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CURRENT PROBLEMS IN RESEARCH

Soil Classification in the United States

Classification of soils at any point in history largely reflects current understanding of soil genesis.

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Much that is of importance to mankind takes place in the soil. It is the foothold, directly or indirectly, for much of the life on this planet. It serves as a foundation for buildings and for roads. It is the realm wherein living creatures mingle with the shell of weathered and weathering rock. As Coffey (*1*) wrote some 50 years ago, "It is the one great formation in which the organic and inorganic kingdoms meet and derives its distinctive character from this union." Earlier, Shaler (*2*) argued that "this slight and superficial and inconstant covering of the earth should receive a measure of care which is rarely devoted to it." If this measure of care is to be provided, the nature of soil and the kinds of soils and their distribution must first be known.

Present over nearly all land areas, the soil mantle is like a surface film. It is a minor part of the outer crust, and the crust in turn is a small part of the earth as a whole. The soil is the outermost part of the regolith, commonly between 1 and 6 feet thick in vertical cross section. The upper boundary of soil is clear, but the lower boundary is often obscure. As a rule, no distinct break sets soil apart from the remainder of the regolith, but the changes in the regolith that give rise to soil profiles occur largely in the the uppermost few feet. Thus, the soil forms a veneer at the surface of the earth (Fig. 1), a thin mantle of major importance to food production and of substantial scientific interest.

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Even though it is so widely distributed as to be commonplace, soil is highly complex. Every soil body consists of a variety of minerals, an assortment of particles of many sizes, a collection of dilute solutions, and a mixture of gases. Under natural conditions it harbors immense numbers of microorganisms and is host to numerous plant roots and small animals. The reactions among the components of the soil and between the soil and the life within it are many and varied, at least during the growing season and in many cases throughout the year. Every body of soil is thus a dynamic system, one which is open rather than closed. The multitude of reactions that occur in the formation of soil and in its continuing change are controlled by larger cycles in the wearing down and building up of land surfaces, the march of climate, and the succession of different forms of life.

The complexity of soil, both in composition and in the variety of reactions under way within it, dictates the approach to its effective study. Such study must draw upon a number of other sciences—for example, geology, physics, chemistry, and biology. Substantial progress in all of these, and in others, is a prerequisite for the successful study of soils. This is but one requirement.

Recognition that the soil is a natural body worthy of attention in itself is also a prerequisite for its effective study. Only within the last century has it been recognized that a soil is a collection of natural bodies paralleling those of flora, fauna, and rock formations. Before this fact was recognized, construction of systems of soil classification applicable to wide areas was not possible. Furthermore, the construction of such systems required some knowledge of the characteristics and distribution of this collection of natural bodies. This is readily evident from a review of a few past efforts in soil classification.

Past Efforts in Classification

The earliest attempt to classify soils systematically seems to have occurred in China some 40 centuries ago (*3*). The soils of the kingdom were reportedly graded into nine classes, apparently on the basis of their known productivity, during the reign of the Yao dynasty (2357–2261 B.C.). The best grade were the yellow, soft soils of Yung Chow (Shensi and Kansu), whereas the next best were the red, rich clayey soils of Su Chow (Shantung, Kiangsu, and Anhwei). Seven additional grades of soil were recognized and given names. Exactly what may have been done 40 centuries ago is not now determinable with any assurance. The available evidence does indicate, however, that soils of the kingdom were classified and that the size of individual land holdings and the tax to be paid the state were related to soil productivity. Comparable efforts to base tax assessment on soil productivity may have been made elsewhere in ancient times, but records of such efforts are lacking. All known attempts of this kind are part of recent history.

Marked impetus was given to the scientific study of soil by a much later effort to relate tax assessment to soil productivity. In fact, this later effort, which took place in Russia little more than a century ago (*4*), led directly to the establishment of pedology as a separate discipline. In 1882 the government of Nizhni-Novgorod employed V. V. Dokuchaiev, a geologist, to take charge of a program for classifying and mapping soils as a basis for tax assessment. This program was carried forward over a period of several years. At the outset, however, Dokuchaiev divided the assignment into two parts: (i) the establishment of a natural classification of soils, and (ii) the grading of those soils according to their agricultural potentiality. The program carried forward in Nizhni-Novgorod included field studies of soil morphology, laboratory analyses of soil samples, construction of maps to show distribution of various kinds of soils, and measurements of crop yields on those soils. The kinds of soils were then graded on a scale ranging from 15 for the poorest to 100 for the best, to show their "natural value," and the ratings were used as a basis for tax levies.

As a result of his studies, Dokuchaiev broke sharply with the concept of soil held in his day by most scientists and by agriculturists. Soil was thought to be disintegrated rock mixed with some decayed organic matter, simply a product of rock weathering (*5*). This concept was widely held during the first few decades of the 20th century (*6*). Dokuchaiev argued (*7*) that soils should be considered as a separate kingdom, similar to the kingdoms of rocks, plants, and animals: "Soil is an independent natural body which must not be mistaken for surface rocks. . . ."

Dokuchaiev and his students attempted to classify soils of Russia on the basis of this concept, using data available at the time. A brief description of the last scheme proposed by Dokuchaiev, in 1900, will illustrate his approach. The scheme consisted of two categories, the higher having three classes and the lower 13. The three classes in the higher category were designated "normal" soils (dry-land vegetative or zonal soils), "transitional" soils, and "abnormal" soils (*7, 8*). There were seven subclasses under normal soils, three subclasses in each of the other two broad classes. The 13 subclasses were called "soil types" and were identified by names such as tundra (dark brown soils), light gray podzolized soils, chernozem, laterite or red soils, secondary alkali soils, and alluvial soils. Use of the name "normal" soils and the relating of each subclass of "normal" soils to climatic and vegetation zones seem to reflect a theory of soil formation in which first place is accorded climate and vegetation as factors in soil formation.

Dokuchaiev and his followers set out to describe and characterize soils as natural bodies rather than as mantles of weathered rock, giving attention first to exterior characteristics, or to soil morphology because it was the most obvious feature. Reporting on these efforts in 1927, Glinka (*9*) stated that pedologists in Russia had arrived at the conclusion that every soil "consists of several separate horizons, following one another in a vertical direction, and united by a common origin [genesis]. . . ." The concept of the soil as an independent natural body possessing a degree of internal organization expressed in the profile, with its horizons, was a major contribution of the Dokuchaiev school of pedology. Recognition of the full soil profile and of the relationships between horizons was a gradual process which took place over a period of many years (*10*). Nevertheless, the ideas developed in Russia have had enormous impact on the study of soils throughout the world.

An immediate practical objective prompted the first efforts to classify and map soils of the United States, as had been the case earlier in China and Russia, though taxation of land was not involved. The first soil surveys in this country were made to increase production of a single crop, tobacco (*11*). Within a year or two the objectives had been expanded to include increasing the production of other crops and providing information on lands proposed for irrigation. Soils were considered a medium for plant growth, and attention was focused primarily on characteristics of soil important for plant growth and on local differences of consequence in crop production (*12*). The prevailing concept of soil as a mantle of disintegrated rock mixed with some organic matter is clearly reflected in a scheme proposed in 1911 (***13***) for the classification of soils.

The first clear argument in the United States for the recognition of soil as a distinct natural entity was offered by Coffey in 1912 (*1*). In a report on soils of this country he states that "the soil is an independent, natural body, a bio-geological formation, differing essentially from the rock which underlies it, although closely related to it. . . ." Coffey later lists requirements for an ideal classification of soils, emphasizing the importance of recognizing inherent differences in the soil itself as fundamental and arguing that each soil had a definite genesis and has a distinct nature of its own. Before listing these requirements, Coffey briefly summarizes and appraises prior approaches in the classification of soils, including that of the Dokuchaiev school in Russia.

One part of Coffey's study is a proposal for classifying soils of the United States. He states that five broad classes, or divisions as he calls them, are known well enough to be recognized. These five are defined on the basis of characteristics of the soils themselves, though some terms relating to climate and vegetation are used in the names. The five divisions are as follows: (i) arid or unleached soils low in humus; (ii) dark-colored prairie soils or semi-leached soils rich in humus; (iii) light-colored timbered or leached soils low in humus; (iv) dark-colored or swampy leached soils high in organic matter; and (v) organic soils or peat and muck. The several hundred soil series recognized in the soil surveys completed prior to 1912 were thought to be classifiable into the five divisions, though the classification was not made at the time.

The first effort in the United States to devise a comprehensive scheme of soil classification, one which might be useful outside as well as within this country, was presented by Marbut (*14*) to the First International Congress of Soil Science in 1927. The scheme consisted of six categories with two classes in the highest category, several thousand in the lowest category, and intermediate numbers of classes in the intermediate categories.

The two classes of soils in the highest category were named pedocals and pedalfers. Pedocals were soils in which calcium carbonate had accumulated while horizons were being differentiated in the profile. Such soils were thought to be restricted in their occurrence to regions of low rainfall. Pedalfers were soils in which aluminum and iron had accumulated in the profile. These were thought to occur only in regions of moderate-to-high rainfall. The information available about soils in 1927 indicated that these two classes were mutually exclusive, though it has since been learned that they are not.

In the construction of this scheme Marbut attempted to meet the requirements for an ideal classification outlined earlier by Coffey (*1*) and himself (*15*). Clearly, he thought of the soil as an independent natural body. His criteria for differentiating classes are mainly characteristics of the soils themselves. As additional information has become available since 1927, however, it has become evident that some of the criteria are inferences as to genesis rather than actual characteristics of soils. Moreover, features outside of the soils themselves seem to have been the actual differentiae in some cases. Weaknesses of this kind are not peculiar to the scheme outlined by Marbut; they are evident in the schemes proposed by Dokuchaiev and in schemes that have been proposed since 1926 (*16*).

It is possible to develop many different classification schemes for natural objects as complex as soils. Many have therefore been constructed, and more can be expected in the future. Therefore, not all the schemes devised in the past are reviewed here. A few examples have been considered to indicate what has been done. These few examples also lend support to certain general conclusions about the process of constructing schemes.

General Problems

Two general conclusions stand out among those that can be drawn from critical study of schemes developed thus far. First of all, no scheme can be any better than the state of knowledge in the soil science of its day. As a matter of fact, the validity of any scheme is a direct reflection of the knowledge of soils and their characteristics on the part of its author or authors. Secondly, the construction of each scheme is circumscribed by the current understanding of soil genesis, the knowledge of soil formation. Whether consciously or otherwise, the selection of characteristics as definitive for classes or as criteria for differentiating classes is governed by the understanding of soil genesis. The relative weights given to individual characteristics of the soil when a number of them must be considered collectively in classification are also largely determined by theories of soil genesis.

Given the importance of theories of soil genesis to the classification of soils, it might be argued that direct use of interpretations of soil genesis as a basis for constructing a scheme would be desirable. Unfortunately, such direct use leads to serious weaknesses in schemes for soil classification. This is due to a combination of reasons.

The genesis of many—perhaps of most—soils seems to have been more complex than is generally realized even now. Certainly, evidence accumulated during the last decade or two clearly points toward more complex histories than were inferred earlier to explain the present characteristics of soils. It now seems that many soils have been subject to all, or part, of more than one cycle of horizon differentiation, even though it may not be possible to identify the features that reflect each of the entire or partial cycles. The simplest cases are explainable, but their existence is in itself an argument for the occurrence of complex cases.

The explanation that can be offered at any point in time for the genesis of a given soil is a matter of inference

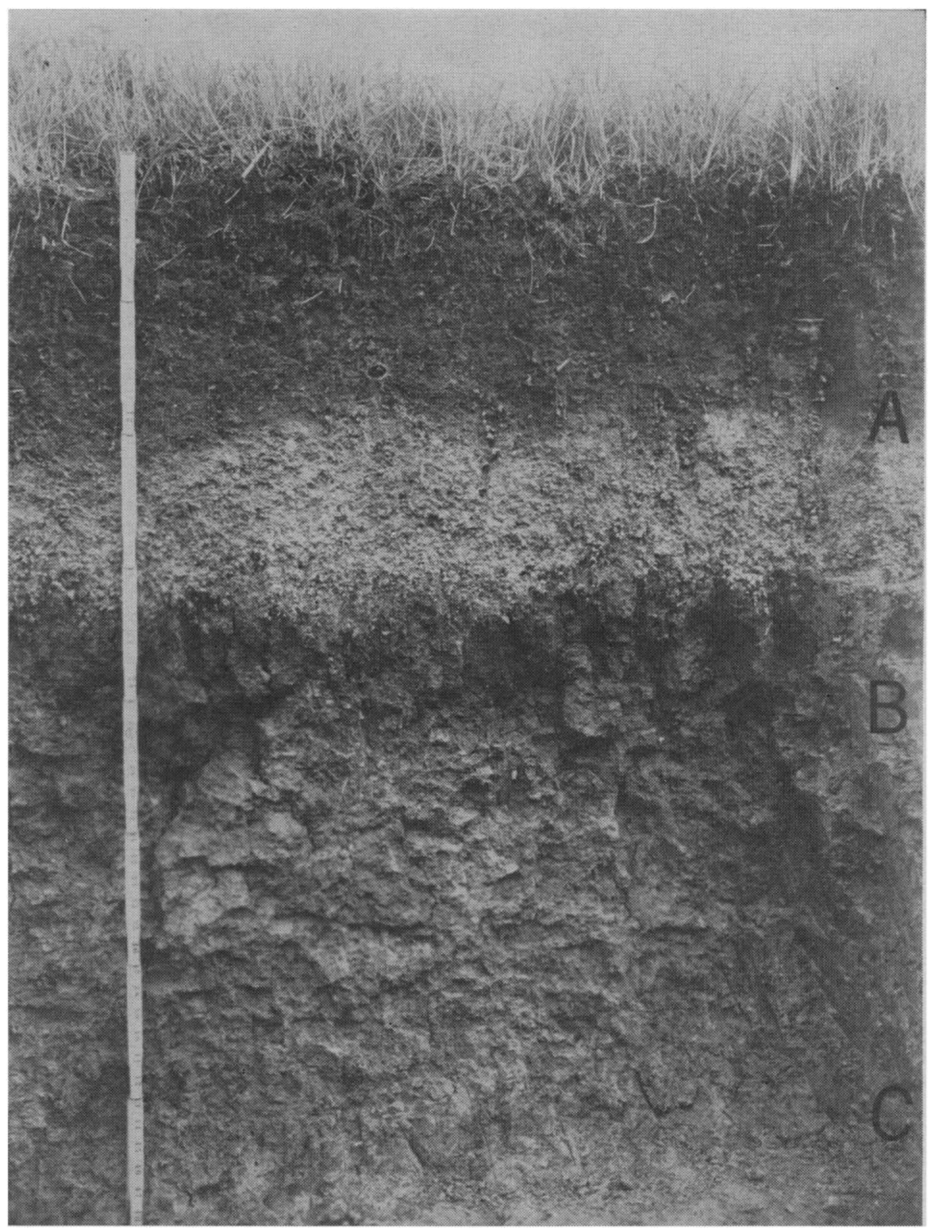

Fig. 1. A soil profile about 4 feet deep showing, in downward succession, a dark A_1 horizon (12 inches thick), a light gray A_2 horizon (6 inches thick), a dark B horizon (12 inches thick), and a C horizon (bottom 6 inches of exposure). This profile represents Edina silt loam, a soil formed from loess under prairie vegetation on flat interfluves in south central Iowa and north central Missouri.

rather than one of direct observation or experiment. Current understanding of soil genesis is limited. Furthermore, it also seems that the genesis of a number of soils is obscure. Inferences can be made as to the probable path of genesis of a given soil, but the factual basis for such inference is always modest.

The basing of classification schemes solely on interpretations of soil genesis is consequently subject to large risks of error. Difficulties may arise in one or more of several ways. Direct reliance on inferences about the genesis of given soils as a basis for their classification may lead to the placing of indistinguishable soils into different classes. Similarly, soils that are not alike in morphology and composition may be placed together in the same class because of the interpretation that their genesis was the same. Finally, there is always the danger that classification will be based on the inferred causes of the present soil characteristics rather than on the characteristics themselves. The importance of using characteristics rather than possible explanations for those characteristics has been stressed by Coffey (*1*) and Marbut (*15*).

The danger that markedly unlike soils will be classed together and that like soils will be put in separate classes exists with any approach in classification, but it is greater in some approaches than in others. In the current status of soil science, the use of morphology and composition of soils as criteria for differentiating classes seems to present the smallest risk of error. The selecting and weighting of characteristics as criteria are best done in the light of current understanding of soil genesis. For the sake of brevity, a scheme so constructed may be called a morphogenetic system. Theories of soil genesis are an important part of the background for choosing criteria in such a system, but the criteria themselves are characteristics which can be observed and measured, not inferences, which cannot be rigorously tested.

Current Effort in the United States

Because it can be no better than the state of knowledge in the soil science of its day, any scheme must eventually be modified or replaced. This is the only way whereby new data or improved understanding of available data can be reflected in soil classification. The need for modifying or replacing old schemes was evident in the several reports on work in progress made to the Seventh International Congress of Soil Science in 1960 (*17*). Among the progress reports was one on the current effort in this country (*18*). The scheme being developed in this country is outlined in its present stage in a monograph (*19*), copies of which were distributed to participants in the congress. Attention is centered on this scheme in the discussion that follows.

The scheme presented by American pedologists to the 1960 congress has been carried through a succession of stages over a period of years. For purposes of identification, these stages have been numbered, and the stage presented to the 1960 congress is identified as the 7th Approximation of a comprehensive system of soil classification. This approximation is currently being tested, as were earlier stages, and some modifications are likely to follow. These are expected to be modifications in details of the scheme, however, rather than in general structure. Hence, it seems that the scheme embodied in the 7th Approximation will be adopted, with minor changes, in this country within the next few years.

The prime difficulty in all efforts to classify soils arises from the fact that soil forms a continuum on the land surface. With few exceptions, changes within the continuum are gradual in character, though horizontal differences in the soil may be substantial over distances measured in meters or tens of meters. Marked differences exist between soils of widely separated regions or even within the continuum as it occurs in a single square mile. Despite the existence of these differences within the continuum, discrete entities, comparable to single plants or animals, do not exist. Hence, there is the initial problem of defining the basic entity or entities that are to be grouped into classes in some way.

The approach toward solution of this problem followed in the 7th Approximation differs from earlier approaches in several ways. An attempt is being made to define a small volume of soil as the basic entity, one for which the term *pedon* (plural, *pedons*) has been suggested (*20*). *Pedon* is proposed as a generic term for small volumes of soil, each large enough for the study of horizons and their interrelationships within the profile and having a roughly circular lateral cross section of between 1 and 10 square meters (*19, 21*).

A group of contiguous pedons belonging to a single class of the lowest category (soil series) in the 7th Approximation is identified as a "soil individual" in the monograph (*19*). Since the monograph was prepared it has seemed that use of some other term to identify such groups of contiguous pedons would be desirable. Consequently, the term *polypedon* (plural, *polypedons*) has been proposed. A single polypedon is defined as a group of pedons contiguous within the soil continuum and having a range in characteristics within the limits of a single soil series.

Like other schemes developed earlier in this country, the 7th Approximation is a multiple-category system. Six categories are used in the scheme. These are identified, from top to bottom, as orders, suborders, great groups, subgroups, families, and series. Among these categories, that of the soil series has been used in the United States for a long time. The concept of the soil series has been changed over the years, but further change is not proposed in the 7th Approximation. In contrast to the category of the soil series, other categories in the scheme do not correspond exactly in level of generalization to any that have been used previously in this country or elsewhere, so far as is known. The "suborder" category in the 7th Approximation does approach in level of abstraction the category of the great soil group currently in use in this country, but the two are not fully equivalent.

Some measure of the span in properties permitted within classes is indicated by the numbers of classes in the categories. The 7th Approximation provides for the recognition of ten classes in the "order" category. The numbers of classes in the other categories (in rounded numbers) are as follows: suborders, 40; great groups, 120; subgroups, 400; families, 1500; and series, 7000. It should be mentioned that the totals for the three lowest categories cover only the soils of the United States. These totals would be appreciably larger if soils of other continents were included. On the other hand, the total number of each of the orders, suborders, and great groups is expected to remain the same, or virtually so, whether the scheme is applied to the United States or to the world as a whole. The intent has been to provide a place in the scheme for all known soils in the world, though this goal may not have been reached. In the construction of the scheme it is recognized that soils not known to the authors of the scheme may have been omitted. It is also recognized that modification of this scheme or its replacement will eventually become necessary as the knowledge and understanding of soils continue to grow.

The nomenclature proposed in the 7th Approximation represents a marked departure from past practice in soil classification. A new nomenclature is proposed for the classes in each of the four highest categories. The proposed names for classes in the order, suborder, great group, and subgroup categories consist of coined terms in which Greek and Latin roots are largely used. The names are distinctive for the classes in each category, so that a name itself will indicate the category to which a given class belongs. Moreover, the names are designed so that each subgroup may be identified, by its name, with the great group, suborder, and order in which it is classified.

The names of the ten orders consist of three or four syllables, and every name ends in the suffix *sol*. The names of the ten orders are "entisols," "vertisols," "inceptisols," "aridisols," "mollisols," "spodosols," "alfisols," "ultisols," "oxisols," and "histosols" (the letter *s* is added for the plural form).

The name of each suborder is a two-syllable rather than a three- or four-syllable term. Each name consists of a prefix syllable with a specific connotation plus a syllable from the name of the order in which the suborder is classified. Fourteen formative elements are used as prefixes in the construction of suborder names. Thus, for example, suborders in the order of entisols are identified as "aquents," "ustents," and "udents."

The name of each great group consists of either three or four syllables. For the most part, the names are three-syllable words, but a few have four syllables. Each name has been constructed by adding a second prefix to the name of the appropriate suborder. Twenty-seven formative elements, in addition to the 14 used in constructing suborder names, are used in constructing names for the great groups. Thus, for example, four great groups in the suborder of udents are the "cryudents," "agrudents," "hapludents," and "plaggudents."

Binomials have been used as names for subgroups. Each binomial is constructed by placing an adjective before the name of the great group to which the subgroup belongs. For each great group, a typifying subgroup is first selected. That subgroup is then named by a combination of the word *orthic* with the name of the great group—for example, "orthic hapludents." The names of other subgroups within a great group are constructed in the same way, except that the adjectives are formed from the names of other groups or of suborders. Thus, in the 7th Approximation, the hapludents, a great group in the suborder of udents and in the order of entisols, comprise several subgroups in addition to the central one. Examples of the names "are "grumaquertic hapludents" and "udalfic hapludents."

Several objectives have been kept in mind in developing the proposed nomenclature. Efforts were made to devise names that were distinctive and could be easily remembered, would suggest a few characteristics of the soils in each class, would identify the categorical level to which a class belonged, would fit into the existing pattern of language readily, and would provide convenient adjective as well as substantive forms (*18*). An effort to reach all of these objectives simultaneously is ambitious, and the several are not compatible in all cases. Hence, it is not surprising that some defects have already been noted in the proposed nomenclature (*18*). In all probability, more will be discovered. It is hoped, however, that the nomenclature can be improved as a result of scrutiny of the names and definitions of classes by a larger group of scientists than could participate in the construction of the scheme.

The major problems in constructing the scheme embodied in the 7th Approximation were encountered in defining classes in the several categories. This is not surprising; the selection and weighting of characteristics as criteria for the definition and differentiation of classes at all levels is a central and continuing problem in the classification of soils (*22*). Efforts to construct schemes of soil classification in the past have not gone far toward defining individual classes fully. General descriptions of classes, often brief, have been offered, without attempts at detailed definition. Furthermore, definitions of many classes have been expressed in terms either of inferences as to genesis or of features external to the soils, or of both. Careful examination of a sample of the schemes proposed in the past will provide a test of this statement. It is not my intent to decry the value of schemes of soil classification devised in the past, but the deficiencies of existing schemes must be recognized before they can be corrected.

Definitions of the classes in the different categories of the 7th Approximation are in terms of morphology and composition of the soils—that is, in terms of soil characteristics themselves. Moreover, an attempt is made to have the definitions as nearly quantitative as currently available data will permit.

The definitions are generally given in two parts. A norm or central concept is given as the first part of the definition in most instances. This consists of a full description of the morphology of a soil profile plus certain analytical data, by horizons, of that profile. This information is meant to provide a ready first picture of the class. The second part of the definition is a statement of the limits of the class, with emphasis on characteristics that set the class apart from the other classes most like it. The limits for classes are given, insofar as possible, in terms of characteristics that can be observed through field study of soils, but some of the characteristics used as definitive can be observed only through laboratory analysis. In all instances, however, an attempt has been made to define classes in terms of soil characteristics that can be observed and measured by competent pedologists.

The ten orders are set apart on the basis of one or more of the following factors: gross composition, degree of horizonation, the presence or absence of certain horizons, and what is in effect a combined index of weathering and weatherability of minerals. The characteristics selected to distinguish the orders are believed to reflect major differences in paths of horizon differentiation (*23*), in stages reached in horizon differentiation, or in both. To state this another way, the intent has been to choose as differentiating characteristics properties that reflect major differences in genesis of the soils. Whether the selections have been successful for this purpose, and if they have been, to what degree, will become evident only after the scheme has been tested for a time.

The bases for distinguishing the ten orders may be made clearer by some illustrations. Full definitions will not be given here for any of the orders, but the principal differentiae for the histosols, entisols, mollisols, and spodosols will be sketched briefly.

The histosols are organic soils, mainly those known as peats and mucks. These are distinguished from soils of the other nine orders by differences in gross composition: histosols are high in organic matter (20 percent or more). The balance among processes of horizon differentiation in soils so high in organic matter is very different from that in dominantly mineral soils.

The entisols are mineral soils with low degrees of horizonation, mainly those that have been identified as lithosols, regosols, and alluvial soils in the United States in recent years. The entisols have few and faint horizons in their profiles. These soils are in early stages of horizon differentiation. Some are forming in regoliths consisting of highly resistant minerals; others in areas where accretions of fresh materials keep pace with horizon differentiation; still others in areas where removal by erosion keeps pace with horizon differentiation.

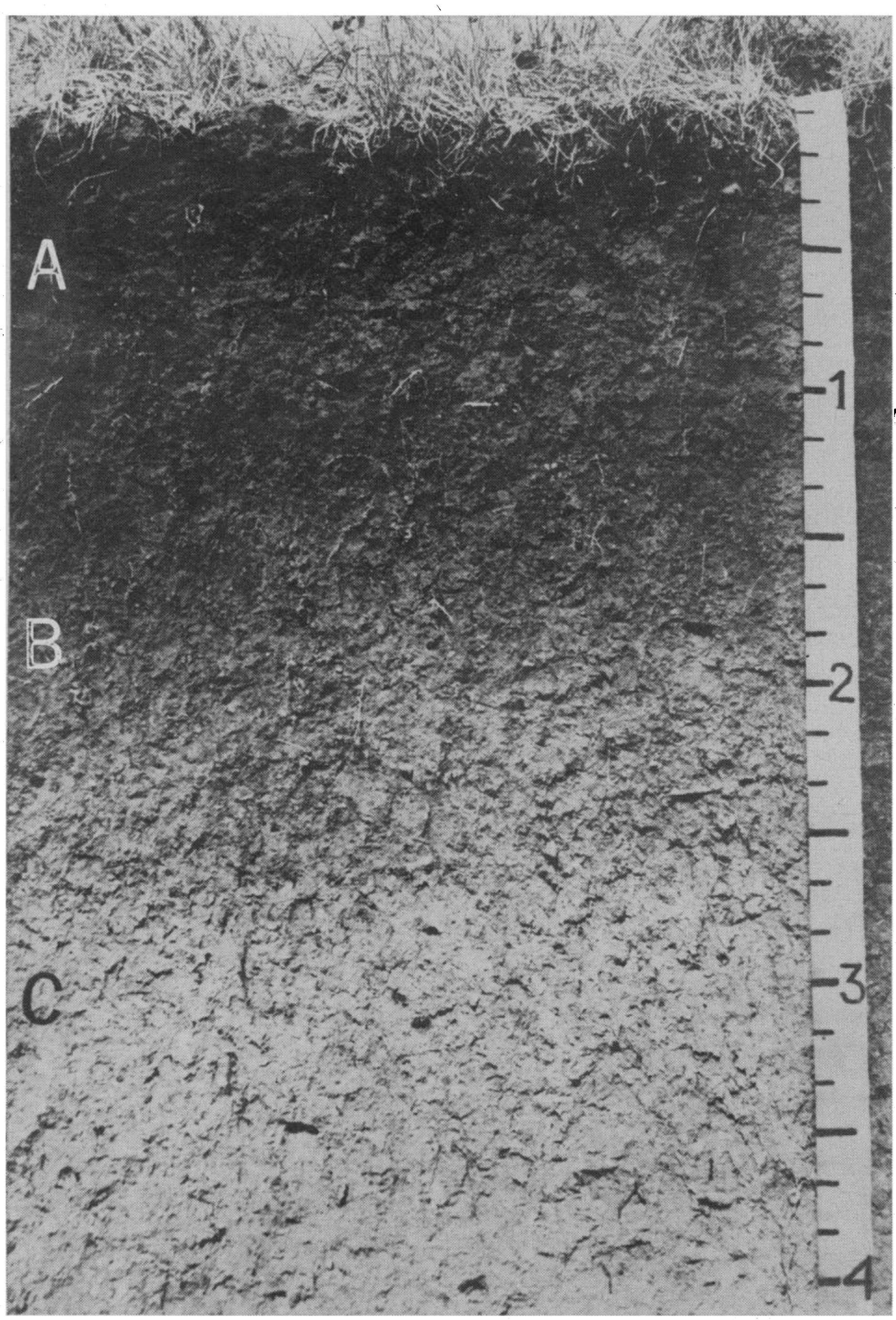

Fig. 2. Profile of a soil with a mollic epipedon, a friable dark surface horizon relatively high in organic matter and high in base status. The thickness of the mollic epipedon is slightly more than 12 inches in this profile, which represents a "brunizem" or "hapludoll," one of the well-drained mollisols derived from glacial drift in the Corn Belt. The scale shows depth in feet.

The mollisols are mineral soils which have a characteristic known as a mollic epipedon (*19*) (Fig. 2). This is a darkened surface layer of considerable thickness, relatively high in organic matter, high in base saturation, and friable. For identification as a mollic epipedon, minimum requirements for thickness, color, base saturation, level of organic matter, and consistence are given. Unlike the histosols and entisols, mollisols tend to occur within certain geographic zones. Such soils are the major ones of the Corn Belt and Great Plains in the United States. Mollisols have been formed almost entirely under prairie vegetation in semiarid-to-subhumid climates. Included in the mollisols are the chernozems, studied almost a century ago by Dokuchaiev (*7*) in Russia.

The spodosols are mineral soils which have a characteristic known as a spodic horizon (*19*) (Fig. 3). This is a subsurface horizon of illuvial accumulation of humus, usually in conjunction with accumulation of iron or aluminum, or both. The spodic horizon corresponds closely to the B horizon of podzols, as those soils have been described in North America and western Europe. Like the mollisols, the spodosols tend to be associated with certain climatic and vegetation types. These soils are found in cool, humid regions, for the most part, and they are formed mainly under coniferous forest or under vegetation dominated by plants such as heather. The spodosols occur extensively in eastern Canada, in New England and the northern Lake States, and in the taiga region of the Soviet Union. Such soils often have strikingly different horizons in the same profile, and this may be why they were among the first to be studied with care.

The basic approach followed in defining orders in the 7th Approximation is carried down to the suborder and great-group categories, though the same characteristics are not used as criteria. Additional characteristics of the soil are introduced as criteria for distinguishing classes at each level.

The kinds of characteristics used in differentiating suborders within orders are moisture regimes, temperature, mineralogy, and specific kinds of horizons. One suborder is set apart in each of eight orders because of the evidence of wetness in the morphology of the soils. In two of the orders, one pair of suborders is distinguished mainly on the basis of temperature. The mineralogy of the soil—for example, very high levels of quartz, dominance of allophane, or high proportions of calcium carbonate—provides criteria for recognizing at least one suborder in each of four orders. Characteristics such as an argillic horizon, a cambic horizon, and the tonguing of an albic horizon into an argillic horizon are definitive for at least one suborder in each of five orders.

The setting apart of great groups within suborders is based on the same kinds of criteria as is the distinguishing of suborders within orders. Great groups are distinguished within suborders by the presence or absence of characteristic horizons or other features, the occurrence of horizons extraneous to the sequence required for the suborder, and temperature. The range of definitive characteristics within individual classes has been reduced step by step in coming down the ladder from the order to the suborder to the great group. Thus, the soils of a great group are more homogeneous in their characteristics than are soils of classes in higher categories. For each great group, the soils have the same kinds of horizons in the same sequence within pedons, except for surface horizons, which may be obliterated by plowing or by erosion.

The approach in defining subgroups differs from that followed in defining classes in higher categories. As explained earlier, a typifying subgroup is first defined for each great group and identified by the term *orthic* preceding the great-group name. This subgroup has the median expression of the definitive characteristics of the great group. In addition to the orthic subgroup, other subgroups are set apart as intergrade or extragrade subgroups. Intergrade subgroups have some characteristics definitive of another great group, either in the same order or in some other order. Extra-grade subgroups have some properties that are not definitive of any known great group. In both intergrade and extragrade subgroups, however, the soils are more like the orthic or central subgroup of the great group to which each belongs than to any other known kind of soil. Recognition of orthic, intergrade, and extragrade subgroups is one device for recognizing that the soil mantle forms a continuum in which changes are gradational rather than abrupt.

Mention has already been made of the family and series as the two lowest categories in the 7th Approximation. Work is still in progress on the selection of appropriate criteria for differentiating families within subgroups. There are a number of difficulties to be overcome before the known soil series of the United States can be grouped into families on a uniform basis. Possible approaches have been tested through trial groupings of soil series into families, and these tests are being continued (*19*).

The soil series has been used in the classification of soils in the United States since the early days of this cen-

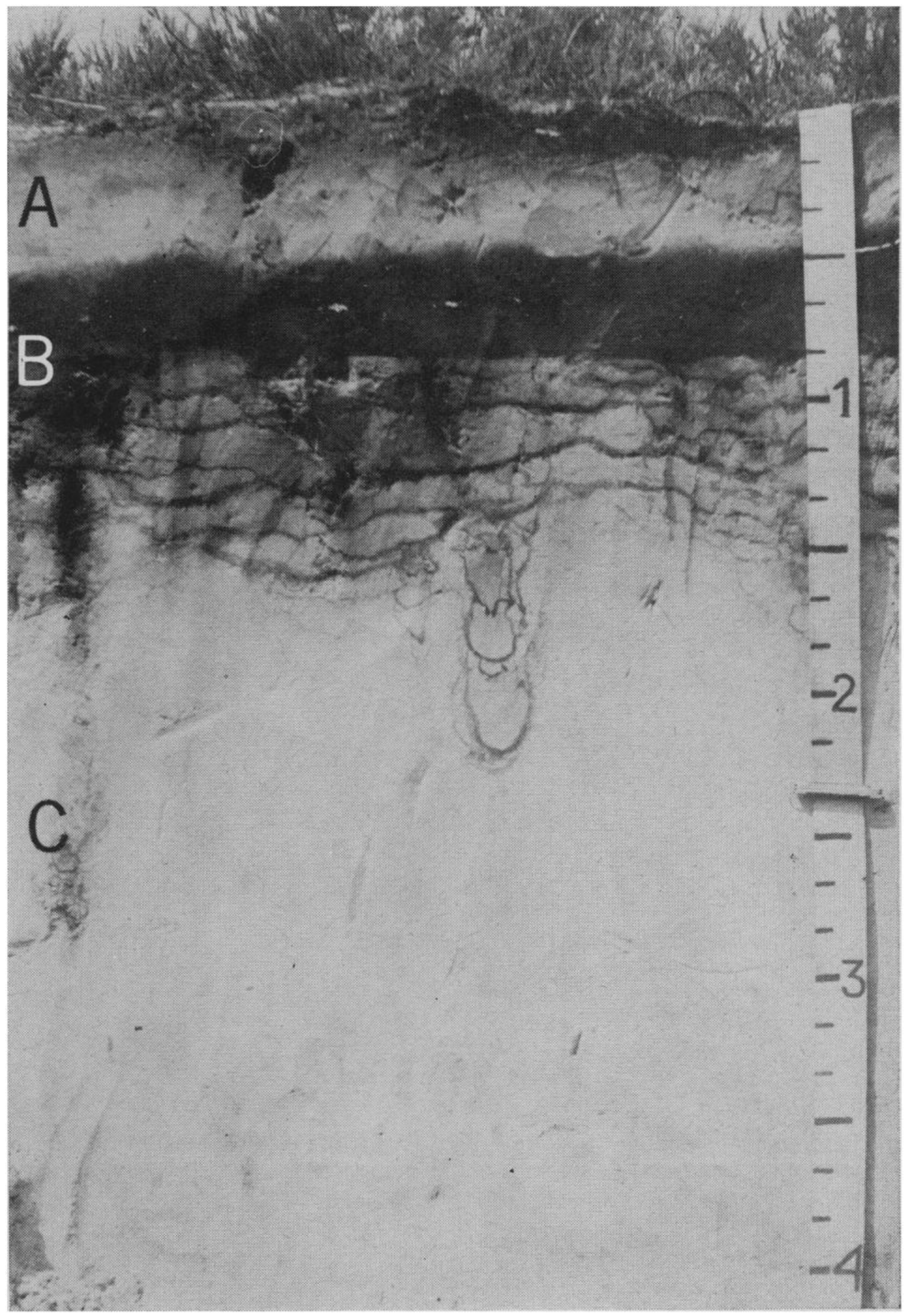

Fig. 3. Profile of a soil with spodic horizon—a subsurface horizon of illuvial accumulation of humus with or without concurrent accumulation of aluminum and iron. The dark layer below a depth of 6 inches is the spodic horizon. The soil is a podzol or spodosol formed from sand under heather near Eindhoven, Holland. The scale shows depth in feet.

tury (*22*). The concept of the series has evolved greatly during this time. However, changes in the concept of the soil series have been discussed elsewhere (*22*) and have not been considered in this article. The concept of the soil series and the relationship of that category to the higher categories in the scheme are discussed in the monograph on the 7th Approximation (*19*).

Concluding Remarks

The scheme of soil classification now being developed in the United States differs from earlier schemes prepared in this country and elsewhere in several ways which are important. This scheme reflects evolution in the concept of soil itself. Basic to the scheme is the concept that soil comprises a continuum on the land surface, one which can be subdivided into classes in a variety of ways. Also basic to the scheme is an effort to achieve more quantitative definitions than have been devised heretofore. Definitions of classes at every categoric level are expressed in terms of properties that can be observed or measured. These are important departures from schemes developed earlier for classifying soils.

The basic objectives of the classification scheme are essentially the same as those of earlier schemes, despite the differences in approach. The scheme must first of all organize, define, and name classes in the lowest category, and it must group these classes into progressively broader classes in higher categories and provide names for these classes. Its general purpose is to make the characteristics of soils easier to remember, to bring out relationships among soils and between the soils and other elements of the environment, and to provide a basis for developing principles of soil genesis and soil behavior that have prediction value. It is hoped that these purposes may be served better by the new scheme than by earlier ones, though only time will tell whether this hope has been realized.

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Sexual Sterilization of Insects by Chemicals

Eradication of harmful insects may be achieved with analogs of cancer chemotherapeutic agents.

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The successful eradication of the screw-worm, *Cochliomyia hominivorax* (Cqrl.), a serious pest of livestock, from the island of Curaçao, and subsequently from Florida and other states of the Southeast, by the systematic release of large numbers of male insects rendered sterile through irradiation (*1*) has attracted worldwide attention. Knipling (*2*), who originated this idea, has recently pointed out that chemically produced sterility has great potential compared with conventional insecticides for insect eradication. The irradiation technique has some obvious limitations. It requires mass release of the sterilized males, and this may often be undesirable or not even feasible. It requires a rather expensive, uniquely designed plant with specialized equipment to rear, transport, and irradiate the insects (irradiation is usually most effective on the pupal stage), and then it demands airplanes to dispense the packaged, sterilized insects. In some species (for example, the boll weevil, *Anthonomus grandis* Boh.) the irradiation dosage required for sterilization is so high that it drastically reduces the competitiveness of the insects or even kills them. The radiation-sterilization approach has other disadvantages, but the difficulties mentioned are sufficient to point up the desirability of developing a less costly and more practical method to achieve the same end with greater efficiency and flexibility. An effective male chemosterilant could be used to achieve the same result far more cheaply than irradiation. The prospects of developing effective chemosterilants which can be used safely under field conditions appear to be very good and are worthy of thorough investigation.

An insect chemosterilant may be defined as a chemical compound which, when administered to the insect, will deprive it of its ability to reproduce.

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