narrower ranges than in the past. Second, much more mapping was being done than in the previous decade.

Portrait of Curtis F. Marbut. In charge of soil surveys in the United States from 1910 until his retirement in 1934, Marbut had one career as a geologist prior to 1910 and another as a pedologist afterward.

After the 1937 Soil Survey Manual was published, a program was begun to prepare and distribute standard descriptions for all soil series in the country. The need for standards and their possible forms had been discussed by Baldwin (1934) several years earlier. Series descriptions, most of them very brief, were then on file at the headquarters of the Division of Soil Survey in Washington but were available to few people. The first standard descriptions for distribution were put out in mimeographed form in 1938. Even those were brief. Plans were to revise the descriptions and re-issue them periodically to keep them up-to-date.

Three years after the scheme developed by Marbut was published in final form, it was superseded (Baldwin et al., 1938). The new or modified system also had six categories called type, series, family, great soil group, suborder, and order from the bottom to the top. Changes were made to correct what were considered two major deficiencies in the earlier system and to drop the concept of soil maturity. The first purpose was to accumulate all of the geographic bias of the system in the top category, that of soil orders. That category was revised by replacing the two orders (Pedalfers and Pedocals) by three to be called zonal, intrazonal, and azonal. Those terms had been used by Sibirtsev (1901a, 1901b) prior to 1900. A second purpose was to recognize extensive and important soils lacking a clear place in the Marbut scheme. Such soils were set apart as great soil groups in the intrazonal and azonal orders.

The effort to correct deficiencies was partly successful. Like its predecessor, however, the system of Baldwin et al. (1938) was a skeleton with the same two shadow catagories, the second and fourth from the top. Some geographic bias also persisted into the category of great soil groups. Moreover, the system was never completed by grouping soil series into the classes in progressively higher categories. Specimen series were listed for families and for great soil groups but more was not attempted generally (Simonson, 1980). Trial groupings of series into families were made prior to World War II in each of Iowa and New York but those were not published. Modification of the system of Marbut had to be hurried so that the results could be published in the 1938 Yearbook of the U.S. Department of Agriculture, "Soils and Men". The decision to cover soils in that yearbook was made in 1937, allowing a short lead time for preparation of materials to be published. I took part in the scramble for a while, working in Washington, D.C., during the summer of 1937 to edit and revise manuscripts for the next yearbook. My blue pencil marks were on several dozen of the manuscripts that were printed the next year.

Even after the classification system by Baldwin et al. (1938) was published for ostensible use in the American soil survey program, the old framework of physiographic provinces remained the primary one for recognition and naming of soil series (Simonson, 1980). Nonetheless, some changes were being made, e.g., ranges in series were being narrowed. Thus, for example, a total of 20 series had been proposed by 1954 for soils that were all part of the Sassafras series in 1900 (Lyford and Quackenbush, 1956). Greater attention was also being given, though not wholeheartedly, to identification of soil profiles with the great soil groups of the 1938 system.

Later Efforts in Classification

A step toward placement of all series into the current classification system was taken at the soil survey conference in 1945 by adoption of a requirement that each standard description should identify the series with the appropriate great soil group unless that were clearly impossible. At least the order should be named. Some participants in the conference, as for example, James Thorp, objected to such a requirement because of probable difficulties. Nevertheless, the proposal was adopted, chiefly on the grounds that we should be using the system or quit saying that we were. The anticipated difficulties followed quickly. At the 1946 conference, committees were set up to review and sharpen the concepts and definitions of a number of great soil groups. Summaries of the efforts over the next few years were published first by Thorp and Smith (1949) and later in more complete form by Simonson and Steele (1960).

Discussion and debate over the concepts and definitions of great soil groups -- and also of families -- continued at the annual conferences until 1950 without turning up satisfactory answers. By that time, conference participants had learned that changes in any category could affect others in the system. Additional difficulties had also been encountered. Consequently, the conference decided in 1950 that piecemeal modification of the 1938 system was unsatisfactory and that the whole system should be overhauled. That decision led eventually to the 7th Approximation and to "Soil Taxonomy".

With work started in 1950, much of the coming change in the American classification system had been accomplished by 1960 under the leadership of Guy D. Smith. Six proposals, identified as numbered approximations except for the first two, were developed by 1958. None of these was published for general criticism. The first to be issued for general review and criticism was the 7th Approximation put out in time for the Seventh International Congress of Soil Science (Soil Survey Staff, 1960). Summaries of the approximations and of some discussions have been assembled by Cline (1979).

Reactions to the approximations were mostly negative. Thus, the first one, which covered only the four top categories and had relatively few classes in each, drew heavy fire because of the coined names. Subsequently, names were omitted and classes were identified by a decimal numbering system until the 7th Approximation was issued. The hope was that attention and criticisms would be focused on the structure of the system and on the concepts and definitions of categories and classes. The 3rd and 5th approximations were circulated widely within the United States and to a limited extent outside the country. In contrast, copies of the 7th Approximation were given to all participants in the Seventh International Congress in 1960. Copies were also shipped to many individuals and organizations in other countries. I recall vividly how my friends from other countries recoiled in horror and shock at first sight of the names in the proposal.

Still under development in 1960, the 7th Approximation was not adopted immediately in the American soil survey program. Consequently, during the fifties and first half of the sixties, three systems of soil classification were in existence in the United States. One system was being born, so to speak; another was presumably being followed in the survey program (the 1938 system with some modifications); a third was still an important framework for recognition of new series, though not acknowledged (physiographic provinces, series, and types). Most of the soil series on the books had been recognized within the early system and a large residue remained in the collective minds of soil scientists.

The 7th Approximation with some modifications was adopted for general use in the American soil survey program at the beginning of 1965. By that time, several trial groupings of the soil series of the country had been completed and circulated widely for review and criticism. These provided guides for application of the system, the adoption of which did bring changes in its train. All series in a survey area had to be placed in the system when a report was prepared for publication. Moreover, all standard series descriptions had to be revised as well to show their placements. The revision of the standard descriptions of the 11,000 series on the books continued well beyond 1970.

Formal adoption of the 7th Approximation did not automatically eliminate use of previous systems. Some people reverted to one or the other of the previous systems from force of habit. Some preferred an earlier system. Supervising soil classification and correlation in the United States during the sixties, I frequently found that series were proposed or their validity defended within one or the other of the systems described by

Whitney (1905) and Baldwin et al. (1938), more often the former than the latter. Thus, three systems were being used concurrently. That situation is not unique to soil classification. Ideas once widely accepted are not easily replaced but persist for a long time (Simonson, 1980).

After recovering from their initial dismay over the 7th Approximation in 1960, soil scientists could consider it more thoughtfully. Furthermore, information was presented on the historical background and general structure (Simonson, 1962), the objectives and basic assumptions (Smith, 1963), and the logic (Cline, 1963). Evidence of growing interest was indicated by requests for a few thousand reprints of my 1962 paper. Further evidence came during the excursion prior to the Eighth International Congress of Soil Science in Romania in 1964. Asked to comment on the first profile, a Chernozem not far from Bucuresti, and recalling reactions of participants in the 1960 Congress, I confined my remarks to comparisons of the profile with soils in central Nebraska. When I stopped, a man in the pit asked, "Where would you put this in your 7th Approximation?". The people around the pit responded in lively fashion to my calling the profile a Vermustoll. At all subsequent stops during the excursion, Americans were asked for placements of profiles in the 7th Approximation unless those had already been volunteered.

Additional evidence of interest could be drawn from a number of sources but only one more will be cited. This comes from introductory remarks in a bulletin outlining a system of classification for South Africa:

> This was an exciting time pervaded by an atmosphere of experimentation and improvization. In the United States, the USDA Soil Survey Staff was developing an imaginative new system through concerted application of talent and experience that is unique in contemporary soil science. This was happening in full view of world attention. The logic of the approach was refreshing and...it loosened the shackles of traditionalism and stimulated re-thinking on soil classification... (MacVicar et al., 1977).

Whatever the reasons, various national systems of soil classification were proposed during the sixties. Three examples will illustrate differing approaches. Bakker and Schelling (1966) described a system for the Netherlands which shares some criteria with the 7th Approximation but differs from it in many ways. The nomenclature is also different. Rather fine distinctions are recognized, consistent with the size of the universe. Northcote (1965) revised a bifurcating scheme for Australia in which a limited number of properties are considered with emphasis on morphology. Classes are rather broad and are identified by symbols rather than names. The Canada Soil Survey Committee (1978) developed a system over a period of years in parallel with efforts in the United States. The Canadian system thus shares a number of features with the 7th Approximation. Diagnostic criteria overlap in part but there are differences as well. Nomenclature is quite different.

Quite apart from any effects on soil classification generally, the 7th Approximation was the basis for a general soil map of the USA, published in the National Atlas (Douglass et al., 1969). The map was at a scale of 1:7,500,000, the same as the one in the 1938 Yearbook of Agriculture, "Soils and Men".

General soil maps were being published in other countries, of which three examples will be cited. The Stichting voor Bodemkartering (1961) put out a map of the Netherlands at a scale of 1:200,000. The map scale could be large because the universe covered was small. For the somewhat larger universe of Ireland, a scale of 1:575,000 was used (Gardiner and Ryan, 1969). For the much larger universe of Australia, a scale of 1:2,000,000 and 10 sheets were needed (Northcote et al., 1960-1967). The individual sheets together with explanatory notes were completed over a period of years with contributions from a number of individuals. Another general soil map of Australia was prepared for the Ninth International Congress of Soil Science held in Adelaide. It was on a single sheet at a scale of 1:10,000,000 (Stace et al., 1968). The intent of all of these maps was to present a general picture of the soils of a country.

APPLICATIONS OF SOIL SURVEYS

The purpose of the first soil surveys in the United States was to show on maps the kinds of soils that differed in crop response, especially in yields. To be considered were all features "which appear in any way to influence the relation of soils to crops." At the same time, Whitney (1900) recognized that only such features could be shown as were "apparent in the field." Early in the program, Whitney (1901) compared the suitability for specific crops of soils of several areas where surveys had been made. Later, more attention was given to general suitability of soils as more and more surveys were completed.

One application of soil survey findings must have been made before the ink was dry on the first printed maps. Introduction of Sumatra tobacco was proposed in the Connecticut Valley, Connecticut and Massachusetts, because some of the soils had the same texture as those being used for the crop in Florida. Moreover, the weather during the summer months was similar in the Connecticut Valley and Florida (Cameron, 1901). It seems farfetched now that introduction of a new crop would be proposed on the basis of similarities in soil textures and summer weather. Even more farfetched is the fact that the proposal was successful. As a consequence, Whitney must have been more convinced than ever that soil texture was the key to productivity. His conviction lasted for years and led to acrimonious arguments (Hilgard, 1904; Hopkins, 1904; Whitney, 1904) and even to some ridicule of the Bureau of Soils (Russell, 1905).

A summary statement of the purpose of soil surveys is given in the book of instructions published in the 16th year of the American program. The long sentence follows: "The purpose of the soil survey is to map, classify, and correlate soils, to determine and describe their characteristics, to report on the actual use being made of the soils and on their adaptation to various crops, so far as that can be determined, and upon the relative productiveness of the several soil types" (Bureau of Soils, 1914). For some reason, this long sentence is in a section of the book on "Administration." The style of this long sentence and others in the book combined with the interchangeable use of "soil units" and "soil types" throughout suggest to me that it was written by C.F. Marbut even though no author is identified. The instructions were prepared at least three years after Marbut had become Chief of the Division of Soil Survey. Moreover, he had earlier been the senior author of the massive tome that came to be known among field men as "Bulletin Ninety-Six".

The long sentence tells not only what was being done in 1914 but also what was done for the next 20 years with few exceptions. The survey publications furnished information on the uses of soils, on the crops being grown, and on the relative productivities of soil types. This can be illustrated by the information in the survey report for Prince Georges County, Maryland (Perkins and Bacon, 1929). Collington fine sandy loam was said to be one of the most important soils in the country. Moreover, most areas were in a "high state of cultivation." Corn, wheat, and tobacco were the major crops although others were also grown on the soil. Ranges in yields are given for several crops, plus some information on management practices, including fertilizer use. The description and discussion of Collington fine sandy loam as one of the most important soils in the county rates 2½ printed pages. Less important or less extensive soils are given less space.

The general practice in presenting results of a soil survey during the first 30 years of the American program matched the pattern illustrated for Prince Georges County. Amounts of information given about the map units were adjusted to their importance in a survey area. Stress was not placed on precision in estimating usefulness and productivity; general information was considered enough. Furthermore, from about 1910 through 1930, Marbut placed major emphasis on completing a map to show soils of the country (Simonson, 1980). He made some changes in his last few years and more followed his retirement in the early thirties.

Modifications of earlier approaches in the use of soil survey information were already evident in the early thirties. One example, mentioned previously, was the soil survey of McKenzie County, North Dakota (Edwards and Ableiter, 1942), made especially to provide information for tax assessment (Kellogg, 1933). Other examples are soil surveys used in the design and construction of highways in Michigan (Allemeier, 1973). During the late twenties, the Michigan Department of State Highways provided funds for some fellowships at Michigan State College for the study of frost-heaving in subgrades. One such fellowship supported graduate study by Charles E. Kellogg.

A further change in the information provided by soil surveys during the thirties was the introduction of productivity ratings for map units (Ableiter, 1937). Initially, the rating was supposed to express the "inherent productivity" of a soil. Within a few years, however, soil scientists realized that production required some kind and level of management. Examples of ratings on that basis are provided in Tama County, Iowa (Aandahl and Simonson, 1950). Those ratings were prepared in 1940. Productivity ratings were initially expressed on a scale of 1 to 10 of 0 to 100. Ratings on the latter scale were in steps of 5, allowing 20 in all.

Some applications of soil surveys during World War II departed from the ordinary. The soils as mapped in existing soil surveys in north-central Iowa and south-central Minnesota were graded into three classes in 1942 according to their expected suitability for the production of hemp. I took part in the rating of soils in north-central Iowa, county by county. The ratings were then used as bases for allotments of acreage for growing hemp on farms. Considerable quantities of the crop were produced during the war; 18 factories for processing hemp were in operation in Iowa. A parallel effort was conducted in the southeastern part of the country to identify soils best suited for production of peanuts. I provided some help on that project after joining the BPISAE staff in Knoxville, Tennessee. Results of that project were summarized after the war (Bachman et al., 1947). A third application of survey data on the nature and distribution of soils was made through contributions to terrain intelligence studies (Cady et al., 1945). These were for use in areas of combat outside the United States.

The interpretations and applications of survey data were expanded appreciably after World War II. Traditional applications were continued and new ones added. The variety of applications is indicated by those covered in a symposium at the meetings of the Soil Science Society of America in 1957 (Aandahl, 1958; Klingebiel, 1958; Odell, 1958; Stokstad, 1958). These applications included use and management of land for farming, forestry, and range; land appraisal for tax assessment and loans; highway engineering; and residential development.

Traditional applications of information on the nature and distribution of soils in planning their use and management on farms were increased and made more specific during the last 30 years, as discussed by Klingebiel (1958).

Yield estimates replaced productivity ratings (Odell, 1958). These were made more explicit by defining management components more completely.

It was but a short step from yield estimates to their use in appraisals of rural land for tax assessment. As a bit of history in this connection, desire for a better basis for tax assessment and equalization had been a prime mover in the birth of pedology through the work of Dokuchaiev and his colleagues in Russia little more than a century ago (Yarilov, 1927). Soil survey data were made part of the basis for tax assessment in Iowa

(Aandahl, 1953; Aandahl et al., 1954). Initiated in a few counties the approach spread throughout the state, with county governments contributing funds toward survey costs. This same approach, also applied in Fairfax County, Virginia, has spread to other states as well.

Soil surveys have long been used in the design and construction of highways in Michigan (Stokstad, 1958). A "Field Manual of Soil Engineering" has gone through a half-dozen editions (Michigan Department of State Highways, 1970). The use of soil survey data by state highway departments spread rapidly during the fifties (Olmstead, 1957), in part because of a cooperative program between the Bureau of Public Roads and USDA to obtain certain engineering test data and include those in soil survey reports.

Applications of soil survey data in residential development began in Fairfax County, Virginia, in 1953 and spread elsewhere. Three years earlier while acting as Chief, Division of Soil Survey, BPISAE, I had decided that the Division should participate in making a soil survey of the rural parts of the county. Large numbers of septic tanks in the county were failing and some action was necessary (Clayton et al., 1959). If better information about the soils would help to solve this health problem, that would be a distinct public service. If soil survey data would not be useful, we ought to find that out and the sooner the better. Applications of the survey data turned out better than anyone had anticipated (Henry, 1960). After having used the information for a few years, Fairfax County officials reported that the soil survey was saving the county as much each month ($ 40,000) as it had contributed toward the initial cost (Clark, 1959). Moreover, the findings have continued to be useful (Pettry and Coleman, 1973). The approach followed in Fairfax County has since spread to other areas.

Efforts in the interpretation and application of soil surveys were increased in the sixties, with most efforts going to provide more complete information and to spread it more widely. In the United States, county soil survey reports continued to provide information on usefulness and productivity of soils for crops, pasture and range, forests, and wildlife. Information was also included on suitability of soils for subgrades, septic tanks, fills, embankments, and the like. Examples of these kinds of information are given in a report for Bamberg County, South Carolina (Crow et al., 1966).

Applications of survey data can be illustrated from many places. Three more examples are a guide for land use planning (Maine Agricultural Experiment Station, 1967), a report on the soils and their uses around Syracuse, New York (Olson et al., 1969), and the interpretations of surveys for wildlife management (Wertz, 1966). A variety of applications were discussed in a symposium during the meetings of the Soil Science Society of America in 1965 (Bartelli et al., 1966). Reports on uses of soil surveys were published by the Highway Research Board (1961) for highway planning and construction and by the Federal Housing Administration (1963) for urban development. These last illustrate especially the expansion underway in non-agricultural applications of soil surveys in the industrialized countries (Simonson, 1966; Haans and Westerveld, 1970). Some more esoteric applications are illustrated among a group of papers published during the first half of the seventies (Simonson, 1974).

Soil surveys have been applied in various ways in a number of countries, as will be illustrated by some examples. Agronomic implications of map units were discussed for England (Mackney, 1969), a variety of applications in each of New Zealand (Gibbs and Leamy, 1968) and Portugal (Cardozo, 1968) and estimates of soil productivity for the Soviet Union (Fridland and Grigor'yev, 1967). Mention was also made earlier of applications in the Netherlands (Haans and Westerveld, 1970). Possible applications were also reported in a bulletin on soil survey interpretation published by the Food and Agriculture Organization of the United Nations (Steele, 1967).

What share of the public does know about the interpretation and application of soil surveys is itself not known. I doubt that the share is large, even among the people who would benefit most. Since applications of survey data were started in Fairfax County, Virginia, more than 30 years ago, the soil survey has received publicity every now and then from local newspapers and radio stations. Each bit of publicity brings a batch of new phone calls to the county soil scientist. The number of phone calls has remained about the same after each bit of publicity, suggesting that a large share of the public does not know of the soil survey. That situation prevails in an area where the applications have been widespread and have taken many forms.

Approximate proportions of benefits derived from applications of soil surveys were estimated by Kellogg (1974) when he reported on developments in soil genesis, classification, and cartography during the life of the International Society of Soil Science at the time of its 50th anniversary. He thought that 50% of the benefits gained from soil surveys in the United States were from their use in planning suburbs and towns; 25% from planning and construction of highways, airports, and pipeline; and 25% from farming, forestry and grazing. At times in the past, I have thought as well that survey applications outside might some day exceed those inside agriculture. What might happen remains to be learned but for the world as a whole the production of food and fiber will continue to be of prime importance.

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