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SOIL CLASSIFICATION

A COMPREHENSIVE SYSTEM

7th Approximation

SOIL SURVEY STAFF
SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE
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Contents

The Soils of the United States by C. F. Marbut was published as Part III of the Atlas of American Agriculture in 1935, the year of his death. Although he drew widely on the work of others, Marbut's monograph was primarily his own personal work.

Since Marbut, efforts on systems of soil classification in the Soil Survey have been staff undertakings. In 1935, however, the greatest need appeared to be some kind of orderly statement of guidelines for describing and mapping soils in the field. The first edition of the Soil Survey Manual was prepared during that year and the next and published in 1937.

Late in 1936, the then Secretary of Agriculture, Henry A. Wallace, asked that a comprehensive statement about the soils of the United States and their uses be prepared as the 1938 Yearbook. Although we explained that our knowledge was hardly adequate for the task, the Secretary felt that one of the values of such a book would be evidence of research need.

So, despite the shortness of time, the Soil Survey staff prepared a new soil map of the United States, a new statement of the system of classification, and descriptions of the soils as they knew them then. What a year that was! Great soil groups were defined, including a few new ones. Time was not available for detailed descriptions or for adequate field testing. For example, the Planosol group was defined to include those soils of humid and subhumid areas with prominent hardpans and claypans that did not fit into the other groups as formerly defined. It turned out that our definition of Planosol was too broad.

Yet the final result, included in Soils and Men, was useful to a great many people. The job of preparing it made the gaps and inconsistencies more apparent to the Soil Survey staff than any other experience could have done. Above all it reemphasized more strongly than ever the compelling need for soil descriptions in more precisely defined terms.

Staff committees went to work on the establishment of defined classes for the various soil properties and standard terms for soil descriptions; on the definition of local classificational units; on soil-mapping procedures; and on the interpretation of the classificational units in terms of predicted behavior under alternative systems of management. Drafts of these committee reports were widely circulated and criticized. In the winter of 1949-1950 I brought these materials together into one document. During the next few months it was mimeographed and circulated widely within the United States and to many of our colleagues overseas. In the final draft, soil drainage and a few other parts were completely revised. Thus the current Soil Survey Manual was published in 1951.

Meanwhile staff committees were also working on the redefinition of the great soil groups, particularly in terms of existing definitions of the soil series that were thought to belong in these groups. The results were gotten together as a new statement of our system of soil classification and published at the request of Firman E. Bear as an issue of Soil Science (February 1949).

Since many parts of the Soil Survey Manual had been issued in advance, by 1950 more accurate and detailed soil descriptions were becoming available. Further, the soil maps were being tested in practical use more than ever before. This was true in many countries.

Immediately after World War II worldwide efforts were made to improve the economies of underdeveloped areas. These efforts gave enormous emphasis to tropical soils, which had been (and still are) the weakest parts of all systems to soil classification developed in the United States and Europe.

With the new data from our efforts in the United States and those from our colleagues overseas it seemed to us that we should make a fresh approach to the problem of developing a new scheme of soil classification. We needed one that would include as many of the new data as possible, provide for the incorporation of data that would become available, and furnish a basis for predicting how the various soils of the world would respond to modern management.

This is not to say that the older systems are not useful. We will continue to have need for the concepts of zonal, intrazonal, and azonal soils, even though we leave them out of the system of classification. But we felt a growing need for a new system that would get away from the bias of genetic factors outside the soil itself and from the extreme emphasis on virgin soils.

So in 1951 the decision was taken by the staff to make this fresh approach. It should be clear that the same staff had to continue their regular duties in an expanding, going soil survey program. No one could give full time and attention to soil classification alone; least of all myself. Success depended on utilizing not only the knowledge and experience of soil scientists in the United States but also those of our colleagues overseas. To keep the work organized, Guy D. Smith, Director of Soil Survey Investigations, was given staff leadership. Members of the Soil Survey staff have taken opportunities that presented themselves to work with our colleagues overseas in their own countries. Many of them have worked with us in the United States. And, of course, much has been done by correspondence.

Since our suggestions had to be written down even for test and study, we called them "approximations" toward a system. The discussion herein presented is the most elaborate of the seven approximations prepared since 1951.

A final system for adoption has not yet been achieved. But we think that we have arrived again at a place where what has been done needs to be set down in detailed form for study, criticism, and testing. Some gaps and inconsistencies are pointed out. Perhaps there are others. But regardless of these we believe that the system is a forward step made by many soil scientists working together toward a common end.

Charles E. Kellogg
Assistant Administrator for
Soil Survey

This book gives the present status of a comprehensive system of soil classification being developed by the Soil Survey staff. The Soil Survey uses a classification to see relations among soils and between soils and their natural and cultural environment. Predictions are made about soil behavior from the relations of soils for which we lack experience to soils on which we have conducted research or have experience. Thus, classification is a basic tool used in our research, extension, and technical assistance.

The classification used in a soil survey program should be able to accommodate all soils. In soil surveys of agricultural land, it is desirable that the soils of the entire landscape be classified—not just a few soils at selected points. The larger the area left unclassified, the less useful the survey will be.

For many years in the United States, soils were described and named as soil series. Any newly described soil was given a series name to identify it, but its relation to other series was not necessarily known. Often it was possible to establish the position of a series in a catena, and usually to state the differences between a particular series and a few other closely related series. These statements were commonly inadequate to show the relationships between soils in States a few hundred miles apart.

Soil classification was also approached in terms of the great soil groups. Many series could be fitted into these clearly, but others could not without modifying the definitions of either the series or the great soil groups. Considerable modification of both has been going on as our knowledge has expanded. But at no time have all the soil series been fitted into a scheme of relationships progressive from the series to the great soil groups.

About 1946, we in the Soil Survey staff undertook the task of placing all established soil series in the classification system now in use. It soon became apparent that it would be impossible to find places for all soil series without substantially changing the system. And not all of the soils in a given great group appeared to be closely related. Clarification of the definition of one great group merely shifted the problem to others, for the limits of any great group were also limits of other groups.

In 1951, we started to develop a new system. We believed that the most useful system would be a comprehensive one that could accommodate all soils, not just the soils of the United States. Much of what we know about our soils has been learned from research and experience on other continents. And we can expect to learn much more. We realized that a workable system could not be developed without the cooperation of a great many soil scientists. The number would have to be large if it were to include men experienced with a very wide variety of soils, a number too large to work effectively as a group. Consequently, we decided to develop the system by a series of approximations, testing each one to discover its defects and thus gradually approaching a workable system. The first approximations were circulated to only a few soil scientists in the United States. The third and all subsequent ones were circulated to an ever increasing number of soil scientists, as many as could be discovered with an interest in the project. In the United States the approximations have been tested by placing established and tentative series in each of the approximations, beginning with the third. The groupings that resulted were examined by many soil scientists, each with his own viewpoint. Their criticisms formed the basis of the succeeding approximation. This is the seventh approximation, and it is hoped the last tentative one before a system will be ready for adoption and use by the Department of Agriculture and the cooperating agricultural experiment stations and State agencies concerned with the Soil Survey of the United States.

This is not a book for beginning students of soil classification. It is written to introduce the new system to people who are familiar with the present system. It assumes knowledge of the Soil Survey Manual terminology for describing soils. If the reader is not familiar with the meaning of terms for describing texture, structure, consistence, and color as defined by the Manual, he will find much of this book meaningless or confusing. For those who do not have ready access to the Manual, the definitions of terms for structure, consistence, color, horizon boundary, and texture are reproduced in the Appendix. The color terminology requires access to a Munsell color chart, or to one of the other color charts that can be interpreted in terms of the Munsell system. The reader who is not accustomed to using the Manual terminology should review the definitions in the appendix before he attempts to read chapter 5 or any subsequent chapter.

The classification system presented here is incomplete in several respects. The families are undefined. All definitions are tentative; the definitions of subgroups are incomplete in many respects. The place of once naturally well drained soils that have been long used for paddy culture is undetermined. The subgroup definitions have been tested only once and a number of defects are undoubtedly present. Definitions of the classes of soil that do not occur in the United States have not been tested; many remain to be written.

The development of the system has not proceeded uniformly in all of the orders. Two orders, the Oxisols and Histosols, require much more additional work than do the other orders. One suborder, the Andepts, is also in need of much more work. Other specific short-comings are pointed out in the text.

The reader will perhaps note some inconsistencies in the descriptions of the soil profiles used as illustrations. These profiles were collected and described by many people over a period of years, and for many reasons. Few were selected with the intent to use them here.

Few readers need be concerned with the entire text. Suggestions for the improvement of this system by refinement of the definitions are most apt to be made about soils with which the reader is thoroughly familiar. Suggestions that can be submitted within the next year are solicited. It is anticipated that the system will not be complete for another 3 or 4 years, but the work on families cannot be completed if definitions of subgroups and higher categories are continually changed.

Guy D. Smith
for the Soil Survey Staff

Chapter 1. Soil and the Soil Individual

Soil, as used in this text, is the collection of natural bodies on the earth's surface, containing living matter, and supporting or capable of supporting plants. At its upper limit is air or water. At its lateral margins it grades to deep water or to barren areas of rock, ice, salt, or shifting desert sand dunes. Its lower limit is perhaps the most difficult to define. Soil includes all horizons differing from the underlying rock material as a result of interactions between climate, living organisms, parent materials, and relief. Thus, in the few places where it contains horizons impermeable to roots, soil is deeper than plant rooting. More commonly soil grades at its lower margin to hard rock or to earthy materials essentially devoid of roots. The lower limit of soil therefore is normally the lower limit of the common rooting of the native perennial plants, a diffuse boundary that is shallow in deserts and tundra and deep in the humid Tropics.

The word "soil" is not everywhere defined as it is here. Like many common old words, it has several meanings, even within soil science. We can only try to define the sense in which we use the word here. Soil, in its traditional meaning, is the natural medium for the growth of land plants, whether or not it has developed soil horizons. This meaning, as old as the word soil itself, is still the common meaning, and the greatest interest in soil, by far, is centered on this meaning. The people of the world are concerned with soil primarily because it supports plants that supply food, fibers, drugs, and other wants of men. In this sense soil covers land as a continuum, except on bare rock, areas of perpetual frost or the bare ice of glaciers, and perhaps some areas of shifting sands and the salty playas in the deserts. In this sense soil has a thickness that is determined by the depth of rooting of plants.

About 1870 a new concept of soil was developed and introduced by the Russian school led by Dokuchaiev.[1] Boiled down to its essentials, soils in the Russian concept were conceived to be independent natural bodies, each with a unique morphology resulting from a unique combination of climate, living matter, parent rock materials, relief, and time. The morphology of each soil, as expressed in its profile, reflects the combined effects of the particular set of genetic factors responsible for its development.

This was a revolutionary concept. The soil scientist did not need to depend wholly upon inferences from the underlying rocks, the climate, or other environmental factors, considered singly or collectively; rather, he could go directly to the soil itself and see the integrated expression of all these in its morphology. This concept made it not only possible but necessary to consider all soil characteristics collectively, in terms of a complete, integrated natural body, rather than individually. In short it made a soil science possible.

The Russian concept of soils as independent natural bodies with genetic horizons led to a concept of soil as the portion of earth's crust with properties reflecting the effects of local and zonal soil-forming agents. The solum[2] was the genetic soil developed by soil-building forces, and the parent material was "not-soil." This concept had limitations. If a solum is thick, there is little conflict between the concept of soil as solum and the concept of soil as the natural medium for the growth of land plants. If genetic horizons are thin, and unconsolidated parent material lies only a few inches below the surface, there is serious conflict between the concepts. Dokuchaiev realized this conflict and, despite the lack of any solum, included alluvium and peat in his classification of soil.

Soil, as defined in this text, does not need to have readily discernible horizons, though the presence or absence of horizons is of extreme importance in its classification. Soil is a natural thing out-of-doors. Like a river, it cannot be brought into the laboratory or a greenhouse, even as undisturbed monoliths, without changing some of its characteristics, such as its temperature and its moisture regime.

Since one cannot distinguish accurately under all conditions between what is and what is not part of the soil, a short, precise general definition is perhaps impossible. The same is true of other well-understood basic words such as "house," "plant," or "stone." Some soil-landscapes that support plants gradually thin to open water or to lichen-covered rock and finally to bare rock with no clear separation between soil and not-soil that applies generally.

Areas are not considered to have soil when the surface is permanently covered deeply enough by water that only floating plants are present, or where survival conditions are so unfavorable that only lichens can exist.

Plants may be grown under glass in pots filled with samples of soil, with peat, with sand, or even with water. Under proper conditions all these media are productive of plants but are "not-soil." Plants even grow on trees; but trees are regarded as "not-soil." Yet perhaps the most important quality of soil is its productivity for plants. Its lower boundary with "not-soil" is the vague lower limit of common rooting of the dominant native perennial plants, or the vague lower limit of the genetic horizons, whichever is the deeper.

In some places the lower limits of soil can be set only arbitrarily. A croute calcaire, or hardened caliche, may extend some 10 to 25 feet below the surface. The upper part of this caliche will normally be a part of a modern soil, but the lower part may be parent material from which soil is forming. In the past we have had no method to distinguish the lime

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[1] Glinka, K. D. Dokuchaiev's Ideas in the Development of Pedology and Cognate Sciences. Acad. of Sci., U.S.S.R. Russ. Pedol. Invest., 1, 32 pp. Leningrad, 1927.

[2] In most soils the solum includes the A and B horizons.

recently redeposited from the lime deposited in some earlier geologic period. Studies of C14 will probably permit an eventual distinction, but the limits will be uncertain until much work has been done.

Another example of difficulty in determining the lower boundary of soil may be taken from gleyed soils. Gleyed soil material may begin a few centimeters below the surface of hydromorphic soils and, in some instances, continue on down for several meters essentially unchanged. Such conditions can arise through the gradual filling of a wet basin, with the A horizon gradually being added to at the surface and being gleyed beneath. Finally the A rests on a thick mass of gleyed material, which may be relatively uniform. Obviously, the upper part is soil, and the lower part is not. In such an uncertain situation, we have no alternative but to set the lower limit of soil at the lower limit of common rooting of the native perennial plants--a matter of a meter or two.

For those who need a brief definition of soil, we may say that it is the collection of natural bodies on the earth's surface, supporting plants, with a lower limit at the deeper of either the unconsolidated mineral or organic material lying within the zone of rooting of the native perennial plants; or where horizons impervious to roots have developed, the upper few feet of the earth's crust having properties differing from the underlying rock material as a result of interactions between climate, living organisms, parent material, and relief.

An almost entirely different meaning of the word "soil" is used by many laymen and engineers. To them, soil is regolith or any unconsolidated material, regardless of depth or mode of formation. In this text the term "earth" is used as a general term for the unconsolidated material whether it is or is not included by our definition of soil.

Another meaning of soil in lay and in technical literature has been one of earth darkened by humus. The older geologic literature, for example, contains many descriptions of sections in which the only "soil" is the humus-rich horizon. This is not the concept used here.

A SOIL, OR THE SOIL INDIVIDUAL

A soil individual is not found as a discrete entity, clearly separated from all others, but grades on its margins to other soil individuals with unlike properties. A boundary may be abrupt along a vertical scarp, but more commonly is gradual, and takes place over distances of a number of meters. A concept of the soil individual must be developed before soils can be classified, and different concepts would lead to different classifications. The concept presented here is not the only one possible, but it is one that follows logically from the definition of soil and from the purposes of classification.

The transition between two soils differing in a particular horizon may be of at least two kinds. The given horizon of one soil may disappear over distance by a very gradual weakening of its development. Or it may disappear over distance by breaking into discontinuous spots, which occur with decreasing frequency, and either with or without marked decreasing strength of development.

The transition forms with discontinuous horizons are troublesome to classify. One must decide whether the area is one soil with a discontinuous horizon, or two soils. Trouble cannot be avoided by arbitrarily saying that two soils are present if a diagnostic property or horizon is present in some spots and missing in others. Some arbitrary limit of area must be set. If one sets no arbitrary limit, a vertical hole made by a burrowing animal is "not-soil." It becomes a soil when filled or, if a coating is present the coating becomes a soil. This would be absurd. Such a soil could not support plants, could not have structure, and could not be sampled for determination of its properties. The view that areal limit to "a soil" cannot be set, if carried to extreme, leads to other odd conclusions. With this view, if columns or prisms are present, the exteriors of the prisms are different soils from the interiors whenever there are coatings on the exteriors. A definition of the smallest area of "a soil" as equivalent to the size of the largest ped would have no meaning in structureless soils. No escape from a somewhat arbitrary minimum limit to the area of "a soil" seems possible. The <u>pedon</u> was devised as the solution to this problem.

The Pedon

A pedon (Gk. <u>Pedon</u>, ground; rhymes with head on.) is the smallest volume that can be called "a soil." It is comparable in many ways to the unit cell of a crystal. A pedon has three dimensions. Its lower limit is the vague and somewhat arbitrary limit between soil and "not-soil." The lateral dimensions are large enough to permit study of the nature of any horizons present, for a horizon may be variable in thickness or even discontinuous. Its area ranges from 1 to 10 square meters, depending on the variability in the horizons. Where horizons are intermittent or cyclic and recur at linear intervals of 2 to 7 meters (roughly 7 to 25 feet), the pedon includes one-half of the cycle. Thus each pedon includes the range of horizon variability that occurs within these small areas. Where the cycle is less than 2 meters or where all horizons are continuous and of uniform thickness, the pedon has an area of 1 square meter. Again, under these limits, each pedon includes the range of horizon variability associated with that small area. The shape of the pedon is roughly hexagonal. One lateral dimension should not differ appreciably from any other.

Some examples follow to clarify the concept of the pedon. Figure 1 illustrates a soil with discontinuous horizons which recur at intervals of less than 1 meter. In this soil the pedon is 1 square meter.

This soil is near Brugge, Belgium in an area covered by eolian sand of Wisconsin (Würm) age. The plow layer, 14 inches thick, is a very dark brown fine sand or loamy fine sand. Most sand grains are free of any visible coatings. The lower boundary of the plow layer is abrupt and irregular, showing many clear spade marks.

The next layer is a discontinuous B horizon with at least three materials. The first of these is a nodular, dark-brown (7.5YR 3/4, moist) fine sand. The nodules range from about 5 to 20 cm. in diameter and are firm to friable in the interior but have a very firm crust about 1/2 cm. thick. The crust is stronger in chroma and redder in hue than the interior, suggesting iron segregation. The interiors of the nodules are free of roots.

The second material is a very friable, single grain, fine sand, grayish brown (10YR 5/2, moist) in color, with many fine fibrous roots. This material surrounds the nodules described above and continues with little change to a thin buried muck, dated as Alleröd (Two

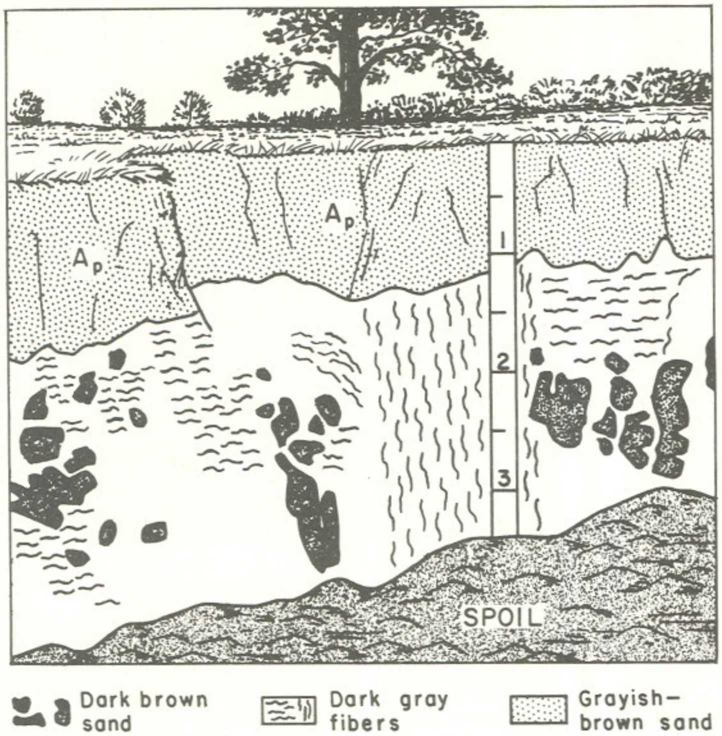

Figure 1.–Soil with a discontinuous B horizon that has illuvial iron and humus (spodic horizon), Brugge, Belgium.

Creeks) by C14. It would normally be considered parent material, or the C horizon.

The third material is very friable, single grain fine sand in more or less gross tubular forms up to 2 feet in diameter. The sand is similar to the second material in color, but it contains many fine, dark-gray to very dark-gray fibers comparable to those found in or below the B horizon of the humus Podzols formed under heath.

It would be possible in this soil to select columns 1 cm. in diameter that, below the Ap, would consist entirely of grayish-brown sand or C horizon. Columns could also be selected in which the principal component would be sand with humus fibers. Other columns would pass through one or more of the dark brown nodules. If the minimum lateral dimensions of a pedon were something like 1 cm., the profile illustrated in figure 1 would consist of several kinds of soil with rather contrasting horizons.

It would be more valid to consider this as a single kind of soil with intermittent horizons. The history of this soil has been studied by the staff of the Institute for Soil Survey, IRSIA, Ghent.[3] While under forest it was a Brown Earth. With the clearing of the forest and the invasion of the heather (Calluna vulgaris), a humus Podzol developed. During the 17th and 18th centuries, flax became an important crop in Flanders, and the linen was woven in the farm homes in the winter. To get high yields of high quality flax, large amounts of manure and chalk were applied to the fields. The influence of the calcium and nitrogen was to destroy the B horizon of the humus Podzol, first in spots and then completely. Figure 1 shows the partial destruction of the humus Podzol.

The processes of either formation or destruction of many horizons may not operate uniformly and may first produce intermittent horizons. In other instances the forces operate with remarkable uniformity and produce weak but continuous horizons. Genetically, therefore, the discontinuous horizons can have significance equivalent to weakly expressed but continuous horizons.

Examples of intermittent or cyclic horizons are very common in soils developing in hard rock. In these, there is commonly a B horizon in the spots with the thickest regolith. Figure 2 shows a profile near Mt. Gambier, South Australia, in a soil developing in eolianite, a consolidated eolian sand composed largely of shell fragments. The profile shows a continuous plow layer of dark brown (7.5YR 3/3, moist) hard, massive loamy fine sand. The next horizon is discontinuous, a strong-brown (7.5YR 4/6, moist) loamy fine sand present over perhaps 60 percent of the area. In some places its lower boundary is abrupt, with rock at a depth of 20 cm. In other places there are deeper tongues that grade to a horizon of clay accumulation at a depth of about 1 meter. This horizon of accumulation, a dark-brown (7.5YR 4/6, moist) illuvial sandy clay, covers about 10 to 20 percent of the area in the form of tongues that are 20 to 40 centimeters in diameter and are spaced at intervals of 1/2 to 2 meters. This illuvial horizon rests on the rock at depths of 2 meters or more.

If a soil is considered as an assemblage of horizons, there are at least three kinds of soil present. From a genetic viewpoint, it is difficult to show that the areas with shallow rock have not contributed both water and clay to form the illuvial B horizons in the deepest tongues. Without the contributions from areas with shallow rock, the deep tongues should be shallower and the clay content smaller. The pedon in this soil has a variable size of from 1 to about 2.5 square meters.

Other kinds of irregular and intermittent horizons are shown in figures 3 and 4. Figure 3 shows a soil

[3]Personal communication from R. Tavernier.

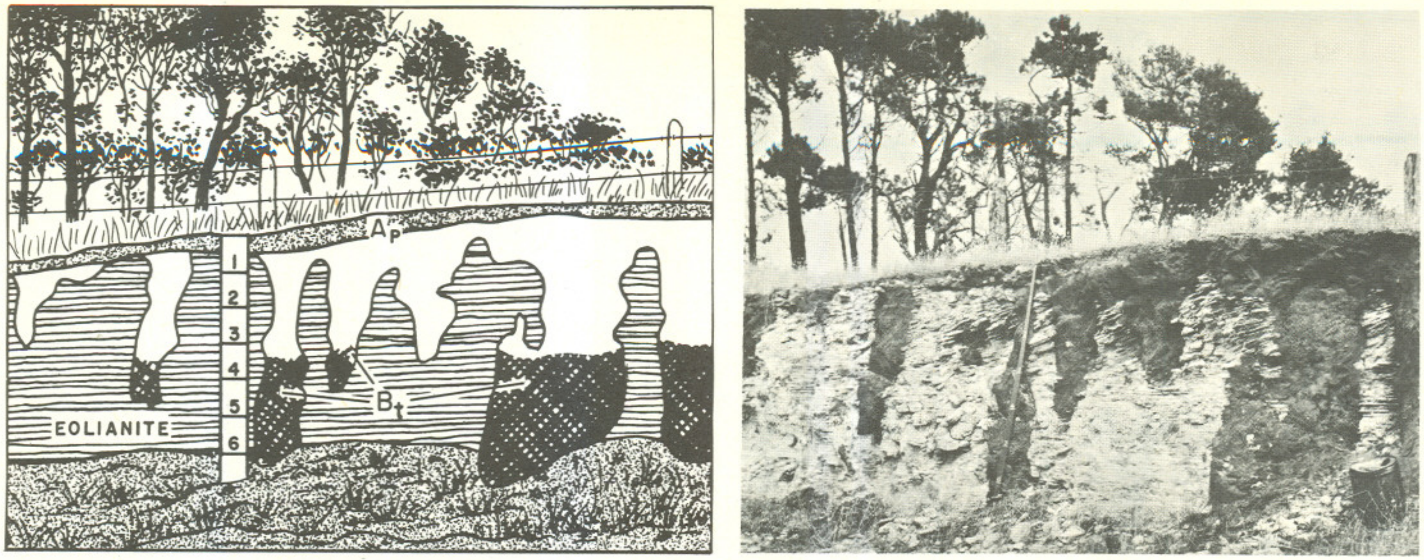

Figure 2.–Soil with a discontinuous B horizon that has illuvial clay (argillic horizon), Mt. Gambier, S. Australia.

near Winnipeg, Manitoba, developed in lacustrine montmorillonitic clay, in which the thickness of the black A1 horizon varies from foot to foot. The deep tongues of A1 occurred in the depressions in the virgin gilgai microrelief. They now form a polygonal network, with polygons of something like 1.5 to 3 meters in diameter. The pedons will vary from about 1 to 2 and 2.5 square meters. Figure 4 shows a soil near College Station, Texas in which the A horizon varies greatly in thickness within distances of a meter or so. The thicker portions of the A horizon form a more or less polygonal pattern. Where the A horizon is thickest, there is a bleached horizon just above the very fine textured B horizon. The pedons in this soil have areas of from about 2 to 7 square meters. The soils shown in figures 3 and 4 developed in swelling clays and have irregular or intermittent horizons as a result of the swelling and contraction of the clays. The volume changes over a considerable area are required to produce the tongues of A1 shown in figure 3, or the intermittent bleached A2 horizon shown in figure 4.

If soil is considered primarily as the natural medium for the growth of plants it is possible to consider each profile illustrated as a single kind of soil with intermittent or cyclic horizons. In each situation it would be difficult to have a mature, native, perennial plant whose roots were not in contact with all of the possible combinations of horizons. It can also be argued in each instance that the intermittent or cyclic nature of the horizons is an essential to the understanding of the genesis of the soil and is as significant to a proper classification as is the presence of the horizons themselves.

Depending on the concept of soil and of the pedon, there might be quite different classifications of the soils. With the concept of soil and pedon as outlined, the pedon may include markedly differing horizon sequences.

Since the genesis of any soil often is not understood, or is disputed, it can be used only as a general guide to our thinking in the selection of criteria and forming of concepts. Generally, a more or less arbitrary definition of a pedon serves the purposes of classification better at this time than a genetic one. For that reason, the following may be used: A pedon is a three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations. Its area ranges from something like 1 to 10 square meters, depending on the nature of the variability of the horizons. Where horizons are intermittent or cyclic, and recur at linear intervals of 2 to 7 meters, the pedon includes one-half of the cycle. Where the cycle is less than 2 meters, or all horizons are continuous and of uniform thickness, the pedon has an area of approximately 1 square meter. If horizons are cyclic, but recur at intervals greater than 7 meters, the pedon reverts to the 1 meter size, and more than one soil will usually be represented in each cycle.

The Soil Individual

The soil individual, or "a soil" consists of one or many contiguous pedons, bounded on all sides by "not-soil" or by pedons of unlike character in respect to one or more characteristics diagnostic for a soil series. It should be noted that a soil may surround other soils as water surrounds an island, but the limits of a soil are reached where soil stops or where the pedons include characteristics diagnostic of a different soil series. The soil individual, or "a soil," may therefore have a minimum area of something like 1 square meter and an undetermined maximum area. A soil may have characteristics, such as shape, transitional margins, and natural boundaries, not possessed by its component pedons.

The soil series is discussed in more detail in chapter 3. We need to emphasize here, however, that "a soil," or the soil individual, is a small three-dimensional segment of the landscape, with lateral boundaries that are also boundaries of other soils. The lateral boundaries are often gradational, and difficult to locate precisely in the field. Yet they do exist. Having determined the criteria for the limits of a soil series, the boundaries of the areas that come within those limits can be determined. The pedons of a soil individual vary in their properties within the limits of the definition of the series.

Soil individuals are related to but rarely identical to the areas delineated on maps and identified by a

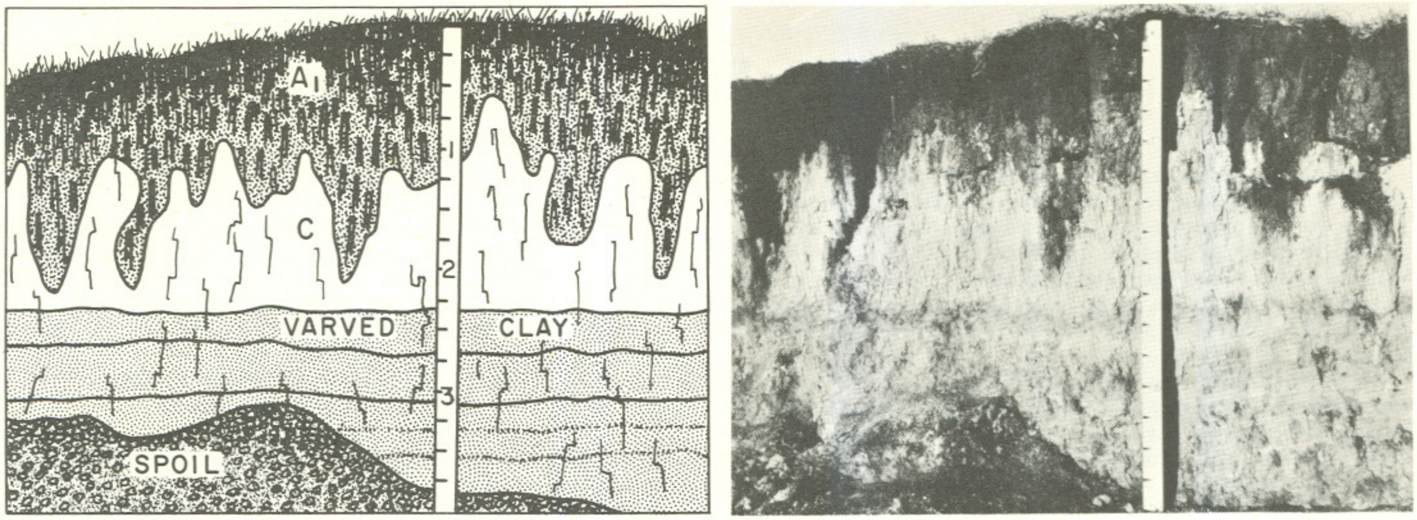

Figure 3.—Soil with an irregular A1 horizon, Winnipeg, Canada.

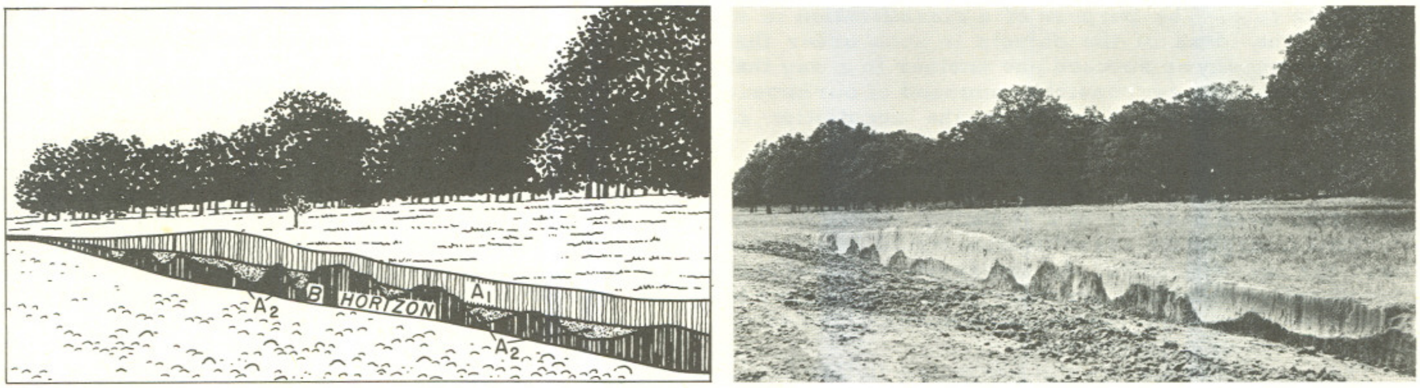

Figure 4.—Soil with a discontinuous bleached A2 horizon (albic horizon), College Station, Tex.

series name. This relationship is a source of confusion to some. The areas identified by soil maps as to series are at best rough representations of the soil individuals. Many inclusions of other soil individuals may be present, or conversely, several individuals of a given series may be combined. Large individuals are often subdivided into types and phases in order to make possible more precise statements about soil behavior. In some situations, a number of individuals of two or more series may be grouped and shown as a complex. However, if given a large enough scale and sufficient time, it would be possible to make a map showing the position of each soil individual. As soil maps are usually made, the use of a series name merely indicates that the major part (85 percent or more) of the area belongs in that series. The soil individuals are the real things that we want to classify into series and higher categories.

Chapter 2. Soil Classification

Classifications are contrivances made by men to suit their purposes. They are not themselves truths that can be discovered. Therefore, there is no true classification; a perfect one would have no drawbacks when used for the purpose intended; the best classification is that which best serves the purpose or purposes for which it was made or for which it is to be used.

As knowledge expands, new facts or closer approximations of truths not only make possible improvements in classifications but also often make changes imperative. Thus, classifications are not static things but need to change as knowledge expands. It has been said: "Classification is the mirror, in which the present condition of science is reflected; a series of classifications reflect the phases of its development."

A classification is an ordering or arrangement of objects, in the mind, and distribution of them into compartments. The purpose of a classification is to arrange the ideas of the objects in such order that ideas accompany or succeed one another in a way that gives us the greatest possible command of our knowledge and leads most directly to the acquisition of more.[1]

Many classifications of soils are possible and may be either natural or technical. The capability classification is an example of a technical classification. Perhaps interpretive classification would be a better term for use with soils. An interpretive classification of soils is one that arranges soils into classes to permit more or less specific statements about some aspect of use or management.

The classification system presented in this handbook is a natural, or taxonomic, system. Many such systems have been developed in the past, and it is quite probable that many more will be developed in the future. No attempt will be made here to review the literature on soil classification; rather, some selected examples are included to illustrate the problems that led to the system presented here.

A natural classification of soils was impossible until it was recognized that soils were independent natural bodies with distinctive morphologies. The first such classification was that of Dokuchaiev[2] and his school. To them soils were independent, subaerial, natural bodies, with properties reflecting the effects of local and zonal soil-forming agents. Recent alluvium on river flood plains, and formations under water, such as coastal marshes, were "not-soil," for the former showed no effects of the soil-forming agents, and the latter were subaqueous. It should be pointed out that ideas of the drastic climatic changes associated with the Pleistocene and post-Pleistocene period had not been developed, and Dokuchaiev assumed that soils had developed their characteristics under the climates in which he found them. With this concept of soil and climate, and with extremely limited data, Dokuchaiev developed the first soil classification shown in table 1.

There is apparent inconsistency between Dokuchaiev's classification and his concept of soil. Classes III and VI (table 1), which to him were not soil, were nevertheless included in the classification. He explained as follows:

"According to my understanding of the term, only the members belonging to class I, and part of those belonging to classes II, IV, and V, may be considered as typical soils; while members of the other classes--III and VI--seem to belong as much to geology as to soil science. But owing to the fact that with time they are frequently converted into true soils, and that besides they are connected with the members of the first four classes by means of innumerable transitional

TABLE 1.--1886 Classification of Soils by V. V. Dokuchaiev

According to position (to presence of primary genetical features)	According to origin	According to climatical regions (and to humus content)	Accordind to zeolite clay (each soil)
A. Normal	*I cl.* Dry land vegetative soils	1. Light grey northern soils 2. Grey transitional " 3. Chernozem 4. Chestnut transitional " 5. Southern brown alkaline soils: primary, secondary, periodical, eroded, burrowed	Sandy Sandy-loamy Loamy Clayey
	II cl. Dry land moor-soils	6. Soils of swamped forests 7. Meadow soils	
	III cl. Moor (bog)-soils (soils in potentia)	8. Tundra soils 9. Peats 10. Water logged flood plains, etc.	
B. Transitional	*IV cl.* Washed soils *V cl.* Dry land sedimentary soils		
C. Abnormal	*VI cl.* Sedimentary soils		

[1]John Stuart Mill, In his A System of Logic, 8th ed., Harper & Bros., N. Y., 1891, expressed it this way:

"The general problem of classification...may be stated as follows. To provide that things shall be thought of in such groups, and those groups in such an order, as will best conduce to the remembrance and to the ascertainment of their laws.

"The ends of scientific classification are best answered, when the objects are formed into groups respecting which a greater number of general propositions can be made, and those propositions more important, than could be made respecting any other groups into which the same things could be distributed. The properties, therefore, according to which objects are classified, should, if possible, be those which are causes of many other properties; or, at any rate, which are sure marks of them. Causes are preferable, both as being the surest and most direct of marks, and as being themselves the properties on which it is of most use that our attention should be strongly fixed. But the property which is the cause of the chief peculiarities of a class, is unfortunately seldom fitted to serve also as the diagnostic of the class. Instead of the cause, we must generally select some of its more prominent effects, which may serve as marks of the other effects and of the cause.

"A classification thus formed is properly scientific or philosophical, and is commonly called a Natural, in contradistinction to a Technical or Artificial, classification or arrangement."

[2]The discussion of Russian classifications is summarized from: Afanasiev, J. N. The Classification Problem in Russian Soil Science. Acad. of Sci. U.S.S.R. Russ. Pedol. 5. Leningrad. 1927.

TABLE 2.--Final (1900) Classification of Soils by V. V. Dokuchaiev

Class A. Normal, otherwise dry land vegetative or zonal soils

Zones	I. Boreal	II. Taiga	III. Forest-steppe	IV. Steppe	V. Desert-steppe	VI. Aerial or desert-zone	VII. Subtropical and zone of tropical forests
Soil types	Tundra (dark brown) soils	Light grey podzolised soils	Grey and dark grey soils	Chernozem	Chestnut and brown soils	Aerial soils, yellow soils, white soils	Laterite or red soils

Class B. Transitional soils

VIII. Dry land moor-soils or moor-meadow soils	IX. Carbonate containing soils (rendzina)	X. Secondary alkali-soils

Class C. Abnormal soils

X. Moor-soils	XI. Alluvial soils	XIV. Aeolian soils

forms, they cannot and ought not to be excluded from a soil classification."

Dokuchaiev, in his final classification in 1900 (table 2) retained the normal, transitional, and abnormal divisions, but dropped a category. The types (great soil groups in the United States) were re-grouped, and some classes apparently disappeared, notably class IV, the "Washed soils," which presumably corresponded to Regosols and Lithosols. The influence of Dokuchaiev's work on soil classification has been enormous.

Sibirtsev, Dokuchaiev's closest collaborator, followed Dokuchaiev's last groupings closely, but introduced the concepts of zonal, intrazonal, and azonal soils in place of Dokuchaiev's divisions of normal, transitional, and abnormal. Sibirtsev included a type, "Rough coarse soils (not on floodplain)" for what were later called Regosols and Lithosols. He apparently considered peats and mucks as "not-soil," for he made no provision for them in his system. Other Russian soil scientists, such as Zakharov, Kossovich, and Glinka, did include the peats in their soil classifications.

The Russian soil types, roughly equivalent to great soil groups, in the United States, are defined in part by climate and vegetation, and to this extent the definitions are genetic. But the definitions also include color and other morphologic features, and to this extent are taxonomic.

Many systems were later developed in other parts of Europe. One of these, that of Gedroiz, was based on the nature of the exchangeable cations and was a taxonomic system. The others have had classes based in part on genesis and in part on morphologic features.

In the United States the first clear recognition of soil as an independent natural body was by Coffey,[3] in 1912. Coffey believed that the criteria of classification should be the properties of the soils themselves and objected to a classification based on climate and vegetation <u>per se</u>. Hilgard had earlier drawn attention to important soil differences associated with climate and vegetation but had not attempted a classification. Coffey concerned himself only with the soils of the United States, and recognized five major kinds of soil. These were defined in terms of soil characteristics, but the names were suggestive of climate and vegetation. Coffey's major classes of soils were:

1. Arid soils
2. Dark-colored prairie soils
3. Light-colored timbered soils
4. Black swamp soils
5. Organic soils

Each class was subdivided into series on the basis of parent material, including its mode of deposition, and the series were subdivided into types on the basis of texture.

In 1913[4] Marbut reflected the opinion of most of his colleagues when he wrote: "It is of vast importance. . . .in the classification of soils to recognize not only the character of the rock from which the material has been derived but also the agencies which have acted in the transportation and deposition of the soil material and the changes which have taken place since its deposition. The character of the parent rock material, with the influences of general physiography dependent upon this, the transportation and redeposition of such material or its sedentary character are the factors on which the soil province is based. The changes which have been wrought in the material since its deposition or in the case of untransported material since its formation, together with the influences in minor differences in rock character, are the factors on which the. . . .soil series, is based." (At this period texture of the soil, not the plow layer, determined the type. Texture was a summation of the effects of particle size and consistence.)

By 1922, Marbut's opinions had changed drastically. He wrote:[5] "I think I may lay down the proposition as an absolute one that the basis of grouping should be the characteristics of the objects grouped. They should be tangible, determinable by a study of the objects themselves and by direct observation and experiment."

Between 1913 and 1922, Marbut's concept of soil shifted from unconsolidated material or regolith to the concept of an independent natural body with horizons. In the later period, he conceived of soil as equivalent to solum. Marbut's system of soil classification was presented first in 1927,[6] and developed in more detail in 1936.[7] The final outline is shown in table 3. To understand his classification, one must remember the enormous emphasis he placed on what he called the normally or fully developed soil, or the "mature" soil. Marbut recognized that soils change with time and in early stages of development may have only weakly expressed horizons. Because characteristics of immature individuals are not considered in the

[3] Coffey, G. N. A Study of the Soils of the United States, U. S. Dept. Agr. Bureau of Soils Bul. 85, 114 pp., illus. 1912.

[4] Marbut, C. F. Progress of the Soil Survey. In Soils of the United States. U. S. Dept. Agr. Bur. of Soils Bul. 96:7-16. 1913.

[5] Marbut, C. F. Soil Classification. Amer. Assn. Soil Survey Workers, Bul., 3:24-32, 1922.

[6] Marbut, C. F. A Scheme for Soil Classification. 1st Internatl. Cong. Soil Sci. Proc. 4:1-31, illus. 1927.

[7] Marbut, C. F. Soils of the United States. <u>In</u> U. S. Dept. Agr. Atlas of American Agriculture, pt. 3, 98 pp., illus. 1936.

TABLE 3.--Soil Categories by Marbut

	Pedalfers (VI-1)	Pedocals (VI-2)
Category VI-----	Pedalfers (VI-1)	Pedocals (VI-2)
Category V------	Soils from mechanically comminuted materials. Soils from siallitic decomposition products. Soils from allitic decomposition products.	Soils from mechanically comminuted materials.
Category IV-----	Tundra. Podzols. Gray-Brown Podzolic soils. Red soils. Yellow soils. Prairie soils. Lateritic soils. Laterite soils.	Chernozems. Dark-brown soils. Brown soils. Gray soils. Pedocalic soils of arctic and tropical regions.
Category III----	Groups of mature but related soil series. Swamp soils. Gley soils. Rendzinas. Alluvial soils. Immature soils on slopes. Salty soils. Alkali soils. Peat soils.	Groups of mature but related soil series. Swamp soils. Gley soils. Rendzinas. Alluvial soils. Immature soils on slopes. Salty soils. Alkali soils. Peat soils.
Category II-----	Soil series.	Soil series.
Category I------	Soil units, or types.	Soil units, or types.

classification of plants or animals, Marbut believed they should not be considered in the higher categories in soil classification. The analogy was misleading. Soils are not living things. Individual plants and animals do not change species, but changes in vegetation or other soil-forming factors can in time change the properties of a soil. Examples might be the conversion of Brown Earths into Podzols under heath, or Chernozems into Gray Wooded soils by the invasion of the forest. During the change, properties of both classes are present. Nevertheless, Marbut used the analogy to justify ignoring the properties of some soils while considering those of others. For example, Marbut included some Alluvial soils and peats with Pedocals. The Pedocals were supposed to be soils with a lime horizon. He thought the Alluvial soils in dry climates would, in time, develop lime horizons. To this extent their inclusion with the Pedocals was a genetic grouping and not a classification based on properties. The reason for inclusion of peats with the Pedocals is not clear from Marbut's writings. In the United States, Marbut did succeed in changing the concept of soil from that of weathered rock to that of an independent natural body. The old concepts, however, still linger in the definitions of some soil series.

The most recent U. S. classification was that of Baldwin, Kellogg, and Thorp.[8] This was published in 1938, and revised in 1949.[9] The outline of the last revision is shown in table 4.

This system was developed because Marbut's system contained such serious defects, and because it was desirable to expose the shortcomings of the knowledge of that period. While it was called a classification according to soil characteristics, it was in fact no more so than many others. The classes of the two highest categories were defined, in part, in genetic terms. Baldwin, et al. wrote: "Except where the continuity of the landscape is interrupted by mountains or large bodies of water, zonal soils occur over large areas, or zones, limited by geographical characteristics. Thus, the zonal soils include those great groups having well-developed soil characteristics that reflect the influence of the active factors of soil genesis--climate and living organisms (chiefly vegetation). These characteristics are best developed on the gently undulating (but not perfectly level) upland, with good drainage, from parent material not of extreme texture or chemical composition that has been in place long enough for the biological forces to have expressed their full influence.

"The intrazonal soils have more or less well-developed soil characteristics that reflect the dominating influence of some local factor of relief or

[8]Baldwin, M., Kellogg, Charles E., and Thorp, J. Soil Classification. In Soils and Men. U. S. Dept. Agr. Ybk. pp. 979-1001, illus. 1938.

[9]Thorp, J., and Smith, Guy D. Higher Categories of Soil Classifications: Order, Suborder, and Great Soil Groups. Soil Sci. 67: 117-126. 1949.

TABLE 4.--Soil Classification in the Higher Categories

Order	Suborder	Great soil groups
Zonal soils	1. Soils of the cold zone	Tundra soils.
	2. Light-colored soils of arid regions.	Desert soils. Red Desert soils. Sierozem. Brown soils. Reddish-Brown soils.
	3. Dark-colored soils of semi-arid, subhumid, and humid grasslands.	Chestnut soils. Reddish Chestnut soils. Chernozem soils. Prairie soils. Reddish Prairie soils.
	4. Soils of the forest-grassland transition.	Degraded Chernozem. Noncalcic Brown or Shantung Brown soils.
	5. Light-colored podzolized soils of the timbered regions.	Podzol soils. Gray wooded, or Gray Podzolic soils.1/ Brown Podzolic soils. Gray-Brown Podzolic soils.1/ Red-Yellow Podzolic soils.1/
	6. Lateritic soils of forested warm-temperate and tropical regions.	Reddish-Brown Lateritic soils. Yellowish-Brown Lateritic soils. Laterite soils.1/
Intrazonal soils	1. Halomorphic (saline and alkali) soils of imperfectly drained arid regions and littoral deposits.	Solonchak, or Saline soils. Solonetz soils. Soloth soils.
	2. Hydromorphic soils of marshes, swamps, seep areas, and flats.	Humic Gley soils 1/ (includes Wiesenboden). Alpine Meadow soils. Bog soils. Half-Bog soils. Low-Humic Gley soils.1/ Planosols. Ground-Water Podzol soils. Ground-Water Laterite soils.
	3. Calcimorphic soils	Brown Forest soils (Braunerde). Rendzina soils.
Azonal soils	----------	Lithosols. Regosols (includes Dry Sands). Alluvial soils.

1/ New or recently modified great soil groups.

parent material over the normal effect of the climate and vegetation. Any one of these may be associated with two or more zonal groups, but no one with them all.

"The azonal soils are without well-developed soil characteristics either because of their youth or because conditions of parent material or relief have prevented the development of definite soil characteristics. Each of them may be found associated with any of the zonal groups."

The azonal order was defined in terms of soil characteristics. The zonal and intrazonal orders, however, were defined primarily in genetic terms. When new great soil groups had to be placed in the system, the proper order had to be selected genetically. An example is the problem of the placement of the Ando soils in this system. If the dark surface is the result of the fibrous roots of the bamboo, the Ando soils can be considered zonal. If, on the other hand, the dark colors are the result of the parent material, volcanic ash, they are intrazonal soils. Since the genetic cause of the dark surface was not known, the Ando soils were not placed in the 1949 revision of the system.

Several major defects have been common to nearly every system proposed. One is the vague definitions of the classes. The great soil groups were defined in the American system in terms of soil properties, but the definitions were brief, and serious difference of opinion developed on the interpretation of a number of the definitions. To be useful, definitions must be precise enough that different readers have approximately the same understanding of the meanings. Ideally, a definition of properties should be in such precise terms that every competent soil scientist, after making the necessary determinations, could know with assurance that the property did or did not exist in a given soil. And, every competent soil scientist who had made the measurements would agree. This is the ideal, and the goal of the system presented here, but unfortunately it has not been attained. In too many places knowledge and methods are lacking.

Another general defect of previous systems is that they have been based primarily on the genesis or on the properties of virgin soils in the natural landscape. Cultivated soils have either been ignored, or classified on the basis of the properties that they are presumed to have had when virgin.

Since it is still perhaps the most common view that soils should be classified on the properties of the virgin profiles, it should be emphasized here that a general system of soil classification must be applicable to all soils and not just to those which, for one reason or another, have not been brought under cultivation or affected in other ways by man's activities. The classification of soils on their virgin properties is an appealing escape from the use of properties. Assuming that it is possible to reconstruct the virgin profile (not always a safe assumption), a property which has existed in a soil, but which does not now exist and cannot be expected to exist again, would seem inappropriate for a classification of the present soil.

Man's influence on the soil stems chiefly from his ability to change one or more of the soil-forming factors, from additions he makes to the soil, and from plowing with its subsequent hazard of erosion or mixing of horizons. Under the changed environment a new cycle of soil development begins. Changes in the soil may be very slow or may take place within a few years. Adjustments in kinds and amounts of organic matter may be appreciable in a few decades, but it seems likely that a few hundreds of years are required to reach a new equilibrium with respect to organic matter. Changes in color may take place in less than a year, or in a few years at most, when an area is diked out from the sea or when a new rice paddy is formed. Erosion may remove horizons completely, or plowing may merely mix them.

In lands where cultivation is very recent, the properties acquired under man's management may be less significant than those acquired over thousands of years under the natural environment. Yet in some parts of the world man has been using soils for many centuries, and the soils have changed so drastically that many of the former properties have vanished. Yet these are soils--just as truly soils as those that have escaped man's influence. New B horizons may have been formed. This seems the case with most of the humus Podzols of western Europe that formed under heath--a vegetation induced by man's activities. And, having formed, these B horizons may have been largely destroyed again by the use of amendments or by growth of nitrogen-supplying plants. This seems to have happened in many of the sandy soils of Flanders.[10] Which is the more significant, the present properties, properties that existed some 200 years ago, or the properties that existed 4,000 years ago?

Soils have not been considered static, but there has been inadequate recognition in the classifications of the changes that may take place in the environments that man has created. A rational system of soil classification must be able to provide for changes in the soil itself.

Essentially all of our previous natural classifications have assumed that the soil scientist knew where he was, geographically, in relation to broad climatic and vegetation zones and to land forms. Such knowledge enters into his view of the soil. It prompts him to look for certain features because he expects them. Inescapably, the genetic factors are considered, not simply the morphology of the soil.

This also applies to his view of a soil profile. He looks for a B horizon within certain depth limits because that is where he expects to find it.

In soil classification, one of the prime difficulties that some people have stems from the nature of the soil individual. A horse is a discrete individual. The boundaries of soil individuals are not so obvious, or more strictly, they are vague, somewhat the way the boundaries among the Indian Ocean, the Bay of Bengal, and the Arabian Sea are vague. Yet all these bodies of water exist and, for good and sufficient reasons, each falls in a different class—ocean, sea, and bay. Soils form a continuum, with few discontinuities between individuals, or between classes of individuals. Discontinuities, such as exist between species of animals, can be found in soils only if transitional forms are ignored and points are selected for classification. The limits between soil individuals therefore must be fixed by definition and are arbitrary to this extent. Having fixed the definition, however, we can locate the boundaries in the field. The limits between classes of individuals are fixed purely by definition. The changes in the definition of "Miami" that established the Hillsdale and St. Clair series affected the classification of many soil individuals, but changed the boundaries of very few. A similar situation might exist in plant or animal taxonomy if all kinds of plants or animals that exist or that ever

[10] Tavernier, R., and Ameryckx, J. Le Postpodzol en Flandre Sablonneuse. Pedologie 7: 89-96, illus. 1957.

have existed could be studied and had to be classified in a single system. There is a fundamental difference between soil and plant or animal classification that makes analogies between the classifications misleading.

As soil science gradually grows from nature study to science, it becomes more quantitative. We hope to develop a system of soil classification that reflects the growing precision of the science. It should be based increasingly on the characteristics of the soil, accurately measured, and less on our appraisal of the genetic factors themselves.

Our major problems in developing the classification here presented arise from this attempt to focus primarily on the soils themselves, and in a quantitative rather than a qualitative manner.

With the foregoing in mind, the following assumptions have guided the development of this classification system.

1. A natural classification of the soils of the United States is needed. If it will accommodate soils of other continents, it will be more useful in the United States.

2. A natural classification should be based on the properties of the objects classified.

3. The properties selected should be observable or measurable, though instruments may be required for observation or measurement. Properties which can be measured quantitatively are to be preferred to those which can be determined only qualitatively.

4. The properties selected should be those that either affect soil genesis or result from soil genesis.

5. If an arbitrary selection must be made between two properties of apparent equal genetic significance, but with different significance to plant growth, the property with the greater significance to plant growth should be selected for the higher category.

6. Subdivisions of all classes in a given category need not be made according to a common property or set of properties, but should be made, class by class, according to the properties that give the most useful classification. It is recognized that properties highly significant to one kind of soil often have no relevance to the classification of other kinds of soil.

7. Many soils of the world are unknown, and their placement in the system should not be predetermined. Definitions of classes should accommodate all soils that have been studied in some detail, but may require future modification to include or exclude the kinds of soil now unknown.

8. A classification system should be flexible enough that it may be modified to incorporate new knowledge without the confusion in the literature resulting from the use of a specific name with different meanings in different periods of time.

9. It is normally undesirable to have a change in the classification of a soil as the result of a fire, or a single plowing.[11] Surface horizons that are thin enough to be obliterated by normal plowing, or thin A0 horizons that may be destroyed by fire, should not be used as diagnostic characteristics for a natural classification. Such properties may have enormous importance in the management of forests, but are easily changed. The tilth of a plow layer is of equal importance to the production of row crops, but has not been considered an appropriate property for a natural classification. Similarly, the removal of a few inches of the surface by erosion, blowing, or grading, should not in itself change the classification, except possibly at the lowest categoric level. Where possible, therefore, diagnostic horizons or properties should be those least apt to be lost by truncation or mixed by plowing. In general, horizons or soil properties that are found well below the surface of virgin soils are to be preferred to surface horizons, except, perhaps, in the lowest category.

It has not been possible to follow all of these assumptions rigorously throughout the entire system. Inevitably, the conclusions of a large group of scientists include some compromises of divergent viewpoints. Members of a group representing unlike interests and experience see soils from a number of viewpoints. Different viewpoints toward soil produce different ideas about its classification. Consequently, compromises between the conflicting desires of a number of individuals are not only necessary but might actually produce a system with more general utility than a system which represents a single viewpoint. "Compromise" may not be the exact word. The truth has many facets; each person has a somewhat different view of the truth, and no human can see the whole truth clearly. Our goal has been a blending of many views to arrive at an approximation of a classification that seems as reasonable as we can hope to reach with our present knowledge. Our attempt has made us keenly aware of the great gaps in that knowledge. But it has also given us faith in the value of improvement, when we realize the utility of the old classifications with all their imperfections.

Probably no one person will approve of all of the details of this system; very few will be able to agree upon all of the desirable changes. This, we think, is as it should be at this stage of our knowledge.

[11] If a fire burns a thick peat, or if plowing is deep enough to obliterate all of the horizons and mix a part of the parent material, a change in classification is justified, but the reference is to less drastic alterations.

Chapter 3. The Categories of the System

A category, as used here, is a set of classes, defined approximately at the same level of abstraction, and including all soils in its classes. The orders and suborders, for example, comprise two categories. The other categories are great group, subgroup, family, and series.

One could construct a classification by simple bifurcation, that is, on the presence or absence of a single characteristic, with a separate category for each characteristic. Such a system would have so many categories that it would be impossible to use as anything other than a key; it would serve to identify soils but would hardly be useful in helping one see relationships between soils. In this system the classes in each category are differentiated on the basis of many characteristics.

THE ORDERS

Ten orders are recognized. The number could have been increased or decreased by one or two, depending on one's viewpoint, but the present number has not been seriously criticized. The orders correspond most closely to Dokuchaeiv's soil types, though they are by no means identical.

There is a correspondence between the present orders and the major classes of soil defined by Coffey. Three of his five classes--Arid soils, Dark-colored Prairie soils, and Organic soils--are closely related to three of the present orders. One of his classes, Light-colored timbered soils, has been subdivided into three orders, and his fifth class, Black swamp soils, is distributed among several suborders.

The only resemblance between the present orders and the orders of the 1938 system of Baldwin, Kellogg, and Thorp is that the Azonal soils correspond very roughly to one of the present orders. The suborders in the system devised by Baldwin et al. are much like the Russian soil types (compare tables 2 and 4) and have many similarities to the present orders, though defined in different terms.

The differentiae used among the orders were developed largely by generalization of common properties of soils that seem to differ little in the kinds and relative strengths of processes tending to develop horizons.

As an example, Chestnut, Chernozem, and Brunizem (Prairie) soils seem very closely related. All have the same general sequence of horizons, grade from one to the other, and are, in fact, sometimes difficult to distinguish in the absence of the native vegetation if they developed on comparable parent materials of comparable age. If one abstracts the properties that are always present, he finds that the character of the surface horizon is the most obvious feature that distinguishes these soils from most other soils. It is dark in color, is thick relative to the solum, and has structure, a relatively high base saturation, and a narrow C/N ratio. Preliminary definitions of such a surface horizon were developed and tested by determining which soil series would be grouped by the use of the above differentiae. It was found that, among others, some Rendzinas, some Brown Forest soils, some Grumusols, some Alluvial soils, Regosols, and Lithosols would be grouped with the Chernozems, Brunizems, and Chestnut soils. The soils that had been grouped in this manner were examined from the viewpoint of soil genesis to see whether soils of distinctly unlike genesis were being grouped. If there were such soils, an attempt was made to exclude them by changes in the definition. In the above example, it was felt that the Grumusols, Tropical Black clays, Regur, etc., did not fit well with the other soils in the group, though many could not be excluded by the nature of the surface horizon. They were therefore excluded by modifying the definition of the order.

The present orders perhaps can be best introduced by relating them to kinds of soil recognized in previous classifications (see table 5). The definitions of the orders and the derivations of the names are given later.

It will be noticed that there is no order which can be related to Dokuchaiev's "Dryland moor-soils, or moor-meadow soils," or the "Hydromorphic soils" (Baldwin et al.). These are distributed among the orders according to their other properties. The Humic Gley soils, or Wiesenboden, associated with Chernozems and Brunizems have so many properties common to the chernozemic soils they are placed in the same order; the differences in color associated with differences in soil drainage are disregarded in the orders. If the Humic Gley soils associated with Red-Yellow Podzolic soils have the diagnostic properties of the order that now includes Red-Yellow Podzolic soils, both are placed in that order. Thus, the Humic Gley soils are distributed among several orders.

The differentiae selected for the orders tend to give a broad climatic grouping of soils. The zonal soils of Baldwin et al. tend to be grouped with their associated intrazonal soils in many of the orders. The bias in favor of properties associated with or produced by widely differing climates is deliberate, and possibly is in part the result of our experience with earlier classifications. This product of Dokuchaiev's thinking has been proven useful and has been very widely accepted by several generations of pedologists. The only alternatives which could be found were tested in earlier approximations and found wanting.

Two of the orders, the Entisols which lack distinctive horizons, and the Histosols, or organic soils, have little or no climatic implication and can be found under almost any climate.

The orders, as defined, are almost but not quite all inclusive, for it is possible that soils will be found that do not fit into any order. Although the orders could be defined in such terms that all possible soils could be fitted clearly into one order or another, it seems best at this moment not to prejudge the classification of unknown soils. Modifications of the present definitions will undoubtedly prove necessary as knowledge grows, but the classification can be best adjusted when the facts are at hand.

THE SUBORDERS

Each order has been subdivided into suborders primarily on the basis of the characteristics that seemed

TABLE 5.--Present Soil Orders and Approximate Equivalents in Revised Classification of Baldwin et al.

Present order	Approximate equivalents
1. Entisols	Azonal soils, and some Low Humic Gley soils.
2. Vertisols	Grumusols.
3. Inceptisols	Ando, Sol Brun Acide, some Brown Forest, Low-Humic Gley, and Humic Gley soils.
4. Aridisols	Desert, Reddish Desert, Sierozem, Solonchak, some Brown and Reddish Brown soils, and associated Solonetz.
5. Mollisols	Chestnut, Chernozem, Brunizem (Prairie), Rendzinas, some Brown, Brown Forest, and associated Solonetz and Humic Gley soils.
6. Spodosol	Podzols, Brown Podzolic soils, and Ground-Water Podzols.
7. Alfisols	Gray-Brown Podzolic, Gray Wooded soils, Noncalcic Brown soils, Degraded Chernozem, and associated Planosols and some Half-Bog soils.
8. Ultisols	Red-Yellow Podzolic soils, Reddish-Brown Lateritic soils of the U. S., and associated Planosols and Half-Bog soils.
9. Oxisols	Laterite soils, Latosols.
10. Histosols	Bog soils.

to produce classes with the greatest genetic homogeneity. Only one characteristic, the color associated with wetness, was used to define suborders in each order in which it is found.

The definitions of several orders group some soils that have similar morphology but little or no genetic relationship. Where such groupings resulted, an effort was made to select properties which would separate the soils at the next lower category.

Other orders have included soils with wide ranges of climate. In these orders, an attempt was made to differentiate according to properties that would narrow the climatic range in each surorder.

Examples may help the reader. The lack of horizons in soils of recent origin on flood plains is due chiefly to lack of time for horizons to develop. Yet there are sands so rich in quartz that it is very difficult for horizons to form. Such sands might have been in place for periods much longer than would be required to form horizons in more mixed parent materials, but because horizons are weak, these sands are all grouped in the order of Entisols. Then, since there were different genetic reasons for the lack of horizons in the order of Entisols, suborders were defined to separate the sands from materials of mixed lithology.

A second example will illustrate the reasons for desiring to reduce climatic variations. The definition of Mollisols includes soils which lie near the margin between the steppes and the desert, as well as soils in humid climates that are subject to annual leaching. Some have developed under forest and others under grass vegetation. Some have a horizon of accumulation of soluble salts; others do not. The soils formed near the margin of the desert and the steppe tend to be thin, and to be saturated or nearly saturated with bases. Those formed in the more humid part of the range tend to be thicker and are often acid. Other properties, such as the amount of organic matter, are associated with the climatic variations. Abstraction of the properties that are common to the soils in the drier range of the order and lacking in the soils in the more humid portion led to the selection of the nature of the replaceable bases and the percentage of base saturation as differentiae which would produce suborders with smaller climatic ranges. The differentiae selected are not ideal, for they may only be determined in the laboratory. Perhaps when more knowledge is at hand, better differentiae may be selected.

The differentiae used in the suborder category are numerous. The general picture may be most easily grasped from the statement that the differentiae are primarily chemical or physical properties that reflect either the presence or absence of waterlogging, or genetic differences due to climate and its partly associated variable, vegetation. The remaining differentiae are chemical (or mineralogical) properties and include extreme textures, such as sands; and presence of large amounts of allophane or free sesquioxides in the clay fraction. These properties either control the direction and degree of soil development or are themselves the effects of soil development and weathering.

THE GREAT GROUPS

Each great group is defined, within its respective suborder, largely on the presence or absence of diagnostic horizons and the arrangement of those horizons. Where horizon arrangements do not vary within a suborder, other diagnostic properties were used if necessary, but a few suborders have only one great group. The diagnostic horizons selected are those that we believe indicate both major differences in degree of development and minor differences in kind.

Horizons used as differentiae include those horizons that contain illuvial clay, iron, and humus; thick, dark-colored surface horizons; pans that interfere with root development, water movement, or both; and anthropic horizons that formed under cultivation.

Properties that cannot be considered as constituting horizons are used where differences in horizons are not relevant. For example, diagnostic features that have been used in this category are the self-mulching properties of some clays, the dark-red and dark-brown colors associated with basic rocks, wide difference in base saturation, the property of irreversible hardening, the tonguing of eluvial horizons into illuvial horizons, and low soil temperatures.

From the viewpoint of soil morphology, each great group is to be thought of as uniform with respect to kind and arrangement of diagnostic horizons and features. From a genetic viewpoint, the great groups may be considered as segments of the continuum of soils, spaced with as nearly equal uniformity as our present knowledge permits. Each great group has its central point, or concept, and includes intergrades toward other groups. Ideally, the great groups should be more or less equally spaced in terms of the variability in genesis of soils. Areal extent should not be given weight, but considerable unconscious bias in favor of soils occupying large areas is probably unavoidable. One reason, of course, is that the extensive soils are the ones most apt to have been seen and studied. A unique soil with only a few pedons is not apt to have been noticed, let alone studied.

THE SUBGROUPS

The subgroups, as the name implies, are subdivisions of great groups, and can be defined only in terms of reference to the great groups. If we think of a great group as occupying a segment of the spectrum of soil properties, the core, or central part of that area is one subgroup. The fringes, where the properties of one great group merge with those of others, are areas where the soils intergrade between the great groups. These areas are intergrade subgroups. The dominant properties of the intergrade subgroup are those of the great group to which it belongs. The additional properties of the intergrade subgroup, more weakly expressed, are those of the great group toward which the subgroup intergrades. As an example, we might consider the Gray-Brown Podzolic soils and the Podzols as great groups. The central concept of Podzols includes a bleached A2 horizon and a B horizon which has accumulated free sesquioxides and humus but not silicate clays. The Gray-Brown Podzolic soils have a browner eluvial A2 horizon and a B horizon that contains illuvial silicate clay. As the Podzols and Gray-Brown Podzolic soils come together, one finds that the soils commonly contain two illuvial B horizons separated by an eluvial horizon. The upper B is like that of the Podzol, and the lower one like that of the Gray-Brown Podzolic soil. Such soils have properties of both great soil groups and are considered intergrades between the groups. In these soils, the intergradation is shown by the presence of the additional horizons. In the instance above, the horizons are superposed. In the examples given in chapter 1, the horizons are intermittent.

The Gray-Brown Podzolic soils also intergrade to many other great groups. The intergrade toward the Red-Yellow Podzolic soils has no extra horizons, but it has a profile that is about halfway between that of the typical Gray-Brown and Red-Yellow Podzolic soils. The B of the typical Gray-Brown Podzolic soil has chromas of 3 or 4, and high base saturation. The B of the typical Red-Yellow Podzolic soil has chromas of 6, or more commonly 8, and low base saturation. The intergrades are intermediate in both chroma and base saturation. From a genetic viewpoint, the intergrades seem to be on land surfaces that are intermediate in age between the young land surfaces of the Gray-Brown Podzolic soils and the old ones of the Red-Yellow Podzolic soils.

Several kinds of intergrades are sometimes possible between two particular great groups. The soil may belong in great group X, but either be developing toward Y, or be developing from Y; the properties will rarely be identical in the two situations. And, some soils have aberrant features that are not common to any known kind of soil. The great group toward which these soils are intergrading may simply be unknown or may even be "not-soil." The subgroups then are of several kinds, as follows:

(1) The central concept of the great group
(2) Intergrades to other orders, suborders or great groups, as reflected by properties of the other classes either as--
    (a) a merging of properties throughout the soil;
    (b) additional horizons, including in some instances buried horizons;
    (c) intermittent horizons.
(3) Subgroups with aberrant properties not indicative of any other great group, suborder or order.

THE FAMILIES

The families are differentiated within a subgroup primarily on the basis of properties important to the growth of plants. The differentiae vary from subgroup to subgroup. They are being selected to provide families that will be relatively homogeneous with respect to soil-air, soil-water, and plant-root relationships, and to nutrient-supplying capacities for the major elements other than nitrogen. Within a subgroup the differentiae are based on the solum below the plow layer or an equivalent depth in soils lacking genetic sola. Differentiae include primarily texture, thickness of horizons, mineralogy, reaction, consistence, and permeability. An effort has been made to select characteristics that are relatively permanent. The families produced by the use of these differentiae have not been fully tested in the United States, and have not been tested at all on soils of other countries. It can be expected that additional differentiae will be needed, and it is possible that some of those now being tested can be dropped. Reaction, for example, is not particularly satisfactory but is easily measured. In the absence of mineralogic information it is the only available differentiae that will produce satisfactory groupings of some soils, particularly those found on flood plains without developed horizons.

THE SERIES

The soil series is a collection of soil individuals essentially uniform in differentiating characteristics and in arrangement of horizons; or, if genetic horizons are thin or absent, a collection of soil individuals that, within defined depth limits, are uniform in all soil properties diagnostic for series.

Soil individuals are real things, but series are conceptual. The "Miami" series, for example, cannot be seen or touched, though the soil individuals that we identify as parts of the Miami series can be seen and touched. Soil series names are used with several meanings, resulting in some confusion. We may speak of the Miami series as a taxonomic class that includes all individuals within the defined limits of Miami. Or, we may examine a pedon and say, "This is Miami," meaning that the properties we find in the pedon are those we ascribe to "Miami," and that the pedon is a proper sample of "Miami." The greatest confusion to some, however, comes from the fact that we also use "Miami" as a name for an area shown by a soil map if the Miami series can be identified in 85 percent or more of that area. These are three common uses of "Miami," or any series name, and all are proper. It is important however to keep in mind that a series, as used in this classification, is conceptual; the meaning is not identical with the meaning intended on soil maps, for the latter "Miami" has inclusions of other soil series, and permits inclusions of "Miami" in areas given different series names.

In all instances, the required uniformity within a series is in the part of the soil profile below the plowed layer or its equivalent. Consequently, pedons within a series are essentially homogeneous in the nature of their genetic horizons or in the properties of a defined part of the profile below the plow layer or below the depth of normal plowing. Differentiating horizons may be cyclical in nature and thus not entirely uniform in thickness and properties throughout the dimensions of a pedon. Interruptions of a horizon, as for example passage of an animal burrow through a B horizon, may also occur within pedons. To re-state all this in another way, emphasis is given to the morphology and composition of soils below plow depth in defining soil series, and relatively narrow ranges are permitted in the differentiating horizons or properties. At the same time, no attempt is made to define series so that each will have narrow ranges in all features.

Variability is permitted within a series in features such as slope, stoniness, truncation by erosion, nature of horizons within normal depth of plowing, depth to bedrock, and depth to a lithologic discontinuity. Permissible degrees of variability within series are less than will appreciably modify either the kind, arrangement, and thickness of differentiating genetic horizons or the differentiating properties within the definitive parts of profiles without such horizons. Thus, for example, soils within a series may have a wide range in slope, provided the nature and sequence of horizons in pedons remain essentially the same over that range. Similar statements can be made for stoniness, truncation by erosion, depth to bedrock, and depth to a lithologic discontinuity. Further information on the variability permitted within series in the nature of horizons within normal depth of plowing and in depth to bedrock or a lithologic discontinuity is provided in subsequent paragraphs.

Either or both of thin A1 and A2 horizons are permitted but not required in the definitions of a number of series. Thus, one series may include pedons having a thin A1 horizon (1 to 4 inches thick) and other pedons lacking an A1 horizon. Similarly, one series may include pedons having a thin A2 horizon as well as other pedons lacking an A2 horizon. Pedons within each such series, however, would be alike in the nature of horizons below the A1 or A2 horizon.

Variability in the nature of horizons within normal depth of plowing is permitted within series for two reasons. Thin horizons at or near the surface of the soil are mixed by plowing and may either be obliterated or obscured. They may be removed by slight erosion. If such horizons are used to differentiate series, the classification of a soil would have to be changed after it was plowed for the first time or after it was eroded slightly. Before plowing or erosion, the soil would have to be classified in one series and after plowing it would have to be classified as another series. Such classification would conceal more relationships than it would show. Variability in the nature of thin or faint horizons within normal plow depth is therefore permitted among the pedons in a series. Some variability is also permitted in the extent of truncation by erosion.

Wide but not complete agreement prevails on the variability that should be permitted within a series in the depth to bedrock or to a lithologic discontinuity and in the nature of the underlying materials if they do not appreciably modify one or more of the kind, arrangement, and thickness of the differentiating genetic horizons above. Agreement is general that appreciable modification of genetic horizons is differentiating between series. In the past, differences in the character of underlying rock or a lithologic discontinuity below the solum, and in some instances below the C horizon, have been used as a basis for setting apart series. This was more generally true 20 years ago than it is at the present time. In recent years, the trend has been away from the use of bedrock or lithologic discontinuities below the solum or below the C horizon as series differentiae per se. It has been common practice to make phase distinctions on the basis of underlying rock or a contrasting substratum if the differentiating genetic horizons were unchanged and if the differences at depth were important to the use and management of the soils. Such phase distinctions have been made within one or more soil types in a series. Whether it is more useful and appropriate to base series distinctions or phase distinctions on the depth to and nature of bedrock and on lithologic discontinuities beneath the solum remains under discussion at the time of this writing.

The differentiae among series, i.e., the properties or combinations of properties and their degrees of expression used in distinguishing series from one another, may be considered conveniently in two groups. One group consists of the differentiae used to set apart classes in categories above that of the series. The other group consists of the differentiae used to set apart closely similar series, as for example, those within one family.

Although they are important in defining series, the differentiae for the orders, suborders, great groups, subgroups, and families are not enumerated and discussed in this chapter. Readers of the present chapter should remember that all differentiae for the family category and for higher categories are automatically differentiating among series. Reasons for this will be reviewed before differentiae among similar series are discussed.

All differentiae for classes in categories above that of the series are of necessity differentiating among series. To state this principle in another way, soils that are placed into separate classes in any category above that of the series are also placed into separate series. Once two soils have been set apart at any level in a classification system, they remain apart in every category from that level down to the lowest one in the system. Consequently, the nature and sequence of differentiating horizons or the differentiating properties for the orders, the suborders, the great groups, the subgroups, and the families are all used to set apart series as well. A given combination of horizons or a specified combination of properties differentiating one family from others is also used to differentiate at least one series from others. This rule could be restated with substitution of order, suborder, great group, or subgroup for family. The differentiae for series, considering all series collectively, thus include all differentiae for all classes in all higher categories. Differentiae of this kind comprise the first group listed in the second preceding paragraph.

Differentiae among closely similar series comprise the second of the two groups mentioned in preceding paragraphs. Such differentiae are also of two kinds. Features considered in defining classes in higher categories may also be used to set apart series within a family. Two or more series may be differentiated in one family by subdividing into segments the full range of expression of one or more features, i.e., breaking down the full range allowed within that family. Series may also be set apart in one family on the basis of features that were not considered in defining classes in any higher category.

Within families, the series differentiae are not large, most being rather small. Some are fairly obvious, and others are not. Most often, the differentiae among series in one family are combinations of small distinctions, sometimes obscure ones. In some instances, the differentiae are evident distinctions in one or both morphology and composition.

Generally speaking, series differentiae are expected to meet two requirements. The first is that the properties used as differentiae are observable or can be inferred with reasonable assurance. For the most part, such properties must be observable in the field. Conceivably, there might be properties observable or measurable in the laboratory which should be series differentiae but which could not be related to any field characteristics. In practice, it has thus far been possible to relate differences first noted in the laboratory to features observable in the field. It is obvious that soil features must be identifiable in the field if they are to be used as a basis for mapping.

The second requirement to be met by series differentiae is that properties used have at least limited significance to soil genesis. Most of the time, series differentiae within families also have significance to either or both of plant growth and engineering. Limited significance to soil genesis is all that can be expected for differentiae between series in one family. Major differences significant in soil genesis are recognized in setting apart classes in categories above that of the series. Nevertheless, series differentiae should be tested for their probable meaning in soil genesis. If it is evident that differences between individuals are significant to soil behavior but not to soil genesis, these are separated in mapping by recognition of two or more types or phases within a series.

The play of judgment is important in weighing the magnitude of differences in properties that are observed, measured, or inferred and in testing the probable significance of those differences to soil genesis and to soil behavior. The importance of several features in combination has to be evaluated, usually without the help of any numerical common denominator. The play of judgment furnishes a common denominator for weighting soil features that cannot all be reduced to any one scale of measurement. Effectiveness of the play of judgment depends upon the knowledge and understanding of soil genesis and behavior that can be brought to bear on the questions at hand.

Properties of the solum below plow depth are given greatest weight as series differentiae among soils with evident genetic horizons. For such soils, the differentiae between series within a family may be combinations of small distinctions. These may be obscure in one or more features such as mineralogy, permeability, reaction, or distinctness of horizons. Series differentiae may also be evident distinctions in features such as thickness, color, texture, consistence, and structure of horizons. In some instances, a difference in one feature such as thickness of the B horizon is large enough to justify the setting apart of two series. Frequently, of course, a major difference of that kind is accompanied by other lessor differences. Combinations of small differences are the most common differentiae between series within families.

Properties of an arbitrary section below normal depth of plowing are given greatest weight as series differentiae among soils with thin or no diagnostic horizons. The depth limits for this arbitrary section are set so that it will be roughly equivalent in thickness to the solum in soils with genetic horizons. Approximate limits in use at the present time are depths of 6 and 30 inches (15 and 75 cm.) for the top and bottom of the section. Differences in morphologic features or in composition comparable to those used as differentiae among series within families of soils with genetic horizons are also used as series differentiae among soils with thin or no diagnostic horizons. Efforts are made to have ranges within series comparable in magnitude, whether the series are comprised of soils with or without evident genetic horizons. More problems prevail, however, in the differentiation and definition of series for soils with faint or thin horizons. The application of depth limits in defining such series in the system is therefore not yet fully developed.

Traditionally, series differentiae have included some features external to the soil. Series have been set apart on the basis of physiographic position. Series have also been set apart on the basis of their occurrence in geographic regions of various kinds, e.g. physiographic provinces, type of farming areas, belts of zonal soils, and the like. None of these differentiae are features of the soils themselves, though they are sometimes directly correlated with the distribution of certain soils. Moreover, they may be important in their own right for a variety of reasons. Because these traditional differentiae are features exterior to soils, they are not appropriate criteria for soil series. Concepts and definitions of series are currently being re-examined with a view to eliminating series based on such criteria. Current efforts are to choose differentiae expressed in the nature of the pedons.

All differentiae used in categories above the series have not been used previously as differentiae among series. Consequently, the present definitions of some series permit ranges that cross limits between families or between classes in other higher categories. Two kinds of discrepancies exist between the limits previously permitted in soil series and those proposed for families or higher categories. Not all discrepancies can be eliminated but some can be overcome.

Among series that have ranges crossing limits between families, the full range may occur within most individuals comprising the series and be in properties that cannot be observed in the field. Series of this kind cannot be re-defined so as to have narrower ranges in properties unless new techniques of field observation become available. Hence, such series are now classified on their dominant properties. In other words, such series are classified on the basis of properties of the majority of the individuals comprising them.

Among series that have ranges crossing limits between families, there are also a number in which full range for the series is not expressed in each individual but rather among the individuals collectively. Limited ranges are normal to most individuals and thus some individuals lie within the range of one family and some within the range of another family. It is expected that adjustments will eventually be made in the definitions of the series or in the limits for classes in higher categories in order to eliminate discrepancies of this kind.

THE SOIL TYPE

The soil type has been the lowest category in all previous American classification systems. Types have been distinguished within series on the basis of texture, a single characteristic. At first the distinction involved the texture of the soil, when texture meant a combination of particle size and consistence. In recent years, when texture referred to particle size distribution alone, the texture of the plow layer or its equivalent in virgin soils was used to distinguish types within a series. Since the significance of the texture or particle size distribution of the plow layer is pragmatical, and the texture classes can be made most useful if adjusted to fit circumstances at a given time, the soil type is not being retained as a category of the natural system. This mention is made here to explain its disappearance as a category.

Chapter 4. Nomenclature[1]

A name is essential for each class in each category. One cannot enumerate all of the differentiae each time he wishes to refer to a particular class. Names can be connotative, suggesting some of the more important properties of a class, or they can be abstract, even numbers. The most useful names are those that are most easily remembered, suggest some of the properties of the objects, and show the position of the class in the system. Ideally, one should be able to know from the name of a class the categoric level of that class and its relation to other classes in the same category and in other categories. And, ideally, the name should have a phonetic shape that is adaptable to the existing patterns of any language and free from any undesirable connotations.

One alternative was to adapt the existing names by modifying and sharpening the definitions of the classes they represented and to coin new names only for classes not previously recognized. As the classification system developed, it became apparent that it would be necessary to assign new meanings to all existing names. Such a change in meanings would have a number of disadvantages. Future students of the literature would find that a name had different meanings, depending on the time of publication. Not everyone could be expected to use the system of classification proposed in this text, so names would be in use with both old and new meanings. And, since some existing names now have different meanings in different countries, a given name might have several meanings. The principle of priority could rarely be used to select the appropriate meaning of an existing name, because the original definitions are almost invariably silent on one or more of the differentiae used here. Many of the present names, if used, would have to be translated to fit different languages, just as they need to be translated now. They are an agglomeration of nouns and adjectives; thus they cannot have orderly substantive and adjective equivalents. Some are even phrases. Most existing names are biased in favor of colors and are therefore inappropriate for the new classes. Some are common words taken from the body of language and given very restricted meanings that few other than soil scientists can be expected to remember. "Brown soil" and "Prairie soil" are examples. If present names were to be used, the categoric level in the system proposed could not be recognized, nor would names of closely related soils have any similarities. These are the more important reasons for the decision not to retain the present nomenclature and to use new names.

During the development of this system, in the successive approximations, numbers were used as names to focus attention on the differentiae being proposed. A system of numbers, rather than names, was suggested by some. Numbers have fewer disadvantages than do the existing names. Their most serious disadvantage is that they are abstract, and hence more difficult to remember than connotative names. Only those working continually with soil classification could be expected to remember the numbers; this is a very serious defect. The numbers are retained here as an aid to those who have become familiar with them, but may be dropped when the names become familiar.

Coined connotative names can be easier to remember than abstract names, for they call to mind something of the properties. They can suggest their position in the system. Closely related objects can have similar names. These are the major advantages to coined connotative names. The disadvantages of such names can be serious. For example, the names chemists assign to organic compounds give precise structures, but some are so long they cannot be used in speech. Another disadvantage of connotative names is that concepts of the classes they identify will change with time, and names that connote what now appear to be the important features will, in the future, emphasize these, though it has been discovered that other features are more important. At best, names short enough to be used in speech can connote very few of the properties of a soil.

With all the foregoing considerations in mind, it was decided that the least disadvantageous course would be to devise a completely new system of nomenclature, using coined names, as short as possible and with connotations enough to help users remember the names by mnemonic devices. The names chosen are intended to fit, without translation, into any modern language using the Latin alphabet, though some languages will require a few modifications in spelling. Roots have been taken from several languages. It was intended that the names be short, phonetic, mnemonic, and distinctive in speech in the modern European languages. These intentions conflicted in some instances, and compromises therefore were required.

NAMES OF ORDERS

Names of orders are coined words, formed mostly from Greek and Latin roots. Abstract syllables were used when no mnemonic root could be found that would be clearly distinguished in speech in all modern languages. The order names have a common ending, sol, (L. solum, soil) with the connecting vowel o for Greek roots and i for other roots.

A formative element is abstracted from the name of each order. This element starts with the first vowel preceding the connecting vowel and ends with the last consonant preceding the connecting vowel. It is used as an ending for the names of all suborders, great groups, and subgroups.

The name of each order, the formative element in the name, the derivation of this element, a mnemonicon, and the pronunciation are shown in table 6.

NAMES OF SUBORDERS

Each suborder name consists of two syllables. The first is suggestive of a property of the class, and the

[1]This chapter cannot be written without acknowledging the assistance of Prof. A. L. Leemans, Head, Classic Language Department, State University at Ghent, and Prof. John L. Heller, Head, Department of the Classics, University of Illinois. Without their assistance the development of the nomenclature would have been impossible. They have given their time freely, and if the nomenclature used in this text proves useful, as we believe it will, soil science is deeply in their debt. It should be emphasized that not all of the names proposed meet with their full approval.

Table 6.--Formative Elements in Names of Soil Orders

No. of[1/] order	Name of order	Formative element in name of order	Derivation of formative element	Mnemonicon and pronunciation of formative elements
1	Entisol...	ent	Nonsense syllable.	recent.
2	Vertisol..	ert	L. verto, turn.	invert.
3	Inceptisol	ept	L. inceptum, beginning.	inception.
4	Aridisol..	id	L. aridus, dry.	arid.
5	Mollisol..	oll	L. mollis, soft.	mollify.
6	Spodosol..	od	Gk. spodos, wood ash	Podzol; odd.
7	Alfisol...	alf	Nonsense syllable.	Pedalfer.
8	Ultisol...	ult	L. ultimus, last.	Ultimate.
9	Oxisol....	ox	F. oxide, oxide.	oxide.
10	Histosol..	ist	G. histos, tissue.	histology.

[1/] Numbers of the orders are listed here for the convenience of those who became familiar with them during development of the system of classification.

second is suggestive of the name of the order. Names of suborders can be recognized by the two-syllable length, a length unique to the suborders.

The first formative element suggests a diagnostic property common to the suborder. For example, strongly gleyed soils are recognized as a suborder of each order in which they occur. To suggest this, the formative element aqu (from Latin aqua, water) is used as a prefix. Thus, a strongly gleyed Entisol is called an Aquent. The formative element aqu is used in the names of suborders in 8 of the 10 orders. Other formative elements are repeated in several suborder names. In fact, 5 of the 15 formative elements account for the majority of the suborders. The formative elements used for suborders, their derivations, and their connotations are listed in table 7.

Table 7.--Formative Elements in Names of Suborders

Formative element	Derivation of formative element	Mnemonicon	Connotation of formative element
acr	Gk. akros, highest.	acrobat	Most strongly weathered.
alb	L. albus, white	albino	Presence of albic horizon (a bleached eluvial horizon).
alt	L. altus, high.	altitude	Cool, high altitudes or latitudes.
and	Modified from Ando.	Ando	Ando-like.
aqu	L. aqua, water.	aquarium	Characteristics associated with wetness.
arg	Modified from argillic horizon; L. argilla, white clay.	argillite	Presence of argillic horizon (a horizon with illuvial clay).
ferr	L. ferrum, iron.	ferruginous	Presence of iron.
hum	L. humus, earth.	humus	Presence of organic matter.
ochr	Gk. base of ochros, pale.	ocher	Presence of ochric epipedon (a light-colored surface).
orth	Gk. orthos, true	orthophonic	The common ones.
psamm	Gk. psammos, sand.	psammite	Sand textures.
rend	Modified from Rendzina.	Rendzina	Rendzina-like.
ud	L. ūdus, humid.	udometer	Of humid climates.
umbr	L. umbra, shade.	umbrella	Presence of umbric epipedon (a dark-colored surface).
ust	L. ustus, burnt.	combustion	Of dry climates, usually hot in summer.

Among the Entisols, four suborders are recognized. The Aquents are hydromorphic, with colors associated with wetness. The other suborders are not wet. The Psamments are very sandy. The Ustents are usually dry, and the Udents, not sandy and usually moist.

NAMES OF GREAT GROUPS

Great group names are coined by prefixing one or more additional formative elements to the appropriate suborder name. Each great group name therefore has a suborder name as its final two syllables. If a great group is distinguished from others within the same suborder by a named diagnostic horizon or property, the name of that property is used as the root of a prefix to form the great group name. If the diagnostic property or properties have not been named, a formative element as suggestive as possible is used. All of the formative elements are mnemonic in one or more modern languages, but not all are mnemonic in all languages.

Among the Udents, the great group characterized by the low temperature of the soil is named Cryudent. The formative element cry is derived from the Gk. kryos, for icy cold. Names of great groups can be recognized by the presence of three or more syllables, and the absence of the ending sol. The appropriate suborder is indicated, since its name is the ending of the great group name. And the appropriate order is suggested by the final syllable.

The formative elements to be added to the suborder names to obtain names of great groups are listed in table 8.

Names of the orders, suborders, and great groups are given in table 9.

NAMES OF SUBGROUPS

Subgroup names consist of the name of the appropriate great group modified by one or more adjectives. The adjective orthic is used for the subgroup that is thought to typify the central concept of the great group.

Intergrade subgroups that have, in addition to the properties of their great group, some properties of another class carry the name of the other class in an adjective form. For example, assume a Cryudent that has a B horizon too weakly developed to place the soil in any order other than Entisol but strongly enough developed to be recognizable. We will assume that the aberrant properties in this soil are those that have been used to define a suborder in another order. The name of the subgroup therefore would be formed by modifying the great group name, Cryudent, with the adjective form of the name of the appropriate suborder. If the very weakly developed B were one of accumulation of illuvial humus, defined later as a spodic horizon and diagnostic for the suborder of Humods, the name of the subgroup would be Humodic Cryudent. The names of orders, suborders, or great groups, or any of the prior formative elements of these names may be used in adjectival form for subgroup names. A few soils may have aberrant properties of two great groups belonging in different orders or suborders. With these it may be necessary to use two adjectival forms of class names in the subgroup name. Such situations are probably rare.

Naming of Intergrades Toward Other Great Groups in the Same Suborder

If the aberrant property of a soil is one which is characteristic of another great group in the same suborder, only the distinctive prior formative element of the great group name is used to indicate the aberrant properties. Thus, Orthic Cryaquent is defined as having permafrost at depths of less than 75 cm. (30 inches). If a Cryaquent has a permafrost layer at 1 meter but otherwise fits the Orthic Cryaquent, it is considered to intergrade toward the Haplaquent (the class that lacks permafrost). The name, however, is Haplic Cryaquent not Haplaquentic Cryaquent.

Table 8.--Formative Elements for Names of Great Groups

(Formative element is added to suborder name to obtain name of great group)

Formative element	Derivation of formative element	Mnemonicon	Connotation of formative element
agr	L. ager, field.	agriculture	An agric horizon.
alb	L. albus, white.	albino	An albic horizon.
anthr	Gk. anthropos, man.	anthropology	An anthropic epipedon.
arg	Modified from argillic horizon; L. argilla, white clay.	argillite	An argillic horizon.
brun[1]	L.L. brunus, brown.	brunet	Dark-brown colors.
calc	Modified from calcium.	calcium	A calcic horizon.
camb	L.L. cambiare, to exchange	change	A cambic horizon.
crust	L. crusta, crust.	crust	Crusting.
cry	Gk. kryos, coldness.	crystal	Cold.
crypt[1]	Gk. kryptos, hidden.	cryptogram	With a deep horizon.
dur	L. durus, hard.	durable	A duripan.
dystr	Modified from dystrophic, infertile.	dystrophic	Low base saturation.
eutr	Modified from eutrophic, fertile.	eutrophic	High base saturation.
ferr	L. ferrum, iron.	ferric	Presence of iron.
frag	Modified from L. fragilis, brittle.	fragile	Presence of fragipan.
frag-loss	Compound of fra(g) and gloss.		See the formative elements frag and gloss.
gloss	Gk. glossa, tongue.	glossary	Tongued.
grum	L. grumus, crumb.	Grumusol	Granular structure.
hal	Gk. hals, salt.	halophyte	Salty.
hapl	Gk. haplous, simple.	haploid	Minimum horizon.
hum	L. humus, earth.		Presence of humus.
hydr	Gk. hydôr, water.	hydrophobia	Presence of water.
maz	Gk. maza, flat cake, from massô, knead.		Massive.
nadur	Compound of na(tr), below, and dur, above		
natr	Modified from natrium, sodium.		Presence of natric horizon.
ochr	Gk. base of ôchros, pale.	ocher	Presence of ochric epipedon (a light-colored surface).
orth	Gk. orthos, true.	orthophonic	
phan[1]	Modified from allophane.		Presence of allophane.
plac	Gk. base of plax, flat stone.		Presence of a thin pan.
plag	Modified from Ger. plaggen, sod.		Presence of plaggen horizon.
plint	Modified from Gk. plinthos, brick.		Presence of plinthite.
psamm	Gk. base of psammos, sand.	psammite	Sand texture.
quarz	Ger. quarz, quartz.	quartz	High quartz content.
rhod	Gk. base of rhodon, rose.	rhododendron	Dark-red colors.
sal	L. base of sāl, salt.	saline	Presence of salic horizon.
therm	Gk. base of thermos, hot.	thermal	Warm.
typ	Modified from type, typical.		Typical.
ult	Modified from ultimus, last.	ultimate	Strongly weathered.
umbr	L. base of umbra, shade.	umbrella	Presence of umbric epipedon.
ust	L. base of ustus, burnt	combustion	Dry climate, usually hot in summer.
verm	L. base of vermes, worm.	vermiform	Wormy, or mixed by animals.

[1] Very tentatively proposed for great groups of the Oxisol order.

Naming of Intergrades Toward a Great Group in the Same Order, But in a Different Suborder

The adjectival form of the prior formative element of the appropriate suborder name is used if the aberrant property is the one definitive of the suborder. The Orthic Hapludent is by definition free of mottling within the upper 50 cm. A Hapludent mottled at 35 cm. (14 inches) with colors indicative of wetness is considered to intergrade toward the Aquents. If the mottling is the only aberrant property, the subgroup is named Aquic Hapludent, not Aquentic Hapludent. If, however, it is necessary to show that the soil is both sandy and mottled, it would be named Psammaquentic Hapludent, using the full name of the great group that is both wet and sandy.

Naming of Intergrades Toward Great Groups in Other Orders

If the Hapludent in the above example were mottled within 50 cm. and had more than 40 percent of swelling clay it would by definition be an intergrade toward another suborder, the Aquerts. The adjective form of the suborder name would be taken and the name would be Aquertic Hapludent; if it were necessary to show strong self-mulching or crusting surfaces, adjectives would be formed from the great group names, giving subgroup names of Grumaquertic or Mazaquertic Hapludents. If the clayey Hapludent were not mottled, there would be only one aberrant property, one that is common to all Vertisols, and the subgroup would be named Vertic Hapludent. The general rule is that the simplest possible name is used.

Naming of Subgroups not Intergrading Toward any Known Kind of Soil

Some soils have aberrant properties that are not characteristic of a class in any order, suborder, or great group. One example might be taken from the soils found at the base of slopes, in depressions or other places where new soil material slowly accumulates at the surface. The rate of accumulation of new material may be slower than the accumulation of organic matter, so that in time a very thick dark surface develops. In these soils the A horizon could be considered the parent material of the C. The presence of such over-thickened A horizons is not used to define any great group, for the genetic considerations lead us to believe that they are more appropriately recognized as a subgroup. The soils lie outside the range of the Orthic subgroup and there is no class toward which they intergrade. Hence, a descriptive adjective is required. For this particular situation, the adjective Cumulic (L. cumulus, heap, plus ic, from Gk. ikos) is used to form the subgroup names.

Other soils lie outside the range of orthic subgroups in an opposite direction. Such soils are, in effect, truncated by hard rock and are shallow or are intermittent between rock outcrops. They are, in effect,

Table 9.—Names of Orders, Suborders, and Great Groups

Order	Suborder	Great group
1. Entisol.....	1.1 Aquent.....	1.11 Cryaquent.
		1.12 Psammaquent.*
		1.13 Hydraquent.
		1.14 Haplaquent.
	1.2 Psamment...	1.21 Quarzopsamment.
		1.22 Orthopsamment.*
	1.3 Ustent.....	1.31 Psammustent.*
		1.32 Orthustent.*
	1.4 Udent......	1.41 Cryudent.
		1.42 Agrudent.
		1.43 Hapludent.
		1.44 Plaggudent.
2. Vertisol....	2.1 Aquert.....	2.11 Grumaquert.
		2.12 Mazaquert.
	2.2 Ustert.....	2.21 Grumustert.
		2.22 Mazustert.
3. Inceptisol..	3.1 Aquept.....	3.11 Halaquept.
		3.12 Umbraquept.*
		3.13 Fragaquept.
		3.14 Cryaquept.
		3.15 Ochraquept.*
	3.2 Andept.....	3.21 Cryandept.
		3.22 Durandept.
		3.23 Ochrandept.*
		3.24 Umbrandept.*
		3.25 Hydrandept.
	3.3 Umbrept....	3.31 Cryumbrept.
		3.33 Haplumbrept.
		3.34 Anthrumbrept.
	3.4 Ochrept....	3.41 Cryochrept.
		3.43 Eutrochrept.
		3.44 Dystrochrept.
		3.45 Ustochrept.
		3.46 Fragochrept.
4. Aridisol....	4.1 Orthid*....	4.11 Camborthid.
		4.12 Durorthid.
		4.13 Calcorthid.
		4.14 Salorthid.
	4.2 Argid......	4.21 Haplargid.
		4.22 Durargid.
		4.23 Natrargid.
		4.24 Nadurargid.
5. Mollisol....	5.1 Rendoll....	5.11 --- (Rendoll).
	5.2 Alboll.....	5.21 Argalboll.
		5.22 Natralboll.
	5.3 Aquoll.....	5.31 Haplaquoll.
		5.32 Argaquoll.
		5.33 Calcaquoll.
		5.34 Duraquoll.
		5.35 Natraquoll.
	5.4 Altoll.....	5.41 Vermaltoll.
		5.42 Haplaltoll.
		5.43 Argaltoll.
		5.44 Calcaltoll.
		5.45 Natraltoll.
	5.5 Udoll......	5.51 Vermudoll.
		5.52 Hapludoll.
		5.53 Argudoll.
	5.6 Ustoll.....	5.61 Vermustoll.
		5.62 Haplustoll.
		5.63 Argustoll.
		5.64 Durustoll.
		5.65 Calcustoll.
		5.66 Natrustoll.
6. Spodosol....	6.1 Aquod......	6.11 Cryaquod.
		6.12 Humaquod.*
		6.13 Ferraquod.
		6.14 Placaquod.
		6.15 Thermaquod.
		6.16 Duraquod.
	6.2 Humod......	6.21 Orthumod.
		6.22 Thermhumod.
	6.3 Orthod*....	6.31 Cryorthod.
		6.32 Placorthod.
		6.33 Typorthod.
	6.4 Ferrod.....	
7. Alfisol.....	7.1 Aqualf.....	7.11 Albaqualf.
		7.12 Glossaqualf.
		7.13 Ochraqualf
		7.14 Umbraqualf.
		7.15 Fragaqualf.
		7.16 Natraqualf.
	7.2 Altalf.....	7.21 Cryaltalf.
		7.22 Typaltalf.
		7.23 Natraltalf.
		7.24 Fragaltalf.
	7.3 Udalf......	7.31 Agrudalf.
		7.32 Typudalf.
		7.33 Fragudalf.
		7.34 Glossudalf.
		7.35 Fraglossudalf.
	7.4 Ustalf.....	7.41 Durustalf.
		7.42 Natrustalf.
		7.43 Rhodustalf.
		7.44 Ultustalf.*
		7.45 Typustalf.
8. Ultisol.....	8.1 Aquult.....	8.11 Plintaquult.
		8.12 Ochraquult.*
		8.13 Umbraquult.*
		8.14 Fragaquult.
	8.2 Ochrult....	8.21 Plintochrult.
		8.22 Rhodochrult.
		8.23 Typochrult.
		8.24 Fragochrult.
	8.3 Umbrult....	8.31 Plintumbrult.
		8.32 Typumbrult.
9. Oxisol......		
10. Histosol....		

* Used temporarily for want of a better name. The prior formative element is duplicated in such a way that two different subgroups may have identical names.

intergrades to not-soil, and are called Lithic subgroups.

Other kinds of subgroups may be needed, but they are not being proposed at this time.

Nomenclature for Multiple Subgroups Intergrading Between Two Given Great Groups

More than one subgroup will sometimes be found in a given great group and intergrading to the same class of soil, or even to "not-soil." In one situation the horizons may be continuous, and in the other they may be discontinuous. Or, in one soil, properties of the two classes are mixed in a single horizon but represented by separate horizons in the other. Soils of class X may be developing from or toward class Y and thus producing subgroups with different properties.

Nomenclature for handling multiple subgroups has not been fully developed. It should be developed only when the knowledge is at hand for at least some of the soils.

If the intergrade is one with intermittent horizons, the adjective Ruptic (L. ruptum, broken) is tentatively proposed for use in the subgroup name. The substantive in the name is that used for the profile having the greatest area; the adjectives are formed from the names of the classes with the lesser area, preceded by the adjective Ruptic. Thus, if X is dominant in area, and Y minor, the soil is named Ruptic Y-icX.

If the subgroup is one with a buried soil that is an important part of the present soil, the name includes Thapto (Gk. thapto, buried) as a modifier of the name of the buried soil. Thus, soil X which includes a buried soil, Y, is Thapto Y-ic X.

Other necessary subgroups can be expected, and the nomenclature can be expanded as needed.

NAMES OF FAMILIES

The nomenclature of families cannot be developed until reasonably satisfactory families can be defined. It seems probable that two kinds of family names might prove useful. One is an abstract name, taken from the name of the best known soil series in the family. Thus, the family that contains the Miami series might be called Miami family, after that series.

Such a system of nomenclature is useful to the extent that the properties of the series from which the family names are taken are well known. The names are short and give no difficulty in coining because they are ready at hand. There is no limit to the number.

The system of naming families for an included series has some serious drawbacks. The series to be used have limited geographic extent, and only a few people can be expected to be familiar with very many of them. The names are completely abstract for most people, and there are too many of them to be remembered. In speech and in writing, a family definition will usually be required whenever a series name is used as a family name.

An alternative system of names may possibly be developed from the properties used to differentiate families within subgroups. If texture, mineralogy, and consistence were to be the principal differentiating characteristics, three terms describing the family could be used as the family name. Thus, a coarse-textured, loose solum dominated by quartz could be called by the subgroup name, with addition of the modifiers coarse, loose, quartzose. Whether such a system would prove practical is not known at this time, and will not be known until enough families have been defined to permit trying it.

NAMES OF SERIES

In the United States a series is given the name of a place or a natural feature near the place where first recognized. Descriptive names have been tried and found wanting. Descriptive names that are mutually exclusive are too long for normal speech, and they focus attention on the distinguishing characteristics of the series rather than on the features that are important to the users of the classification.

RULES FOR NOMENCLATURE

For uniformity in usage, certain rules are followed.

1. The names are considered to be modern vernacular nouns. In languages with grammatical gender, they are treated as masculine nouns. While the names of the orders alone contain a suffix meaning soil, the meaning "soil" is understood to be included in all names. Thus, the names are not to be converted to adjectives to modify the word "soil." The prior elements of names of suborders and great groups may be converted to adjectives to modify the word "soil." Thus, one may speak of aquic soils, referring to all classes of soil with names that include the formative element aqu, but one would not speak of aquentic soils.

2. Plural forms of the nouns conform to the rules of the language in which the names are used. If a final vowel makes the name fit better into a particular language, it may be added as needed.

3. Adjectives are formed by using the (Gk.) suffix ikos, shortened or adapted to the modern vernaculars according to the rules of the language used. For example, in English the ending is ic; in French, ique, and in German, isch.

Adjectival forms are placed in the position normal for the language in which they are used.

4. Names of the orders, suborders, and great groups are treated as proper nouns, and the first letter is capitalized. Adjectival forms of these names may be capitalized or not, according to the conventions of printing in the language in which they are used.

5. Pronunciation follows the rules of the modern vernacular in the language in which the words are used. There follows a list of suggestions for pronunciation in the United States.

Orders

The ending for names of orders regularly is sol (L. solum, soil); the vowel is pronounced like the vowel in soluble; plural forms end in the letter s or z.

The accent in the names of orders is regularly on the syllable preceding the connecting vowel (i or o): Vértisol, but Inceptisol, Aridisol, and so on. Following are notes on pronouncing the names of soil orders. The number preceding each name facilitates reference to table 9.

1. Enti-sol (cf. bent).
2. Verti-sol (cf. invert).
3. Incépti-sol (cf. inception)
4. Arídi-sol (cf. aridity).
5. Molli-sol (cf. mollify).
6. Spodo-sol (o as in rod).
7. Alfi-sol (alf as in Alfred).
8. Ulti-sol.

9. Oxi-sol.
10. Histo-sol (cf. histology).

Suborders

The ending for the name of a suborder is abstracted from the accented syllables in the name of the governing order, always beginning with the vowel.

The name of a suborder is always of two-syllable length, and it is accented on the first syllable. Following are notes on pronunciation of the names of suborders listed in table 9:

1.1 Aqu-ent (as in aquarium), also at 2.1, 3.1, 5.3, 6.1, 7.1, 8.1.
1.2 Psamm-ent (like Sam-uel; cf. psammite).
1.3 Ust-ent (as in bust), also at 2.2, 5.6, 7.4.
1.4 Ud-ent (like you'd; cf. udometer), also at 5.5, 7.3.
3.2 And-ept (as in and).
3.3 Umbr-ept (as in umbrella), also at 8.3.
3.4 Ochr-ept (like okra), also at 8.2.
4.1 Orth-id (as in orthophonic), also at 6.3.
4.2 Arg-id (as in Argentina).
5.1 Rend-oll (as in Rendzina).
5.2 Alb-oll (as in album).
5.4 Alt-oll (as in altitude), also at 7.2.
6.2 Hum-od (as in humus).
9.1 Plint-ox (like splint).

Great Groups

The ending for the name of a great group preserves the name of the governing suborder, except for minor euphonic changes:

a. The formative element ud loses its initial y-sound after r or l:
   1.41 Cry-udent (cry-you-dent).
   1.42 Agr-udent (ag-roo-dent).
   1.43 Hapl-udent (hap-loo-dent).
   5.51 Verm-udoll (verm-you-doll).
   5.52 Hapl-udoll (hap-loo-doll).
   5.53 Arg-udoll (argue-doll).
   7.31 Agr-udalf (ag-roo-dalf).
   7.32 Typ-udalf (type-you-dalf).
   7.33 Frag-udalf (frag-you-dalf).
   7.34 Gloss-udalf (gloss-you-dalf).
   7.35 Fragloss-udalf (frag-loss-you-dalf).
b. The formative element hum loses its initial h-sound after h:
   6.21 Orth-umod (orth-you-mod).
   6.22 Therm-humod (therm-hue-mod).

The name of a great group is regularly accented on the syllable preceding that part taken from the name of the governing suborder:

4.23 Nátrargid, but 4.24 Nadúrargid.
7.34 Glóssudalf, but 7.35 Fraglóssudalf.

Following are notes on pronunciation of the names of the great groups listed in table 9:

1.11 Cry-aquent (as in cry), also at 1.41, 3.31, 3.41, 6.11, 6.31, 7.21.
1.12 Psamm-aquent (as if sam-ak-went).
1.13 Hydr-aquent (as in hydrant).
1.14 Hapl-aquent (as in haploid), also at 1.43, 3.12, 3.21, 3.33, 4.21, 5.31, 5.42, 5.52, 5.62.
1.21 Quarzo-psamment (as in quartz).
1.42 Agr-udent (as in agriculture), also at 7.31.
1.44 Plagg-udent (rhyming with sag).
2.11 Grum-aquert (like groom), also at 2.21.
2.12 Maz-aquert (as in maze), also at 2.22.
3.11 Hal-aquept (as in halophyte).
3.13 Frag-aquept (as in fragment), also at 3.46, 7.15, 7.33, 8.14, 8.24.
3.34 Anthr-umbrept (as in anthropology; syllabify thus: an-thrum-brept).
3.43 Eutr-ochrept (as if you-tro-crept).
3.44 Dystr-ochrept (as if dis-tro-crept).
3.45 Ust-ochrept (as if us-toe-crept).
4.11 Camb-orthid (like camp).
4.12 Dur-orthid (as in durable), also at 3.22, 4.22, 5.34, 5.64, 7.41.
4.13 Calc-orthid (as in Calcutta), also at 5.33, 5.44, 5.65.
4.14 Sal-orthid (as in salary).
4.23 Natr-argid (as in natron), also at 5.22, 5.35, 5.45, 5.66, 7.16, 7.23, 7.42.
4.24 Nadur-argid (rhyming with endure; first vowel as in adore).
5.21 Arg-alboll (as in Argus), also at 5.32, 5.43, 5.53, 5.63.
5.41 Verm-altoll (as in vermiform), also at 5.51, 5.61.
6.12 Hum-aquod (as in humus).
6.13 Ferr-aquod (as in ferric).
6.14 Plac-aquod (as if plaque), also at 6.32.
6.22 Therm-humod (as in thermometer).
6.33 Typ-orthod (as in typewriter), also at 7.22, 7.32, 7.45, 8.23, 8.32.
7.11 Alb-aqualf (as in album).
7.12 Gloss-aqualf (as in glossary), also at 7.34.
7.13 Ochr-aqualf (as if okra), also at 8.12.
7.14 Umbr-aqualf (as in umbrella), also at 8.13.
7.35 Fraglóss-udalf (as if frag-loss-you-dalf).
7.43 Rhod-ustalf (as in rhododendron), also at 8.22.
7.44 Ult-ustalf (as in ultimate).
8.11 Plint-aquult (as in splint), also at 8.21, 8.31.

Chapter 5. Criteria of Classification in the Higher Categories

Subgroup, Great Group, Suborder, and Order

SOIL HORIZONS

A soil horizon may be defined as a layer within a soil that is approximately parallel to the soil surface and that has properties that are produced by soil-forming processes but that are unlike those of adjoining layers. A soil horizon is commonly differentiated from those adjacent to it at least partly by characteristics that can be seen or measured in the field, such as color, structure, texture, consistence, and presence or absence of carbonates. According to the criteria we use, horizons are identified partly by their morphology and partly by the properties of overlying and underlying horizons. In identifying soil horizons, however, measurements in the laboratory are sometimes required to supplement field observations.

DESIGNATIONS FOR HORIZONS AND LAYERS

Reference to familiar horizons are at times needed in a text intended to introduce a new system of classification. The meaning of these references needs to be made as clear as possible. The Soil Survey Manual[1] horizon designations have been used insofar as possible, but a few horizon designations used here are modified from those in the Soil Survey Manual. Hence, a complete list, with definitions, is presented here for the horizon designations that have been used throughout this text.

It is assumed that each horizon or layer designation used is merely a symbol indicating the considered judgment of the person describing the soil relative to kind of departure from the original material from which it has formed, including the zero degree of departure in the case of R and some C layers. This implies that each symbol indicates merely an estimate, not a proven fact. It implies that when reading a symbol one must reconstruct mentally the character of the parent material, for this was done when the designation was assigned. It implies that the processes that have caused change need not be known. It also implies that specific morphology need not be consistent from profile to profile and that morphology relative to an estimated parent material is the criterion for judgment. The parent material of the horizon in question, not the material in the horizon or layer designated by the symbol C, is used as the basis of comparison. Morphology is interpreted relative to this assumed parent material, not in terms of absolute values of properties.

Conventions Governing Use of Symbols

1. Capital letter symbols include O, A, B, C, and R. They indicate dominant kinds of departures from the parent material. More than one kind of departure may be indicated by a single capital letter, providing these departures are within the limits of the definitions given further along in this chapter.

2. In a description of a given profile, if a horizon designated by O, A, or B is subdivided, the subdivisions are indicated by placing an arabic number after the capital letter. Thus, symbols such as O1, O2, A1, A2, A3, B1, B2, and B3 are obtained. Each symbol derived in this way stands for an integral unit, and each unit requires its own definition. A given arabic numeral therefore has different implication when combined with different capital letters. Thus, the symbols O1, O2, A1, and A2 indicate specific kinds of O and A master horizons. The symbols A3, B1, and B3 are transitional horizons. Likewise, the symbol B2 indicates that part of the B horizon that is of a nature not transitional either to A or to C. Even if both B1 and B3 are absent, if the B horizon of a given profile is subdivided, the symbol B2, not B, is used. The symbols O, A, and B each indicate a unit that, according to need, can have several subdivisions or none. The symbol C, however, indicates a unit that is not subdivided in the manner of O, A, and B. If a horizon is subdivided, this is done only in the manner described in the following paragraph 3, and the arabic numeral assigned has no consistent meaning except vertical sequence.

3. Vertical subdivision within an otherwise undifferentiated horizon is indicated by primary or secondary arabic numbers assigned, in order, from the topmost subdivision downward. These are not used with O, A, or B without a primary arabic number. Thus, secondary numbers are used with O1, O2, A1, A2, A3, B1, B2, B3, and C. Primary arabic numbers are used with C and Ap. Thus, we use C1 and C2, Ap1 and Ap2, but A11 and A12, B21, B22 or B23, as needed, without consistence in meaning beyond the fact that we have made a subdivision. The reason for the subdivision may be indicated in the text of the description or by a lower case letter suffix.

4. Lower case letters are used as suffixes to indicate selected subordinate departures from the assumed parent material or to indicate selected, specific kinds of major departures from the definition assigned to the symbol O, A, B, C. These are regarded as alternatives to narrative statements of equivalent interpretations in the profile description. These suffixes follow the arabic number in the letter-number combined symbols discussed under item 2 above, (A2g or B3ca), or they may follow the capital letter of a master horizon if it is not subdivided (Bt or Ap). These suffixes also follow arabic numbers used solely for vertical subdivision described under item 3 above. as A21g and A22g or C1ca and C2ca. An exception is made with the lower case letter p. This is used only with the letter A (Ap) and is comparable to the A1 or A2.

5. Roman numerals are prefixed to the master horizon or layer designations (O, A, B, C, R) to indicate lithologic discontinuities either within or

[1]Soil Survey Staff. Soil Survey Manual. U.S. Department of Agriculture. Handbook No. 18, 503 pp. illus. 1951.

below the solum. The first, or uppermost, material is not numbered, for the Roman numeral I is understood; the second contrasting material is numbered II, and others encountered are numbered III, IV, and so on, consecutively with depth. Thus, for example, a sequence from the surface downward might be A2, B1, IIB2, IIB3, IIC1, IIIC2.

A lithologic discontinuity is a significant change in particle size distribution or mineralogy that indicates a difference in the material from which the horizons have formed. A change in the content of clay associated with an argillic horizon (textural B) does not indicate a difference in parent material. Appearance of gravel, or a change in the ratios between the various sand separates, will normally suggest a difference in parent materials. One purpose in identifying lithologic discontinuities is to distinguish between those differences between horizons that are the result of pedo-genesis and those that are geologic. Consequently, a designation with a different Roman number would not normally be used for a buried soil in a thick loess deposit. The difference between the properties of the buried soil and the overlying loess are presumably the result of pedo-genesis. But a stone line usually indicates a need for another Roman number. The material above the stone line is presumed to be transported. If the transport was by wind or water, one must suspect that during the movement there was some sorting of the material according to size.

6. An illuvial horizon (together with its overlying eluvial horizon if one is present) is called a sequum. If more than one sequum is present in vertical sequence, the lower sequum is given A and B designations with a prime accent, as A'2, B'2. The prime accents are not used however for buried soils. These carry the lower case letter b.

Master Horizons and Layers

Organic horizons

O - Organic horizons of mineral soils. Horizons: (1) formed or forming in the upper part of mineral soils and above the mineral part; (2) dominated by fresh or partly decomposed organic material; and (3) containing more than 30 percent organic matter if the mineral fraction is more than 50 percent clay, or more than 20 percent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional organic-matter content.

The O horizons may be found at the surface horizon of mineral soils, or at any depth beneath the surface in buried soils, but they have been formed from organic litter derived from plants and animals and deposited on the surface. The O horizons do not include soil horizons formed by illuviation of organic material into mineral material, nor do they include horizons high in organic matter formed by a decomposing root mat below the surface of a mineral material.

Because organic horizons at the surface may be rapidly altered in thickness or be destroyed by fire or by the activities of man or other animals, the depth limits of organic horizons that are at the surface are always measured upward from the top of the underlying mineral material. Two subdivisions are recognized:

O1 - Organic horizons in which essentially the original form of most vegetative matter is visible to the naked eye.

Identifiable remains of soil fauna, or their excrement, may be present, and the horizon may be filled with fungal hyphae. The vegetative matter may be essentially unaltered, as freshly fallen leaves, or may be leached of its most soluble constituents and discolored. The O1 corresponds to the "L" and some "F" layers mentioned in literature on forest soils and to the "A_{00}" described in the Soil Survey Manual.

O2 - Organic horizons in which the original form of most plant or animal matter cannot be recognized with the naked eye.

Remains of parts of plants and animals commonly can be identified with magnification, and excrement of soil fauna is commonly a large part of the material present. The O2 corresponds to the "H" layer and some "F" layers described in literature on forest soils and to the "A_0" described in the Soil Survey Manual.

The organic horizons in organic soils are not defined here. They are currently under discussion. The organic B horizons in mineral soils are defined under B horizon, along with the mineral horizons.

Mineral horizons and layers

Mineral horizons contain less than 30 percent organic matter if the mineral fraction contains more than 50 percent clay or less than 20 percent organic matter if the mineral fraction has no clay. Intermediate clay content requires proportional content of organic matter.

A - Mineral horizons consisting of: (1) horizons of organic-matter accumulation formed or forming at or adjacent to the surface; (2) horizons that have lost clay, iron, or aluminum with resultant concentration of quartz or other resistant minerals of sand or silt size; or (3) horizons dominated by 1 or 2 above but transitional to an underlying B or C.

A1 - Mineral horizons, formed or forming at or adjacent to the surface, in which the feature emphasized is an accumulation of humified organic matter intimately associated with the mineral fraction.

The mineral particles have coatings of organic material, or the soil mass is darkened by organic particles; the horizon is as dark as, or darker than, adjacent underlying horizons. The mineral fraction may be unaltered or may have been altered in a manner comparable to that of A2 or B. The organic fraction is assumed to have been derived from plant and animal remains deposited mechanically on the surface of the soil, or deposited within the horizon without translocation of humified material through an intervening horizon that qualifies for a horizon designation other than A1. The A1 horizon includes the parts of the diagnostic mollic and umbric horizons that do not qualify as B.

A2 - Mineral horizons in which the feature emphasized is loss of clay, iron, or aluminum, with resultant concentration of quartz or other resistant minerals in sand and silt sizes.

Such horizons are commonly but not necessarily lighter in color than an underlying B. In some soils the color is determined by that of the primary sand

and silt particles, but in many soils, coats of iron or other compounds, apparently released in the horizon and not translocated, mask the color of the primary particles. An A2 is most commonly differentiated from an overlying A1 by lighter color and is generally measurably lower in organic matter. An A2 is most commonly differentiated from an underlying B in the same profile by lighter color, or coarser texture, or both. It must be lower in organic matter than an underlying B that is darkened by illuviated humus; lower in clay than an underlying argillic or natric horizon; lower in free sesquioxides, humus, or both than an underlying spodic horizon, and lighter in color, lower in clay, or both, than an underlying fragipan. An A2 horizon does not normally overlie a cambic horizon, or oxic material, but if present should be 2 units less in chroma than the underlying horizon. The A2 horizon includes the albic horizons, which are diagnostic in the system of classification, as well as many horizons that do not qualify as albic horizons. A2 horizons are commonly near the surface, below an O or A1 horizon and above a B, but the symbol A2 may be used either above or below subsurface horizons; position in the profile is not diagnostic. For horizons at the surface that would qualify equally well as either A1 or A2, the designation A1 is given preference over A2.

A3 - A transitional horizon between A and B, and dominated by properties characteristic of an overlying A1 or A2 but having some subordinate properties of an underlying B.

No distinction is made between the different kinds of horizons that are transitional from A1 or A2 to different kinds of B; they obviously may be quite unlike one another, but the burden of characterization rests on the description of the transitional horizon, plus inferences that can be made after noticing the symbols assigned to the overlying and underlying horizons. The symbol A3 normally is used only if the horizon is underlain by a B horizon. However, where the profile is truncated from below in small places by rock, so as to eliminate the horizon that would be designated B, the symbol A3 may be used for the horizon that is above the rock. For example, in one part of a pedon, a horizon may be transitional between A and B, and thus appropriately designated A3. But, in another part of the same pedon, the same horizon rests on rock, and may appropriately be called A3, even though there is no underlying B.

The symbol A3 is confined to those kinds of transitional zones in which some properties of the underlying B are superimposed on properties of A throughout the soil mass. Those kinds of "transitional horizons" in which parts that are characteristic of A enclose parts characteristic of B are classified as A and B.

AB - A horizon transitional between A and B, having an upper part dominated by properties of A and a lower part dominated by properties of B, and the two parts cannot conveniently be separated into A3 and B1.

Such combined horizons are normally thin; they should be separated if thick enough to permit separation.

A&B - Horizons that would qualify for A2 except for included parts constituting less than 50 percent of the volume that would qualify as B.

Some horizons having "tongues of albic horizons," which are diagnostic in the classification system, would qualify as A and B. Commonly, A and B horizons are predominantly A2 material partially surrounding thin, columnar-like upward extensions of the B or wholly surrounding small, isolated spheres, elipsoids, or other bodies that would qualify as B. In such horizons the A2 appears to be encroaching on an underlying B.

AC - A horizon transitional between A and C, having subordinate properties of both A and C, but not dominated by properties characteristic of either A or C.

B - Horizons in which the dominant feature or features is one or more of the following: (1) an illuvial concentration of silicate clay, iron, aluminum, or humus, alone or in combination; (2) a residual concentration of sesquioxides or silicate clays, alone or mixed, that has formed by means other than solution and removal of carbonates or more soluble salts; (3) coatings of sesquioxides adequate to give conspicuously darker, stronger, or redder colors than overlying and underlying horizons in the same sequum but without apparent illuviation of iron and not genetically related to B horizons that meet requirements of 1 or 2 in the same sequum; or (4) an alteration of material from its original condition in sequums lacking conditions defined in 1, 2, and 3 that obliterates original rock structure, that forms silicate clays, liberates oxides, or both, and that forms granular, blocky, or prismatic structure if textures are such that volume changes accompany changes in moisture.

It is obvious that B horizon, as defined, includes many kinds of things. Item 1 in the definition includes the diagnostic argillic, natric, agric and spodic horizons. Item 2 includes the oxic horizon. Item 3 includes horizons that are in the position of a B, and that are not illuvial horizons, but that are recognizable and differ from the overlying and underlying horizons in color. Item 4 includes the diagnostic cambic horizon. It is not a transition horizon between one of the other kinds of B and the underlying C. Most, but not all, horizons that have been called hardpans and fragipans are excluded. It would, perhaps, be desirable to indicate these different kinds by symbol, but no provision has been made to do so. The definition is written to include, as nearly as possible, the concepts embodied in B horizon, as it is defined in the Soil Survey Manual.

It is obviously necessary to be able to identify the kind of B before one can establish that a horizon qualifies as B. There is no common diagnostic property or location in the profile by means of which all kinds of B can be identified. There are, however, marginal cases in which a horizon might qualify as either of two kinds of B. In such cases, the horizon description should indicate the kind of B that characterizes the dominant condition, in the judgment of the person describing the soil. Laboratory work may be needed for identification of the kind of B, or even to determine that a given horizon is a B.

B1 - A transitional horizon between B and A1 or between B and A2 in which the horizon is dominated by properties of an underlying B2 but has some subordinate properties of an overlying A1 or A2.

An adjacent overlying A1 or A2 and an adjacent underlying B2 are essential to characterization of a horizon as B1 in a virgin soil. In a few instances the horizon may still be recognized in a truncated soil by comparing the truncated profile with a profile of the same soil that has not been truncated. The symbol B1 is confined to those kinds of transitional horizons in which some properties of the overlying, adjacent A1 or A2 are superimposed on properties of B throughout the mass of the transitional horizon. Those kinds of transitional horizons containing parts characteristic of B, separated by abrupt boundaries from parts characteristic of an overlying A2, are classified as B&A.

B&A - Any horizon qualifying as B in more than 50 percent of its volume including parts that qualify as A2.

Such horizons commonly have many vertical tongues of A2 material that extend downward into the B from the A2 or they have thin horizontal bands of A2-like material, which lie between thicker bands of B and are connected with tongues extending from the A2. Tubes filled with A1 material, as in krotovinas or earthworm channels, in a B horizon should be described but should not be designated as B and A. Many B horizons have A2-like material in widely spaced narrow cracks. Such features should be described, but the horizon should be designated as B and A only if the A2 material constitutes more than 10 percent of the volume of the horizon.

B2 - That part of the B horizon where the properties on which the "B" is based are without clearly expressed subordinate characteristics indicating that the horizon is transitional to an adjacent overlying A or an adjacent underlying C or R.

This does not imply that the B2 horizon in a given profile must express to uniform degree the properties diagnostic of B or that it must be confined to a zone of maximum expression in the absolute sense. The horizon B3, which is transitional from B2 to C, commonly exhibits the subordinate properties of C by expressing in lower degree the properties of an adjacent B2. Before the designation B3 is justified, the degree of expression of B2 must be low enough that the properties of C are clearly evident. The definition does not imply that a given kind of B2 has the same degree of expression in all profiles. In some profiles, the most strongly expressed part of the B horizon, which would be designated B2, may be as weakly expressed as B3 in other profiles. The designation B2 is used strictly within the frame of reference of a single profile and not in an absolute sense of degree.

B3 - A transitional horizon between B and C or R in which the properties diagnostic of an overlying B2 are clearly expressed but are associated with clearly expressed properties characteristic of C or R.

The designation B3 is used only if there is an overlying B2; this applies even though the properties diagnostic of B are weakly expressed in the profile. Where an underlying material presumed to be like the parent material of the solum is absent, as in A-B-IIC profiles, B3 is used below B2 in the sense of a horizon transitional to an assumed original parent material. Use of the symbol IIC involves an estimate of at least the gross character of the parent material of the horizons above it. B3 in such cases is based on this estimate of the properties of the parent material of the B. B3 is not used as a horizon transitional from IB2 to IIC or IIR.

C - A mineral horizon or layer, excluding bedrock, that is either like or unlike the material from which the solum is presumed to have formed, relatively little affected by pedogenic processes, and lacking properties diagnostic of A or B but including materials modified by: (1) weathering outside the zone of major biological activity; (2) reversible cementation, development of brittleness, development of high bulk density, and other properties characteristic of fragipans; (3) gleying; (4) accumulation of calcium or magnesium carbonate or more soluble salts; (5) cementation by such accumulations as calcium or magnesium carbonate or more soluble salts; or (6) cementation by alkali-soluble siliceous material or by iron and silica.

This definition is intended to exclude horizons that meet the requirements of A or B but to include certain kinds of alteration that, historically, have been considered to be little influenced by the activity of organisms. These alterations include chemical weathering deep in the soil. Some soils are presumed to have developed in materials already highly weathered, and such weathered material that does not meet requirements for A or B is considered C. Development of the firmness, brittleness, and high density characteristic of fragipans is, by itself, not a criterion of A or B. Fragipans that have distinct silicate clay concentrations are to be indicated as Bx or simply as B. Fragipans lacking such clay concentration, however, are considered to be within the definition of C and are designated Cx. Accumulations of carbonates, gypsum, or more soluble salts are permitted in C if the material is otherwise considered to be little affected by other processes that have contributed to genesis of associated horizons. Such horizons are designated as Cca, Ccs, Csa. Even induration by such materials is permitted and this can be indicated by the suffix m, as in Ccam. Induration by alkali-soluble siliceous material is also permitted and may be indicated by Csim. Induration by iron and silica does not exclude the horizon from C, and horizons or layers thus indurated would be designated Cm. Horizon C, as defined, is intended to include the diagnostic horizons indicated by ca, cs, and sa, and the alkali-soluble pans, the iron-silica pans, and the fragipans, provided these layers do not meet the requirements of B. The C horizon now includes the contrasting layers of unconsolidated material designated as "D" in the Soil Survey Manual. It also includes the "G" horizon of the Soil Survey Manual, if that horizon cannot be designated as A or B. Historically, C has often incorrectly been called parent material. In fact it is impossible to find the parent material from which the A and B horizons have developed; that material has been altered. For this reason, C never was parent material, but was merely presumed to be like parent material. As C is now defined, even this assumption is dropped.

The differentiation between C1 and C2 made in the Soil Survey Manual has been dropped because it is untenable when applied to the variety of conditions recognized as C. If C1 of the Soil Survey Manual were to be recognized, a number of other conditions included under C should be recognized also. Deletion of C1 makes arabic numerals applied to C indicative only of vertical sequence within C.

R - Underlying consolidated bedrock, such as granite, sandstone, or limestone. If presumed to be like the parent rock from which the adjacent overlying layer or horizon was formed, the symbol R is used alone. If presumed to be unlike the overlying material, the R is preceded by a Roman numeral denoting lithologic discontinuity as explained under the heading.

Symbols used to indicate departures subordinate to those indicated by capital letters

The following symbols are to be used in the manner indicated under the heading Conventions Governing Use of Symbols.

b - Buried soil horizon.

This symbol is added to the designation of a buried genetic horizon or horizons. Horizons of another solum may or may not have formed in the overlying material, which may be similar to, or different from, the assumed parent material of the buried soil.

ca - An accumulation of carbonates of alkaline earths, commonly of calcium.

This symbol is applied to A, B, or C horizons and includes, but is not restricted to, the calcic horizons that are diagnostic in the classification system. Possible combinations are A1ca, A3ca, B1ca, B2ca, B3ca. A2ca is probably also possible where accumulation has occurred in an A2 formed under different conditions, but it is not common. The presence of secondary carbonates alone is not adequate to justify the use of the ca symbol. The horizon must have more carbonates than the parent material is presumed to have had.

cs - An accumulation of calcium sulfate.

This symbol is used in a manner comparable to that of ca. Calcium sulfate accumulations commonly occur in the C below ca accumulations in chernozemic soils but may occur in other horizons as well. Before the symbol cs is used, the horizon must have more sulfates than the parent material is presumed to have had.

cn - Accumulations of concretions or hard noncon-cretionary nodules enriched in sesquioxides with or without phosphorus.

The nodules indicated by the symbol cn must be hard when dry but need not be indurated. Nodular plinthite, diagnostic in the classification system, in a master horizon may be designated by cn, but the symbol is not confined to plinthite. The horizon description should characterize the nodules. Nodules, concretions, or crystals do not qualify as cn if they are of dolomite or more soluble salts, but they do qualify if they are of iron, aluminum, manganese, or titanium.

f - Frozen soil.

The suffix f is used for soil that is frozen at the time the soil is described. It may or may not be permanently frozen.

g - Strong gleying.

The suffix g is used with a horizon designation to indicate intense reduction of iron during soil development, or reducing conditions due to stagnant water, as evidenced by base colors that approach neutral, with or without mottles. In aggregated material, ped faces in such horizons generally have chroma of 2 or less as a continuous phase, and commonly with few or faint mottles. Interiors of peds may have prominent and many mottles but commonly have a network of threads or bands of low chroma surrounding the mottles. In soils that are not aggregated, a base chroma of 1.0 or less, with or without mottles, is indicative of strong gleying. Hues bluer than 10Y are also indicative of strong gleying in some soils. Horizons of low chroma in which the color is due to uncoated sand or silt particles are not considered strongly gleyed. Although gleying is commonly associated with wetness, especially in the presence of organic matter, wetness by itself is not a criterion of gleying. The symbol g may be applied to any of the major symbols for mineral horizons and should follow the horizon designations, as A2g, A21g, A3g, B1g, B2g, B3g, and Cg. Bg may be used where B horizons cannot be subdivided into B1, B2, and B3.

No lower case letter is used as a suffix with horizon designations to indicate reduction of iron less intense than that indicated by g. Not given a special designation but described in detail is the condition generally associated with (1) common to many, distinct to prominent mottles on base colors of chroma stronger than 2 in unaggregated material, or (2) evidenced by base chroma greater than 2 with few to common, faint to distinct mottles on ped faces and common to many, distinct to prominent mottles in ped interiors in well-aggregated material.

h - Illuvial humus.

Accumulations of decomposed illuvial organic matter, appearing as dark coatings on sand or silt particles, or as discrete dark pellets of silt size, are indicated by h. If used, this suffix follows the letter B or a subdivision of B, as Bh or B2h.

ir - Illuvial iron.

Accumulations of illuvial iron as coatings on sand or silt particles or as pellets of silt size; in some horizons the coatings have coalesced, filled pores, and cemented the horizon.

m - Strong cementation, induration.

The symbol m is applied as a suffix to horizon designations to indicate irreversible cementation. The ortstein of a Spodosol, a layer cemented by calcium, and a duripan are examples. The symbol is not applied to indurated bedrock. Contrary to usage in the Soil Survey Manual, m is not used to indicate firmness, as in fragipans, but is confined to indurated horizons which are essentially (more than 90 percent) continuous, though they may be fractured.

p - Plowing or other disturbance.

The symbol p is used as a suffix with A to indicate disturbance by cultivation or pasturing. Even though a soil has been truncated and the plow layer is clearly in what was once B horizon, the designation Ap is used. When an Ap is subdivided, the arabic number suffixes follow, as Ap1 and Ap2, for the Ap is considered comparable to the A1, A2, or B2.

sa - An accumulation of salts more soluble than calcium sulfate.

This symbol may be applied to the designation of any horizon and in its manner of use is comparable to that described for ca or cs. If the symbol is used, the horizon must have more salt than the parent material is presumed to have had.

si - Cementation by siliceous material, soluble in alkali, as defined for the diagnostic duripans of the classification system. This symbol is applied only to C.

The cementation may be nodular or continuous. If the cementation is continuous the symbol sim is used.

t - Illuvial clay.

Accumulations of translocated silicate clay are indicated by the suffix t (Ger. ton, clay). Characteristics useful in recognition of translocated clay are discussed under the argillic horizon. The suffix t is used only with B, as B2t, to indicate the nature of the B.

x - Fragipan character.

The symbol x is used as a suffix with horizon designations to indicate genetically developed properties of firmness, brittleness, high density, and characteristic distribution of clay that are diagnostic of fragipans. The character of fragipans is described elsewhere, and is not repeated here. Fragipans, or parts of fragipans, may qualify as A2, B, or C. Such horizons are classified as A2, B, or C, and the symbol "x" is used as a suffix to indicate fragipan character. Unlike comparable use of supplementary symbols, the symbol x is applied to B without the connotative arabic numeral normally applied to B. Arabic numerals used with C to indicate only vertical subdivision of the horizon precede the "x" in the symbol, as C1x, C2x.

All lower case symbols except p follow the last arabic number used, as B3ca, A2g, A21g. If the horizon is not subdivided, the symbol follows the capital letter, as Cg, Bt. The symbol p is restricted to use with A because of the common difficulty of deciding which horizons have been included in the plow layer.

It will be noted that the connotation of the symbol m has been changed to prohibit its use with "fragipans" and that definitions of the other symbols have been modified or elaborated in relation to those given in the Soil Survey Manual. The symbols si and x have been added to the list given in the Manual, and the symbols "r," "G," "D," "M," and "u" have been dropped.

Subdivision of Horizons

In a single profile it is often necessary to subdivide the horizons for which designations are provided, for example, to subdivide Ap, A1, A2, A3, B1, B2, B3, or C so that detailed studies of morphology, sampling, and similar work can be correctly recorded. In some cases, such subdivision is arbitrary in relation to differences observable in the field; in others, it may be needed to differentiate within a horizon on bases not provided by unique horizon symbols. In all such cases, the subdivisions are numbered consecutively, with arabic numbers, from the top of the horizon downward, as B21, B22, B23. If the suffixes consisting of lower-case letters are being used, the arabic numbers precede all lower-case suffixes except p, as B21t, C1g, C2g, but Ap1, Ap2.

Lithologic Discontinuities

Roman numerals are prefixed to the appropriate horizon designations when it is necessary to number a series of layers of contrasting material consecutively from the surface downward. A soil that is all in one kind of material is all in material designated by the numeral I. This numeral therefore can be omitted from the symbol, as it is understood that all the material is I. Similarly, the uppermost material in a profile having two or more contrasting materials is always designated I. Consequently, for the topmost material, the numeral I can be omitted from the symbol because it is always understood. Numbering starts with the second layer of contrasting material, which is designated II, and each contrasting material below this second layer is numbered consecutively, III, IV, and so on, downward as part of each horizon designation. Even though a layer below a layer designated by II is similar to the topmost layer, it is given the appropriate consecutive number in the sequence. Where two or more horizons developed in one of the numbered layers, the Roman number is applied to all the horizon designations in that material.

Following are two examples of horizon sequences using this convention:

A1 - A2 - B1 - B21 - IIB22 - IIB3 - IIC1 - IIIC2

A1 - A2 - B1 - B2 - IIA'2 - IIB'x - IIC1x - IIIC2x - IIIC3 - IVR

In the first example, the first contrasting layer is unnumbered; the second layer, starting in the B2, is indicated by Roman II, as IIB22; the third, within the C, by the symbol IIIC. In the second example, the first contrasting layer is unnumbered; the second, starting at the top of A'2, is numbered II; the third, starting in the middle of the fragipan is numbered III, even though the fragipan is partly in C; and the fourth, starting below C, is indicated by IVR. Note that arabic numerals are used independently of the Roman numerals, in the conventional manner, both as connotative symbols and for vertical subdivision.

The Solum

The solum has been considered the "genetic soil" that developed by soil-building forces. It has not been doubted that A and B horizons are part of the solum, and, to many, solum is equivalent to A and B. There are, however, other genetic horizons in soils, including various kinds of pans and accumulations of carbonates or more soluble salts. Solum is used here to include A and B horizons and, in addition, fragipans and some duripans. Solum, as used in this text, is not a synonym for soil, which often includes or even consists of C material.

Not included in the solum are accumulations of carbonates, sulfates, or more soluble salts, nor zones of cementation caused by silica under strongly alkaline conditions. These are not included because they have no uniform position in the soil relative to other horizons. This is admittedly arbitrary. Accumulation of carbonates, sulfates, and other salts may take place in an A or a B horizon, or deep in the C. They may be in part or entirely geologic and depend on the presence of ground water at depth. If these accumulations were allowed as part of the solum, the solum would be discontinuous vertically, and this would be a nuisance.

Solum includes the following diagnostic horizons, defined later: all epipedons, agric, albic, argillic, natric, spodic, oxic, and cambic horizons, fragipans, and duripans either requiring repeated alternating treatments with acid and alkali to soften or underlain by a spodic horizon.

Paleosols

Through field research we are recognizing more and more polygenetic soils—soils that have formed under climates and vegetation different from those of the present. The horizons formed under the earlier conditions may be wholly or partially preserved. Where they conform to the present surface there may be no good way to determine which characteristics were acquired by the soil under the earlier environment and which were or are being acquired under the present conditions. Certain soils of the coastal plain in Mississippi are examples. Ruston soils occur on the surfaces in the eastern part of the State, but to the west they pass under the loess without apparent change in morphology. Clearly, many of the characteristics of the Ruston soils were acquired before the loess was deposited. Since the Memphis soils, which are formed in the loess, do not belong in the same order as the Ruston soils on the coastal plain, it could be argued that the Ruston soils are Paleosols. By this reasoning one might argue that the properties that distinguish the Ruston from the Memphis soils should be disregarded in the higher categories. Yet there is no way to demonstrate that the properties of the Ruston soils could not have been formed under the present climate, or conversely, that given more time under the present climate, the Memphis soils will not change and come to resemble the Ruston soils. It seems inescapable that we classify both the Ruston and Memphis soils on the basis of their present properties. We have no way to distinguish the features acquired earlier from those forming at present.

PHYSICAL, CHEMICAL, AND MINERALOGICAL PROPERTIES

At the end of this and other chapters there are descriptions of soil profiles referred to by page number at various places in the chapter. A table of laboratory data accompanies each profile on its page. At the heads of some of the columns in these tables there are lower case letters indicating the procedure used in making the laboratory determination. The procedures so identified are described in detail in these publications:

(1) Association of Official Agricultural Chemists
1955. Official Methods of Analysis. Ed. 8, pp. 30-31. Washington, D. C.

(2) Deb, B. C.
1950. The Estimation of Free Iron Oxides in Soils and Clays and Their Removal. Jour. Soil Sci. 1: 212-220.

(3) Hendricks, S. B., and Alexander, L. T.
1939. Minerals Present in Soil Colloids. Pt. 1, Description and Methods for Identification. Soil Sci. 48: 257-271.

(4) Kilmer, V. J., and Alexander, L. T.
1949. Methods of Making Mechanical Analysis of Soils. Soil Sci. 68: 15-24.

(5) ____________ and Mullins, J. F.
1954. Improved Stirring and Pipetting Apparatus for Mechanical Analysis of Soils. Soil Sci. 77: 437-441.

(6) Peech, M., Alexander, L. T., et al.
1947. Methods of Soil Analysis for Soil-Fertility Investigations. U. S. Dept. Agr. Cir. 757, 23 pp.

(7) Piper, C. S.
1944. Soil and Plant Analysis. pp. 132-135. Interscience Publishers, Inc. New York.

(8) Richards, L. A., ed.
1954. Diagnosis and Improvement of Saline and Alkali Soils. U. S. Dept. Agr. Handbk. 60, 160 pp., illus.

(9) Robinson, W. O.
1939. Method and Procedure of Soil Analysis Used in the Division of Soil Chemistry and Physics. U. S. Dept. Agr. Cir. 139, 21 pp.

(10) Uhland, B. E., and O'Neal, A. M.
1951. Soil Permeability Determinations for Use in Soil and Water Conservation. U. S. Dept. Agr., Soil Conserv. Serv. Tech. Pub. 101, 36 pp., illus.

(11) Williams, D. E.
1949. A Rapid Manometric Method for the Determination of Carbonate in Soils. Soil Sci. Soc. Amer. Proc. (1948) 13: 127-129, illus.

Laboratory Methods and Procedures

Briefly described here are the chemical methods and procedures used in compiling data shown at the end of this chapter, and in other chapters throughout the text. An arabic number in parentheses following the description of a method or procedure indicates the publication in the foregoing list that contains a discussion of that method or procedure.

In all chemical procedures, air-dry samples are crushed with a rolling pin, care being taken to avoid fragmenting nonsoil material, to pass a 2 mm. round-hole sieve. Material retained by the sieve is reported as greater than 2 mm. All determinations except bulk density are performed on the less than 2 mm. fraction, and results are reported on that basis.

Particle size distribution analysis: Pipette method—dispersion with sodium hexametaphosphate and mechanical shaking (4, 5); fine clay by centrifuging and pipetting.

pH: Glass electrode, using soil-water ratios indicated (8, 6).
Glass electrode, using 1:1 soil-1 N KCl ratio.

Organic carbon:

- w Wet combustion: Modification of Walkley-Black method (6); 1 meq. $K_2Cr_2O_7$ equivalent to 3.9 mgrm. C.
- d Dry combustion: Modification of W. O. Robinson method (9); combustion in CO_2 free oxygen; gas washed in Ag_2SO_4, concentrated H_2SO_4, and $Mg(ClO_4)_2$; CO_2 adsorbed on commercial adsorbent.

Total nitrogen:

- k Kjeldahl, modified A.O.A.C. procedure (1).
- m Semi-micro Kjeldahl: Digestion in mixture of K_2SO_4 and concentrated H_2SO_4, using selenium metal and CuSO as catalysts; ammonia distillate is collected in boric acid and titrated with H_2SO_4.

Cation exchange capacity (meq./100 gm. soil):

- s Sum of cations (6).
- b NH_4^+ saturation and direct distillation of NH_3 (6).
- e NH_4^+ saturation and distillation of NH_3 from sodium chloride extract (6).
- f Na^+ saturation, displacement with NH_4OAc and determination of Na^+ displaced (8).

Extractable cations (exchangeable cations in nonsaline, noncalcareous soils): Displacement with 1 N NH_4OAc (6).
Ca^{++} and Mg^{++} determined as described in (6), except in profile No. 16, in which Ca and Mg were determined by flame spectrophotometry. Na^+ and K^+ by flame spectrophotometry. (In the presence of soluble salts, extractable Na^+ and K^+ equal milliequivalents Na^+ and K^+ per 100 gm. soil extracted by NH_4OAc minus milliequivalents Na^+ and K^+ in saturation extract per 100 grm. soil.)

Exchangeable H^+ or exchange acidity: Displacement from soil with triethanolamine and barium chloride at pH 8.2 (6).

Exchangeable sodium (percent): Extractable Na^+ minus Na^+ in saturation extract, divided by exchange capacity as determined by NH_4OAc or NaOAc.

Soluble ions or salts in saturation extract: Extraction by filtration of saturated sample, and soluble ions and salts determined as described in reference (8).

Free iron oxide: Modification of Deb's method (2). Mix 1 gm. sodium hydrosulfite ($Na_2S_2O_4$) and 4 gm. of soil, add water, stopper immediately, and shake overnight at room temperature. Acidify to pH 3.5-4.0. Determine by titration with $K_2Cr_2O_7$.

Bulk density (gm./cu. cm.):

- u Core samples, using either 1 by 2 inch or 2 by 3 inch cylinders and a Uhland type core sampler (10).
- c Coated clods; volume determined by water displacement.

Moisture retained at 1/10, 1/3, and 15 atmosphere pressure: Pressure plate and pressure membrane apparatus used on fragmented samples (8).

Calcium carbonate equivalent:

- a Absorption by NaOH of CO_2 evolved when acid is added to soil samples (7).
- n Acid neutralization (8).
- v Measurement of volume of CO_2 evolved when acid is added to soil sample; modification of Passon's and Williams' method (7, 11).

Gypsum: Precipitation with acetone (8).

Loss on ignition: Difference between oven dry (110° C.) and ignited samples.

Elemental Analysis:

- g. [2]Fusion with Na_2CO_3 and silica, iron and aluminum determined gravimetrically, (7).
- h. X-ray spectroscopic analysis: The unfractionated soil samples were prepared for analysis by fusing ground soil in borax. The X-ray fluorescent intensities of the major soil elements except Mg determined with a Philips single position X-ray spectrograph. The percentage of SiO_2, Al_2O_3, and Fe_2O_3 were calculated by a method of successive approximations correcting for matrix absorption and mutual fluorescent effects. The X-ray fluorescent intensities of the clay fractions were determined directly on the powdered specimens. Matrix absorption and mutual fluorescent corrections were made involving solution of simultaneous equations. This method is reliable for the oxide ratios, but does not give absolute oxide percentages.

Clay mineralogy.—Determinations on clay mineralogy reported in this text were made as follows:

Methods: X-ray diffraction with Norelco Diffractometer, FeK_a radiation, scanning speed of 1 degree per minute; oriented samples on glass slides; Mg^{++} saturated samples at room temperature and after heating to 110° C., 250° C., and 500° C.
Differential thermal analysis with apparatus described by Hendricks and Alexander (3).

[2]Data furnished by the Department of Agronomy and Soil Science, Hawaii Agricultural Experiment Station, University of Hawaii, Honolulu, Hawaii.

Interpretation: Relative amounts of montmorillonite, vermiculite, mica (illite), and chlorite estimated from areas enclosed by first-order X-ray diffraction peaks of basal spacings. The amounts of minerals present are thought to be related to the peak areas and are indicated as follows:

x = small   xxx = large
xx = moderate   xxxx = predominant

Estimates are consistent among profiles so far as possible, but small deviations were made to indicate relationships among horizons of individual profiles.

Amounts of kaolinite and gibbsite are estimated from the size of the respective endothermic peaks, as compared to known standards. In a number of the soils the endothermic peak characteristic of kaolinite is very diffuse. Quantitative estimates based on such peaks are indicated by asterisk (*); they are unreliable, and probably too high.

In tables, clay minerals are identified by the following symbols:

Mt	Montmorillonite	K	Kaolinite
Mi	Mica	Gb	Gibbsite
Vm	Vermiculite	G	Goethite
Chl	Chlorite	Q	Quartz

THE ABC HORIZON NOMENCLATURE

The designation A horizon was first applied to the dark-colored surface horizons of the soils of the Russian steppes; the C horizon was the material beneath, essentially unmodified by soil-forming processes; and the B horizon was the transitional horizon between A and C. Then Dokuchaiev and his students applied this same nomenclature to Podzols. In these the A horizon is relatively thin and the B has a concentration of fine materials moved from A. The common, or unifying characteristic of A horizons was position--the A horizons were formed at the surface of the soil. Some were distinguished by accumulations of organic matter, and others by loss of sesquioxides or clay.

Soil scientists of western Europe first adopted the ABC horizon designations as used in podzolic soils, in which the horizon between A and C is a horizon of accumulation. So the early concept of B in western Europe (and the United States) became that of an illuvial horizon.

Some even regard the layer of lime accumulation in Chernozems as a "B" horizon. The concepts of A, B, and C horizons, though differing among individuals, are simple and easily understood. The difficulty in their usage comes from lack of agreement on definition and is most acute when related to soils that have more than three major horizons, or to soils that are quite unlike the soils of Europe. In the first situation, a given soil may have two illuvial horizons, an upper one of free sesquioxides and humus, and a lower one of silicate clays, separated from the upper horizon by a bleached eluvial horizon. Thus, it may have two eluvial and two illuvial horizons. The eluvial horizon at the surface can be designated as A, and both illuvial horizons can be designated as B, but the lower eluvial horizon does not fit well into the ABC nomenclature. It is an eluvial horizon, but it is not at the surface, and many object to calling it a part of the A.

The second situation, that of a soil unlike those in Western Europe is exemplified by the difficulty of applying the ABC nomenclature to Latosols. The horizon at the surface relatively rich in organic matter is generally accepted as an A horizon. The next horizon, however, is not an illuvial horizon, although it is in the normal position of a B horizon. Rather, it is a zone in which a concentration of sesquioxides has been produced by differential removal of other elements. It has many properties that distinguish it from deeper horizons, and some wish to call it B horizon, but others call it C horizon. The contrasting opinions may be held firmly. It should be pointed out, furthermore, that the illuviation of many B horizons is actually less significant than is the concentration of clays brought about by removal of other elements.

There are other problems of horizon nomenclature that have not been so generally recognized. For example, the dark-colored surface horizon of the soils of the steppes is generally considered to be an A horizon. Yet in the lower part of this horizon, there may be pronounced illuviation of silicate clay, which is normally a basis for recognizing a B horizon. Thus, the same horizon is A from one viewpoint but is B from another.

In the absence of general agreement on horizon designation, it is necessary either to propose a new or modified system for defining and designating horizons or to bypass the problem by assigning names to those diagnostic horizons used for classification. It does not seem desirable to have for the purpose of soil classification a separate system of horizon designations that is different from, but no better than, the systems commonly used. In addition, readers who disagree with the definitions used for A and B may reject a useful concept simply because they believe it should have a different designation than A or B. It is the purpose here to test the utility of the concepts. The nomenclature can be decided later, as it is a separate problem. For these reasons, the diagnostic horizons are named by the name of classes for which they are diagnostic, without relating them to A or B.

DIAGNOSTIC SURFACE HORIZONS

Any horizon may be at the surface of a partially truncated soil, but six diagnostic horizons that form at the surface are recognized. The horizons that form at the surface are called epipedons (Gk. epi, over; and pedon, soil). (Ep-i-ped-on, rhymes with head on.) The epipedon includes the upper part of the soil that is darkened by organic matter, or the upper eluvial horizons, or both. Epipedon is not a synonym for A horizon, however, for the epipedon may include part or all of an illuvial B horizon if the darkening by organic matter extends from the surface into or through the B.

Mollic Epipedon

A property or combination of properties was desired to group the Chestnut, Chernozem, and Brunizem soils. These soils are so similar that it is often exceedingly difficult to distinguish one from another in the absence of the native vegetation. From a genetic viewpoint, the differences are in the frequency of seasons with sufficient rainfall to satisfy both the evapo-transpiration and the field capacity of the soil to store moisture and still leave a surplus to move downward to the ground water. Seasons of high rainfall are rare in the zone of the Chestnut soils, and frequent in the zone of the Brunizems, but the differences are as much or more of degree than of kind.

Abstraction of the common properties focuses immediate attention on the surface horizons rather than the deeper ones. In all of the groups some soils have illuvial B horizon enriched with clay, and some do not. Some have horizons of carbonate accumulation, and some do not. Perhaps only those in the drier part of the range have accumulations of both calcium and magnesium carbonate, but the data are too few to be conclusive. The similarities are many, and the differences few and sometimes obscure.

The use of the thick, dark surface horizon as a means of grouping the soils of the steppes was therefore decided upon early in the development of the system. Early approximations of a definition were tested against the soils of the United States to determine the nature of the groupings that would result. It was found that it would be difficult, if not impossible, to write a definition of a horizon that could be used to group the Chestnuts, Chernozems and Brunizems, without including many Rendzinas, Humic-Gley soils, and Brown Forest soils of the eastern part of the United States. From either a morphologic or genetic viewpoint, such groupings seemed better than any alternatives that could be found.

The concept of the mollic epipedon centers on a thick, dark surface layer dominantly saturated with bivalent cations, with narrow carbon-nitrogen ratios and with moderate to strong structure.

From a purely genetic viewpoint the mollic epipedon is formed by the underground decomposition of organic residues in the presence of divalent cations. The underground decomposition is partly decomposition of roots, and partly the decomposition of surface organic residues taken underground by animals. The soil organic matter is probably largely living and dead micro-organisms. Turnover of the organic matter in the mollic epipedon is probably rather rapid and relatively complete within a period of some hundreds of years. The radiocarbon age of the organic carbon is a matter of a few (1 to 6) hundred years on the basis of present fragmentary data (table 9a). It should be noted that radiocarbon age is not a weighted average age of the soil carbon, for the decay of the C14 is an exponential function. Nevertheless, the data indicate that the bulk of the organic matter is very recent.

The definition of the mollic epipedon is in terms of its morphology rather than its genesis, though an understanding of the genetic assumptions may aid the understanding of the definition.

Table 9a.--Radiocarbon Surface Age of Organic Matter in Virgin Mollic Epipedons 1/

Soil series	Great group	Depth sampled	County	State	Radiocarbon age
		Inches			Years
Barnes	5.4	0-4	Cavalier..	North Dakota	350 ± 120
Clarion......	5.5	0-6	Pocahontas	Iowa........	440 ± 120
Cresco-Kenyon intergrade.	5.5	0-4 4-8	Howard....	Iowa........	210 ± 130 100 ±
Edina........	5.2	0-6	Wayne.....	Iowa........	410 ± 100
Webster......	5.3	0-6	Pocahontas	Iowa........	270 ± 120

1/ Not all soil organic matter is so recent as that in the soils listed above. The radiocarbon age of the organic matter in spodic horizons of humus Podzols in Georgia (U. S.) is 1,150 ± 350 years, and in Holland, 940 ± 20 years. The radiocarbon age of the soil organic matter in the A2 horizon of the Edina profile listed above is 840 ± 200 years.
(Ref. Science, vol.124, No. 3213, July '56.)

A mollic epipedon is a surface layer which has, after the surface 7 inches are mixed, as by plowing, the following properties:

1. Soil structure is sufficiently strong that the horizon is not both massive and hard or very hard, when dry.[3]

2. Both broken and rubbed soils have colors with a chroma of 4.0 or less (Munsell notation) when moist, a value darker than 3.5 when moist, and 5.5 when dry; and at least one Munsell unit darker than the IC (both moist and dry), if a IC horizon is present. If only a IIC or R is present, comparison should be made with the next horizon underlying the epipedon.[4]

The mollic epipedon is expected to have dark colors throughout the mass. Some soils lacking dark colors in the matrix become dark on rubbing because fine, soft iron-manganese concretions impart a dark color when mixed with the mass. Such soils are excluded by the broken colors. Other soils lacking dark colors in the matrix have dark coatings and appear to be dark colored until they are rubbed. These soils are excluded by the rubbed colors.

3. The carbon-nitrogen ratio is 17 percent or less if virgin, and 13 or less if being cultivated.

The carbon-nitrogen ratio does not drop from something like 17 to 13 or less as a result of a single plowing. The ratio of 13 for cultivated soils is intended to apply to soils that have been cultivated for something like 25 years or more.

Normally, the carbon-nitrogen ratio decreases with depth in the mollic epipedon to values of something like 8 to 10.

4. The base saturation is over 50 percent by the NH_4OAc method, and Ca is the dominant metallic cation.

5. Contains at least 0.58 percent organic carbon (1 percent organic matter) throughout. If the dark surface horizon is less than 7 inches thick in a virgin soil with a solum of less than 18 inches, the organic carbon content must be sufficient to give an average of 0.58 percent to an Ap that is 7 inches thick. Otherwise, if plowed the Ap would have too little organic matter for a mollic epipedon.

6. The thickness is more than 10 cm. (4 inches) if resting directly on hard rock (R). If the soil contains an argillic, natric, spodic, or cambic horizon, or a fragipan or duripan, as defined later, the thickness of the epipedon must be more than one-third of the thickness of the solum where the solum is less than 75 cm. (30 inches) thick and must be more than 25 cm. (10 inches) where the solum is more than 75 cm. thick.

7. The epipedon has less than 250 parts per million of P_2O_5 soluble in citric acid. This restriction is used to eliminate a number of plow layers of very old arable soils that have acquired, under cultivation, the other properties of the mollic epipedon.

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[3]The name of the order and of the epipedon were both derived from the Latin word, *mollis*, meaning soft.

[4]Some soils formed in carbonaceous shales have dark colors inherited from the elemental carbon in the parent material. Munsell values of 2 and 3 are not uncommon in soils formed in such materials. The requirement that the mollic epipedon be 1 Munsell unit darker than the parent material is introduced to eliminate such soils unless there has been some darkening of the epipedon by pedogenic carbon. Basic igneous rocks are also dark in color, and their weathering products normally have a Munsell value of 3 when moist. Here the darkness is presumably due to the content of free iron. The requirement that mollic epipedon be one Munsell unit darker than the IC, or the next underlying horizon if only a IIC or R is present, breaks down when the mollic epipedon rests directly on a dark-colored R. An exception is therefore made to this requirement if the R is carbonaceous or if a basic igneous rock and if the solum has no argillic horizon (textural B).

This list of properties sets the limits of the mollic epipedon. Four profile descriptions, with accompanying laboratory data, have been selected to illustrate the application of these limits.

Profile 1, page 66, is an example of a soil having a mollic epipedon that rests on a horizon of lime accumulation.

It will be noted that in this soil, only the first horizon, the Ap, comes within the limits of the mollic epipedon. The second horizon is too light in color, though it has enough organic carbon to come within the limits.

Profile 2, page 67, illustrates a mollic epipedon in a soil that has a cambic horizon, a weakly expressed B. The description and data show that the first three horizons, with a total thickness of 22 inches, constitute the mollic epipedon. The fourth horizon is both too light in color and too low in organic carbon to be considered a part of the mollic epipedon.

Profile 3, page 68, illustrates the mollic epipedon in a soil that has a clearly expressed B horizon in which clay has accumulated. In this soil the eluvial horizon is only some 3-1/2 inches thick and is underlain by a horizon some 11 inches thick that contains illuvial clay. The mollic epipedon, however, includes both the eluvial A and the illuvial B. The next lower horizon, between depths of about 14 to 19 inches, includes the upper part of the horizon in which lime accumulated. It contains enough organic carbon to qualify as a part of the mollic epipedon, but its color is too light when it is moist. The mollic epipedon therefore is about 14 inches thick in this profile.

Some soils have a very thin, bleached eluvial A2 horizon within plow depth and just above an illuvial clay B horizon. The A2 horizon may be too light in color and sometimes is too low in organic carbon to qualify as a part of the mollic epipedon. The B horizons of these soils, however, may be dark in color and have a relatively high content of organic carbon. When plowed, the dark A1, the light colored A2, and part of the dark B horizon may be mixed. Profile 4, page 69, and the related laboratory data illustrate this situation.

The A2 horizon, 1 inch thick, is too light in color when dry to qualify as a part of a mollic epipedon. Yet the overlying Ap and the underlying B2 horizons do meet the essential requirements; and if plowed to a depth of 7 inches, the resulting Ap would qualify as a part of the mollic epipedon. Hence, the surface 17 inches constitutes a mollic epipedon but includes an Ap, an A2, and an illuvial B.

Anthropic Epipedon

This epipedon conforms to all the requirements of a mollic epipedon except the limit on acid soluble P_2O_5. It has more than 250 parts per million of P_2O_5 soluble in citric acid. It is formed under long-continued systems of farming that involve large additions of organic matter, and generally considerable supplemental nitrogen and phosphate. Commonly the anthropic epipedon has a clear or abrupt lower boundary, although mixing by earthworms may give a diffuse lower boundary. Except for those in ancient kitchen middens, anthropic epipedons are rarely found in the United States. In western Europe they are rather common, sometimes as roundish areas and commonly as rectangular areas that have nearly straight sides coinciding with former or present field boundaries. The differentia used for this horizon is relatively unsatisfactory; it is proposed tentatively in the hope that better differentiae will be suggested by others.

Umbric Epipedon

Many soils have dark surface horizons that cannot be distinguished by the eye from mollic epipedons, but laboratory studies may show that the dominant exchangeable cation is hydrogen, or that the carbon-nitrogen ratios are very wide, or both. Such epipedons are called umbric. The content of organic carbon may be even higher in umbric than in mollic epipedons. Examples of soils with umbric epipedons would include the Ando soils, Rubrozems, a number of extremely acid Humic Gley soils, and some Tundra soils.

Color is a poor general guide to the content of organic carbon, yet the dark colors of some umbric epipedons are caused by organic carbon, for these epipedons become light colored when the organic matter is destroyed. And, in some kinds of soil, the darkness is roughly proportional to the amounts of organic carbon.

Perhaps it is prejudice or resistance to change, but for some kinds of soil, particularly those in which the content of organic matter is roughly proportional to darkness, the most satisfactory groupings are still those that place soils with a dark-colored surface horizon in different groups from those with a light-colored surface horizon. In those kinds of soil where darkness is not related to the content of organic matter, the soils with light-colored epipedons probably should be separated from those with dark-colored epipedons only at very low categoric levels, perhaps the family or the series.

The umbric epipedon is comparable to the mollic epipedon in its color, organic carbon, and thickness requirements. It includes those thick, dark surface horizons that have base saturation of less than 50 percent, have a carbon-nitrogen ratio greater than 17, or that are both hard and massive when dry.

Profile 5, page 70, illustrates the umbric epipedon. A study of the description and the other data show that the umbric epipedon is about 32 inches thick. The horizons below 32 inches are too light in color to be included. The carbon-nitrogen ratios are too wide and base saturation is too low for a mollic epipedon. The content of organic carbon is high enough for a histic epipedon, but the soil has neither a high water table nor artificial drainage.

Profile 6, page 71, is an example of an umbric epipedon in a soil with a B horizon of illuvial clay (argillic horizon). In this soil the umbric epipedon is about 12 inches thick and includes only the A horizon. While this is a common situation, there is nothing that prevents the umbric epipedon from including all or part of a B horizon.

Histic Epipedon

The histic (Gk. histos, tissue) epipedon normally occurs at the surface, though it may be buried at a shallow depth. It is characterized by a thin organic horizon if virgin, and if plowed is characterized by the very high amount of organic matter that results from mixing of peat with some mineral material. And, since peat deposits are associated with free water, the histic epipedon is either saturated with water at some season of the year or has been artificially drained.

The histic epipedon therefore can be defined as a horizon at or near the surface, saturated with water at some season unless artificially drained, and meeting one of the following requirements:

1. A surface horizon, less than 30 cm. (12 inches) thick, with more than 17.4 percent organic carbon (30 percent or more organic matter) if the mineral portion is half clay; with more than 11.6 percent organic carbon (20 percent or more organic matter) if mineral the portion has no clay; or with intermediate proportional contents of clay and organic carbon. If the epipedon is less than 20 cm. (8 inches) thick, it is still thick enough to satisfy (2) below if the horizons are mixed to a depth of 20 cm. (8 inches).

2. A plow layer having more than 8.12 percent organic carbon (14 percent or more organic matter) if there is no clay; more than 16.24 percent organic carbon (28 percent or more organic matter) if the mineral fraction is half clay; or intermediate proportional contents of clay and organic carbon.

3. A mineral surface layer less than 40 cm. (16 inches) thick that overlies peat or muck, has a content of organic carbon satisfying (1) above, and has a thickness of 10 to 30 cm. (4 to 12 inches).

Ochric Epipedon

Ochric (Gk. ochros, pale, light colored) epipedons are those that are too light in color, too low in organic carbon, or too thin to be mollic, umbric, anthropic, or histic.

Ochric epipedons may have rubbed color values lower than 5.5 when dry or lower than 3.5 when moist, provided they are essentially no darker than the C horizon. The ochric epipedon includes eluvial horizons at or near the surface (A2 and albic horizons) and extends to the first underlying diagnostic horizon or material. If there is no underlying diagnostic horizon or material, the ochric epipedon includes only the material appreciably darkened by humus.

Examples of three situations are given. Profile 7, page 72, has an ochric epipedon because there is no contrast in darkness between the surface horizon and the C. In the surface horizon the content of organic carbon is relatively high and the color values are dark. But the color values for moist condition are 3 throughout the profile. If the contrast in color value between the surface horizon and the C were greater, this soil would have an umbric epipedon. In soils developed from basalt or other highly basic rocks, darkness frequently is poorly related to the content of organic carbon.

Profile 8, page 73, describes a soil with an epipedon that is too light in color to qualify as either mollic or umbric.

Profile 9, page 74, illustrates a soil having a surface horizon that has been darkened by organic matter but is too thin to be either mollic or umbric. Only the surface 3 inches are dark enough and have enough organic carbon to meet the requirements of a mollic epipedon. If this profile were plowed to a depth of 6 inches, the resulting mixture would be too light colored and would contain too little organic carbon to meet the requirements of a mollic epipedon. It is therefore ochric.

Plaggen Epipedon

The plaggen epipedon (Ger. <u>plaggen</u>, meadow) is a man-made surface layer, more than 50 cm. (20 inches) thick, that has been produced by long-continued manuring. In medieval time, sod was commonly used for bedding livestock and the mineral impurities brought in by this kind of manuring eventually produced an appreciably thickened Ap, one up to 1 meter or more in thickness.

Colors and contents of organic carbon depend on the sources of the sod used for bedding. If the sod was cut from humus Podzols, the plaggen epipedon tends to be black or very dark gray, to be rich in organic matter, and to have a wide carbon-nitrogen ratio. If the sod came from forested soils, the plaggen epipedon tends to be brown, to be low in organic matter, and to have a narrow carbon-nitrogen ratio.

The plaggen epipedon may be identified by several means. Commonly it contains artifacts, bits of brick and pottery, throughout. Chunks of diverse materials, such as black and light-gray sand, up to the size held by a spade, may be present. The plaggen epipedon often shows spade marks throughout, and remnants of thin, stratified beds of sand that were produced on the surface by beating rains and later buried by spading. The soil individuals that have plaggen epipedons tend to be rectangular with straight sides, and they may be higher than adjacent individuals by as much or more than the thickness of the plaggen.

Figure 5 shows a soil with a plaggen horizon and the surrounding landscape. Mixing of materials can be seen in this profile. The landscape shows the straight boundaries and raised elevation of the soil. Plaggen horizons are unknown in the United States but are common in parts of western Europe.

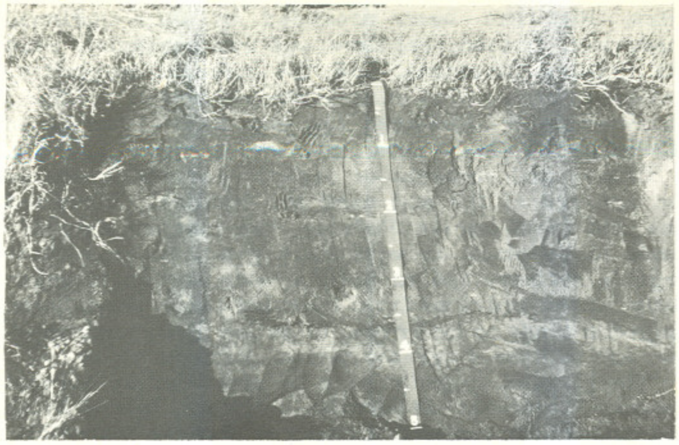
DIAGNOSTIC SUBSURFACE HORIZONS

The horizons discussed in this section form below the surface, though they may at times form immediately below a leaf litter, and they may be exposed at the surface by truncation. Some of these horizons are generally accepted as B horizons, some are considered B horizons by many soil scientists but not by all. Others are generally considered as parts of the A horizon.

Argillic Horizon

An argillic horizon is an illuvial horizon in which silicate clays have accumulated to a significant extent. It therefore must be formed below the surface of the mineral soil, though it may later be exposed at the surface. The movement of one clay particle into a horizon normally would not be detectable, but a limit can be set near the point where the amount moved has been great enough that the evidences can be detected fairly consistently by competent soil morphologists.

The bulk of the clay in most horizons either has formed in place or has been inherited from the parent material. The clay that has moved from one horizon to another is usually only a small part of the total clay. In kind, the clay that has moved normally does not differ from the clay that has not moved, but in its apparent size, the clay that has moved does differ. Thermal and x-ray analyses of the clay fraction of soils with argillic horizons normally show little or no difference between the clay of the A and the B. If the parent materials contain a mixture of clays, including montmorillonite, it does seem that montmorillonite is more completely removed from the A horizon than other clays. Analyses of the whole soil, and of the clay fraction less than 2 microns, are shown for three profiles in table 10. Profile 10 has been considered



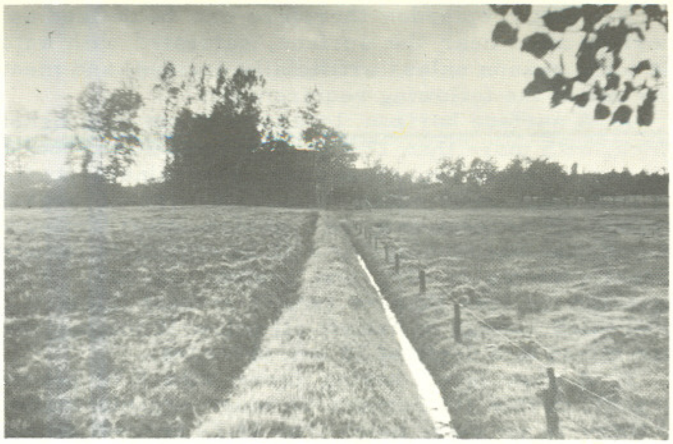


Figure 5.—Plaggen epipedon and surrounding landscape: Left, Plaggen epipedon, 4 feet thick, showing mixing, as with a spade. Right, Straight boundaries and higher elevations of soil individuals having plaggen epipedons (soil with plaggen epipedon lies to left of ditch).

TABLE 10.--Chemical and Mineralogical Analyses of Soils with Argillic Horizons

Depth	Whole soil (<2 mm.)								Clay fraction								
	Clay	K_2O h	CaO h	SiO_2 h	Al_2O_3 h	Fe_2O_3 h	Free Fe_2O_3	SiO_2/R_2O_3	K_2O h	CaO h	SiO_2/R_2O_3 h	Mt	Mi	Vm	Chl	K	Gb
Inches	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Pct.	Pct.							
Profile 10																	
0-6	45.8	1.7	1.1	59.3	18.8	8.0	5.0	4.2	1.5	<0.2	1.7	--	x	x	--	35	--
6-9	45.8	1.7	1.0	59.9	18.9	7.4	5.1	4.3	1.5	< .2	1.7	--	--	x	--	35	--
9-16	1/ 46.8	1.8	.9	59.3	19.7	7.8	5.0	4.1	1.7	< .2	1.7	--	--	x	--	35	--
16-22	50.0	1.8	.8	58.7	19.6	7.6	5.2	4.1	1.7	< .2	1.7	--	--	x	--	35	--
22-36	75.8	1.7	.9	49.9	24.4	9.9	7.5	2.8	1.5	< .2	1.8	--	--	x	--	25	--
36-44	(impurities in limestone)											--	--	--	--	70	5
Profile 11																	
0-6	12.8	2.0	0.5	80.8	8.0	2.5	1.4	14.3	2.5	<0.2	3.0	--	x	--	--	2/ 20	--
6-9	12.4	2.0	.5	80.8	8.0	2.4	1.2	14.3	2.5	< .2	3.0	--	x	--	--	2/ 20	--
9-13	1/ 21.7	2.3	.5	77.4	10.5	3.6	1.8	10.2	2.5	< .2	2.8	--	x	--	--	2/ 20	--
13-22	29.5	2.2	.5	73.4	11.7	5.2	2.4	8.3	2.2	< .2	2.3	xx	x	--	--	2/ 20	--
22-32	27.2	2.2	.5	75.1	11.3	5.1	2.5	8.8	2.1	< .2	2.6	xxx	x	--	--	2/ 20	--
32-48	22.5	2.3	.5	76.4	10.6	4.7	2.5	9.5	2.3	< .2	2.5	xx	x	--	--	2/ 15	--
48-55	19.9	2.3	.5	76.1	10.3	4.5	2.4	9.8	2.5	< .2	2.4	xxx	x	--	--	2/ 20	--
Profile 12																	
0-5	11.4	1.2	0.3	86.2	4.8	1.8	0.6	24.6	1.7	<0.1	2.5	--	xx	3/ x	--	20	--
5-7	20.4	1.3	<.1	82.3	7.5	3.2	1.4	14.6	--			x	x	--	--	25	--
7-14	1/ 49.8	1.5	<.1	69.3	15.3	7.4	4.2	5.9	1.2	< .1	2.1	xx	x	--	--	20	--
14-19	44.4	1.7	<.1	70.9	14.3	7.1	3.4	6.4	--			xx	x	--	--	20	--
19-31	37.4	1.9	<.1	74.1	13.4	5.7	2.3	7.4	1.5	< .1	2.4	xxx	x	--	--	25	--
31-37	34.3	1.7	<.1	75.3	12.1	5.8	2.2	8.1	--			xx	x	--	--	25	--
37-47	31.6	1.9	<.1	76.2	11.4	6.4	2.4	8.3	1.6	< .1	2.6	xx	4/ x	--	--	20	--
47-60	32.3	2.0	.2	74.6	10.6	7.2	2.2	8.3	--	--	--	xx	4/ x	--	--	20	--

1/ Argillic horizon data are underscored.

2/ DTA peak very diffuse; estimates have low reliability and are probably too high.

3/ Vermiculite-montmorillonite interstratified material.

4/ Slightly more than in overlying horizons.

a Terra Rossa soil; profile 11, a Gray-Brown Podzolic soil; and profile 12, a Red-Yellow Podzolic soil. The constancy of the SiO_2/R_2O_3 ratios of the clay fraction and the uniformity in the clay mineralogy in the various horizons of each soil attest to the lack of large differences between the clays of the illuvial and eluvial horizons. In contrast to the analyses of the clay fraction, the analyses of the whole soil show appreciable changes, which can be explained by the movement of the clay.

In kind, the illuvial clay is similar to that formed in place or inherited from the parent material, but in size, it is normally finer than the other clay. Table 11 shows some representative analyses. Although there is no certainty about the size that has actually been measured, data reported from different laboratories on different kinds of soil show similarities indicating that the clay that has moved in a soil behaves differently in sedimentation from clay that has not moved.

By observing its orientation, translocated clay can be distinguished from other clays in the field in many cases, and in the laboratory in most cases. Clay particles are generally platy in shape, and if they have been moved and deposited, tend to be oriented with their long axes parallel to the surfaces on which they were deposited. Halloysite and allophane are the principal exceptions. The movement of clay may be from one horizon to another, or may be within a horizon. Since water is the agent that moves the clay, the translocated clay tends to form coatings of oriented clay particles on the channels through which water moves. These channels are principally the cleavage faces between peds and the pores left by roots or animals.

Clays deposited in sediments such as shale or till may be oriented with the depositional surface. Clays that formed in place within the soil may be oriented according to the crystal structure of the original mineral grain from which they formed, i.e., micas and feldspars. However, neither the mineral grains nor the planes in the shale or till are oriented with respect to any soil feature. Consequently, in thin sections, the layers of oriented clays in peds, on the surfaces of pores, and on the surfaces of peds usually can be distinguished from the rest of the clay. Figures 6, 7, and 8 show the appearance of the layers of oriented clays in thin sections. Figure 6 shows the layering on a ped surface; figure 7 shows a pore that has been filled with clay; figure 8 shows how clay accumulates in a sand as coatings on the grains of sand and as bridges between the grains. The layered appearance of the clay coatings in these figures suggests cyclical illuviation. Each figure includes two photographs; A was taken with ordinary light, and B under crossed polarizers. The birefringence, or brightness, of the oriented clays under crossed polarizers is evidence of orientation of the clay particles. Extinction of transmitted light through the clay occurs in certain planes when the thin section is rotated. The pattern of light transmission or extinction indicates that the orientation is parallel to the surfaces on which the clay has been deposited.

Figure 9 is included for contrast. It shows a ped surface in the cambic horizon, or B, of a Dystrochrept (Sol Brun Acide). The layered clays are absent. Instead, one finds weak orientation of the silts and clay, but no distinct difference in texture between the ped coat and the ped interior.

In the field, the oriented clays on the ped surfaces and in pores, variously called clay skins, clay films, clay flows, or tonhaütchen, can be recognized with high precision if they are well developed and in medium-textured materials. Uncertainty of recognition increases if the layers are thin, or if the matrix material has a clay texture. Figure 10 shows, under magnification, a thick clay skin in a pore and very thin clay skins on the ped surfaces of an argillic horizon. Figure 11 shows clay skins and clay bridges in a sand.

Examination of ped surfaces and pores with a 10- to 20-power hand lens usually discloses one or more of the features common to most clay skins. The skins may differ from the ped interiors in color as well as texture. Pores emerging on the lower side of a ped often have irregular lips where the clay protrudes. The surfaces often have an irregular shape, with channels and apparent flow lines formed by running water; and if the clay skins on ped surfaces are thick, the tracings of roots are often visible.

Clay skins are difficult to identify in the field in horizons with fine texture, particularly in those soils rich in swelling clays. The pressures generated when the soils swell produce irregular but smooth ped surfaces with clay textures. In thin sections some orientation of the clays may be deduced from the birefringence of the ped faces; because no differentiation by particle size or mineralogy has occurred, the oriented clay is indistinguishable from unoriented clay by any other criterion.

Structureless or massive soils obviously cannot have clay skins on ped surfaces, since they have no peds. The clays in the illuvial horizons of these soils are usually found as coatings on the individual sand grains, and are often oriented with the surfaces of the grains (see fig. 8). Occasional pores in these horizons persist long enough to have patchy or continuous clay skins, with flow lines. These appear in figure 8 in both upper and lower centers.

The clay skins are important in the field identification of most argillic horizons because they indicate translocated clay. Yet clay skins alone are inadequate at times to identify an argillic horizon. Because of the turbulent flow of water down wide cracks, clay skins might be formed by a single rain in a soil having no significant illuviation. For this reason, clay skins in an argillic horizon should occur on all sides of the peds, not just on the vertical faces.

If we start with the simplest situation--a medium textured soil developed from a single parent material with no lithologic discontinuities--the loss of about 10 percent of the clay in the eluvial A horizon and its accumulation in the B normally produces a textural change that can be recognized consistently by trained soil morphologists. At this point the ratio of the clay in the B to the clay in the A is about 1.2 (i.e., 25 percent in the A, or surface, horizon and 30 percent in the argillic horizon). In most medium-textured soils a ratio of this magnitude seems to make a fairly satisfactory division point for the recognition of an argillic horizon. In sands, however, an arbitrary and somewhat higher percentage limit seems necessary. If the clay content of the parent material is only 1 percent, the movement of 10 percent of the clay from the surface horizon to the B would give clay contents of 0.9 and 1.1 respectively. The difference is too small to be detected in the field, or even in the laboratory by ordinary procedures. For this reason, an arbitrary difference between the A and B of at least 3 percent has been selected as a division point for soils with less than 15 percent clay in the A horizon. With a difference of less than 3 percent clay between the A and B, an argillic horizon is not recognized, although

TABLE 11.--Particle size Distribution of Selected Soils with Argillic Horizons

Profile 13 1/

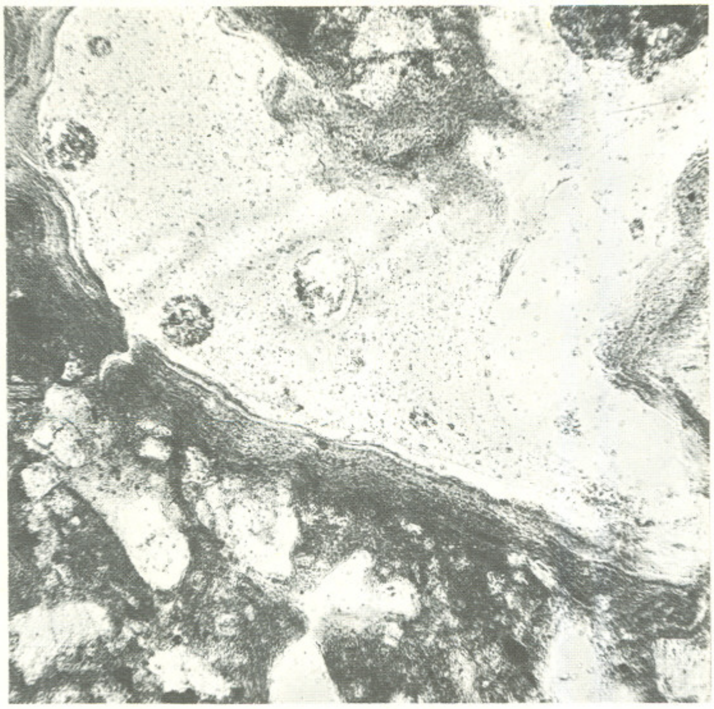
Depth	Particle size distribution (mm.)								
	2-1	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.002	< 0.002	0.002-0.0002	< 0.0002
Inches	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
0-7	2.5	4.7	6.5	10.5	6.2	47.0	22.6	15.8	6.8
7-10	1.7	4.3	5.7	9.8	6.9	45.4	26.2	18.8	7.4
10-14	2/ 1.7	3.4	3.9	6.3	5.1	34.3	45.3	25.1	20.2
14-23	1.5	3.0	3.3	6.2	5.9	37.3	42.8	26.6	16.2
23-29	2.4	3.7	3.5	6.5	7.4	41.8	34.7	25.2	9.5
29-35	1.8	4.1	3.8	6.1	7.1	44.2	32.9	24.0	8.9
Profile 14 1/									
0-7	1.1	1.3	1.9	4.7	6.3	51.6	33.1	24.6	8.5
7-10	.9	1.1	1.6	4.2	6.7	53.1	32.4	23.2	9.2
10-16	2/ .7	1.0	1.3	3.1	5.6	47.9	40.4	24.6	15.8
16-21	.6	1.0	1.3	2.8	4.1	45.2	45.0	25.0	20.0
21-28	.3	1.0	1.1	2.8	4.9	48.5	41.4	23.3	18.1
28-47	.5	1.3	1.6	3.2	4.7	50.7	38.0	23.3	14.7
47-56	1.7	3.5	3.8	7.9	8.6	54.0	20.5	15.6	4.9
56-80	2.0	3.1	3.3	6.1	7.8	57.4	20.3	15.3	5.0
80-100	26.7	14.6	6.2	6.3	3.8	30.1	12.3	9.5	2.8
Profile 15									
0-1½	3/ 3.6	4.1	4.9	11.6	10.6	43.5	21.7	16.4	4/ 5.3
1½-3	3/ 2.2	4.1	5.2	13.1	11.9	39.2	24.3	16.7	4/ 7.6
3-8	3/ 2.3	4.7	6.0	13.9	11.5	32.3	29.3	16.4	4/ 12.9
8-11	3/ 3.7	4.5	5.8	13.8	10.9	33.0	28.3	21.3	4/ 7.0
11-23	3/ 3.1	4.2	4.7	11.3	10.7	34.5	31.5	26.8	4/ 4.7
23-39	3/ 3.8	3.8	4.3	11.7	12.0	36.6	27.8	25.1	4/ 2.7
39-60	3/ 3.3	3.9	4.0	10.5	10.6	37.7	30.0	26.2	4/ 3.8

1/ Data from Ohio State University Soil Survey Laboratory.

2/ Argillic horizon data are underscored.

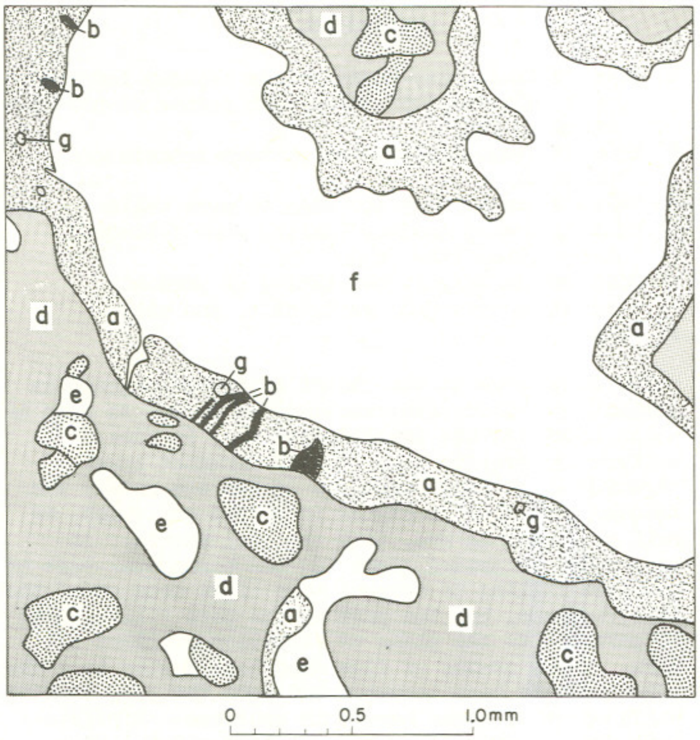
3/ Organic matter in sand fraction.

4/ 0.001 data from: Chestnut, Chernozem, and Associated Soils of Western North Dakota. C. A. Mogen, J. E. McClelland, J. S. Allen, and F. W. Schroer., Soil Sci. Soc. Amer. Proc. v. 23, pp. 56-61. 1959.



A, Viewed under plain light

B, Viewed under crossed polarizers
╳ Planes of polarization of light



C, Diagram

EXPLANATION

a Coatings of oriented clay

b Extinction bands

c Mineral grains larger than very fine sand

d Matrix consisting of unoriented particles of clay, silt, and very fine sand

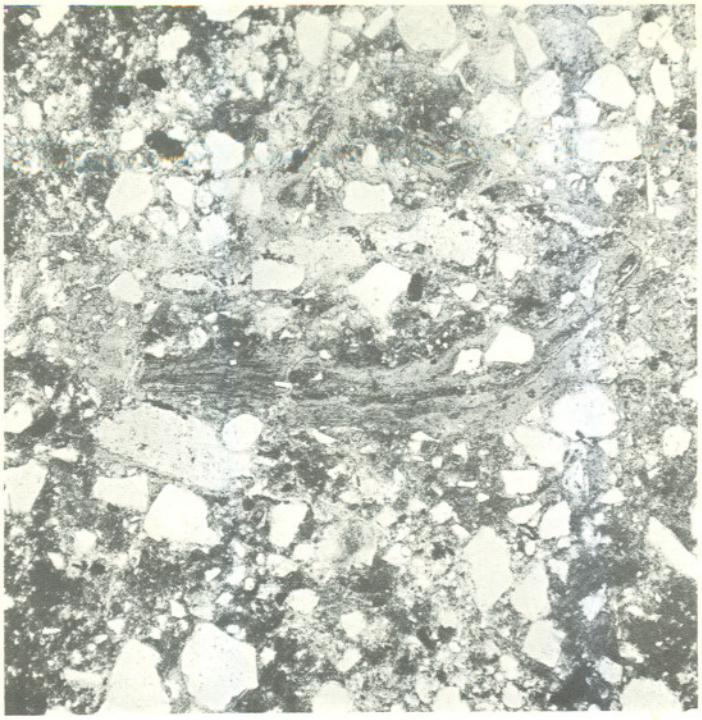
e Small pores within peds

f Voids between peds (particles in voids are impurities from section preparation)

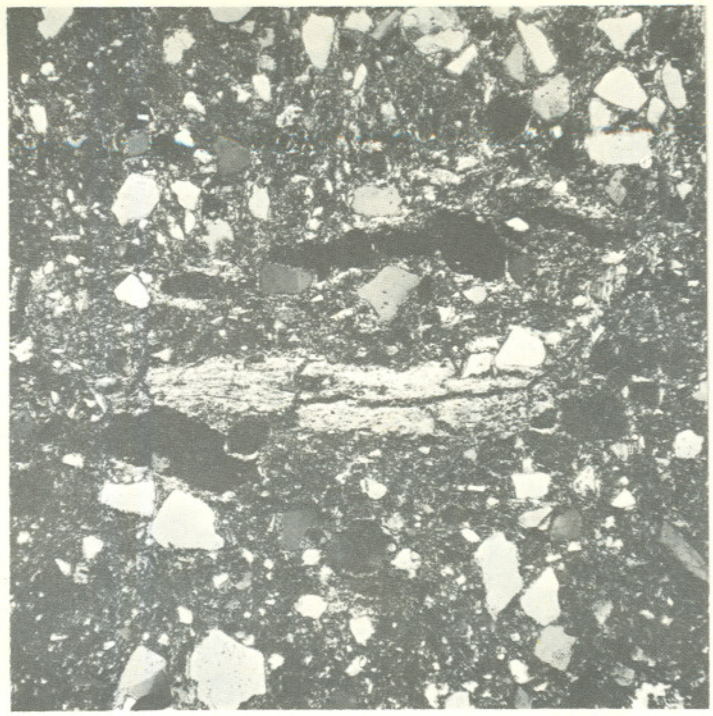
g Very fine grains of sand in the clay coatings

Cyclical illuviation is suggested by the layering parallel to the ped surface, and by the inclusion of grains of very fine sand. The brightly illuminated part of the coating in micrograph B is at a 45° angle to the planes of polarization of light in the microscope; the dark section on the left and the narrow "extinction bands" (item b in diagram) are segments of the coatings where the clay particles are parallel to the planes of polarization. Upon rotation of the microscope stage, the dark extinction bands seem to sweep across the coatings.

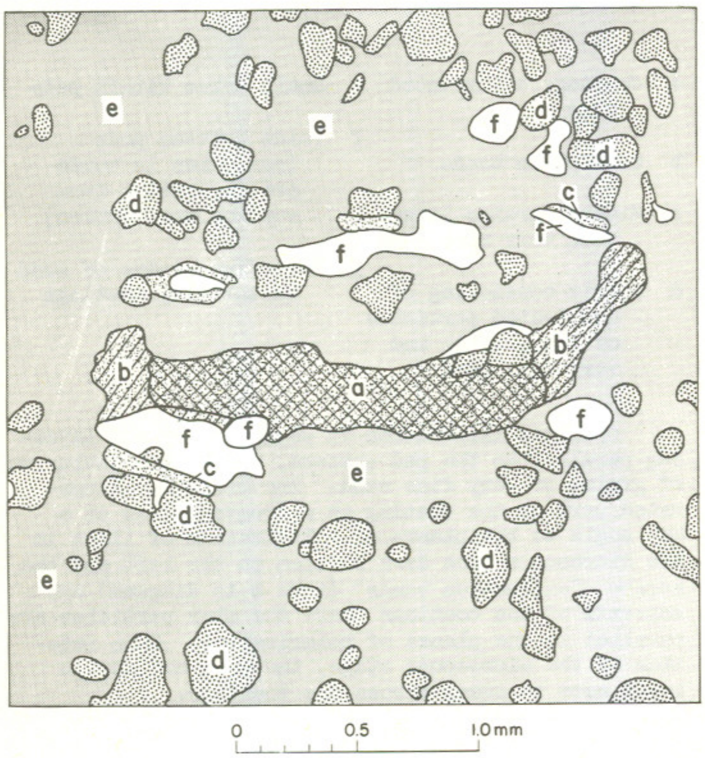
Figure 6.—Thin section of a clay skin on a ped surface.



A, Viewed under plain light



B, Viewed under crossed polarizers
X Planes of polarization of light



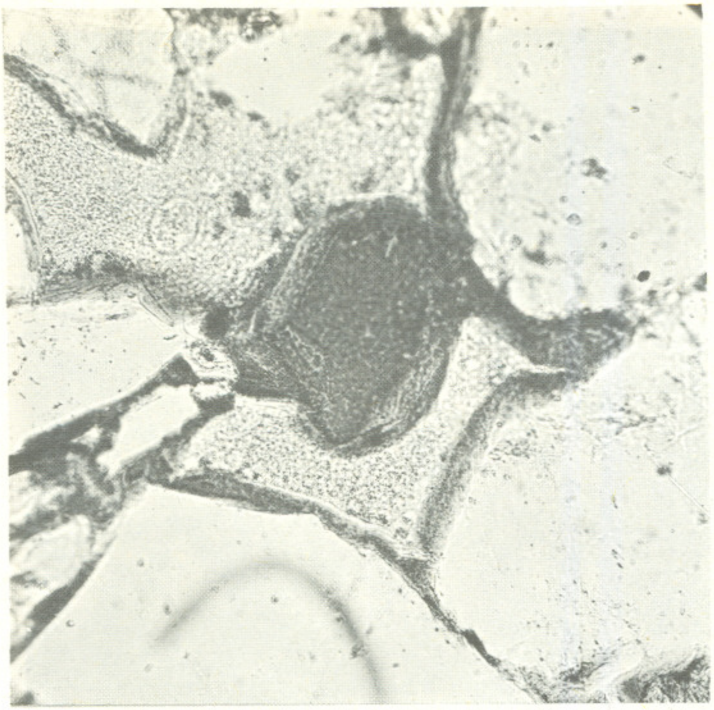
C, Diagram

EXPLANATION

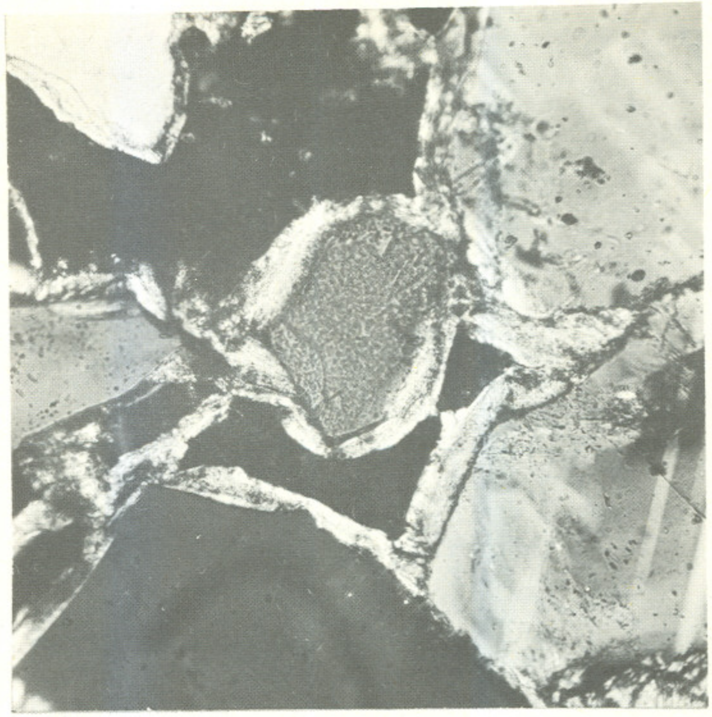
a Pore filling--clay particles at maximum interference position (45° angle with planes of polarization of light)
b Pore filling--clay not at maximum interference position
c Thin, oriented clay coatings on pore walls
d Mineral grains (mainly quartz, some feldspar) larger than fine sand
e Soil matrix largely consisting of randomly arranged very fine sand, silt, and clay
f Pores

The large pore in the center of the micrograph is completely filled with translocated clay. As seen in plain light (A) the translocated clay is fine, uniform in particle size, and of distinct layer structure. In most soils, as in the one shown, the translocated clay is higher in chroma and value, as well as redder in hue, than the soil matrix. As seen under polarized light (B) the horizontal part of the pore filling is transmitting light because of the birefringence, but the part of the pore filling that is parallel to the plane of vibration of light is dark. A few grains of fine sand have fallen into the pore and have been incorporated into the pore filling. Walls of other pores have thin coatings. Birefringent zones around the grains of sand and the birefringent streaks within the matrix result from pressure orientation of the particles of clay and silt that have not been translocated.

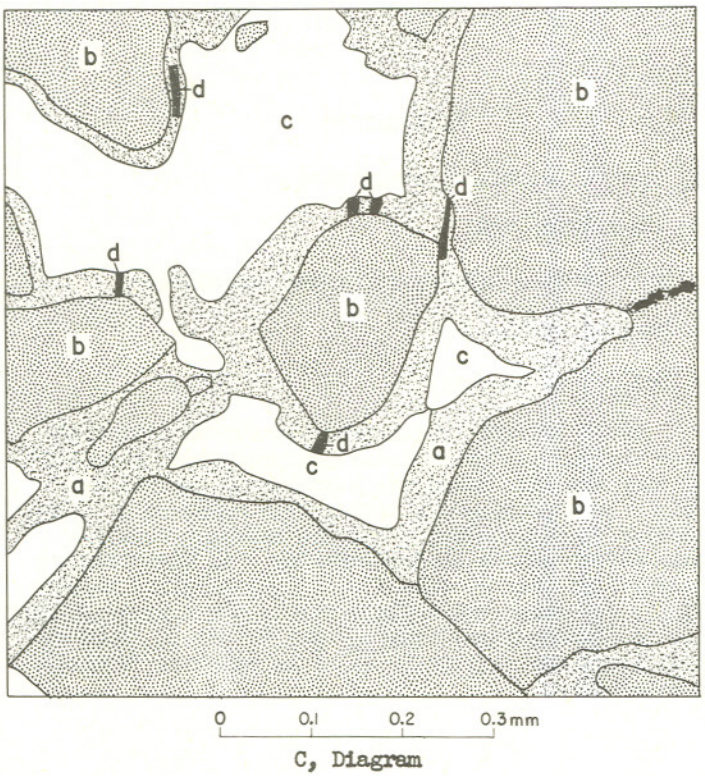
Figure 7.–Thin section of a clay skin in a pore.



A, Viewed under plain light



B, Viewed under crossed polarizers
+ Planes of polarization of light



C, Diagram

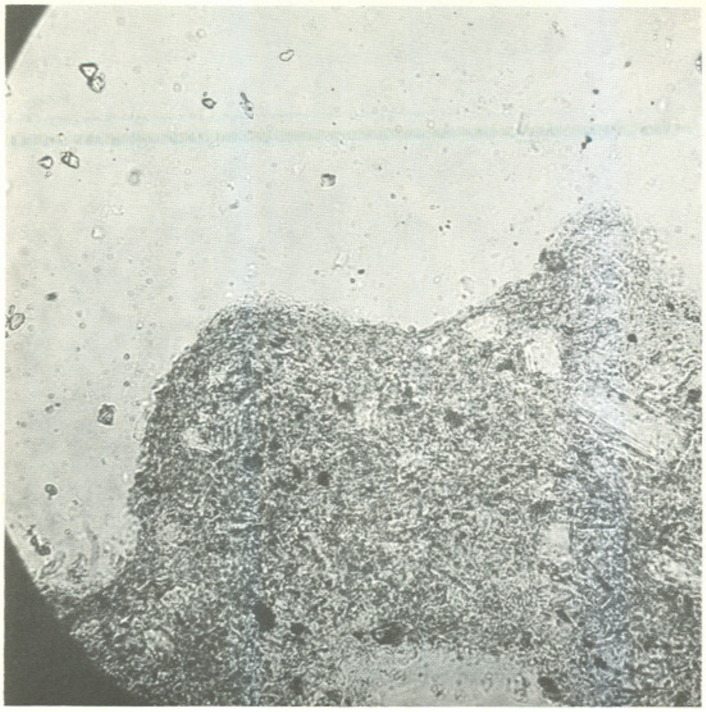
EXPLANATION

a Coatings of oriented clay c Voids

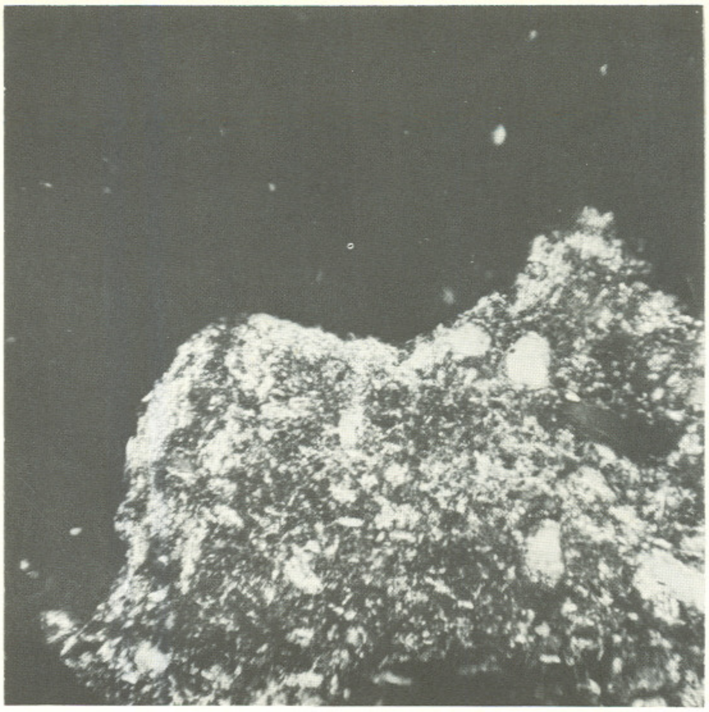
b Mineral grains d Extinction bands

Coatings of translocated clay cover all of the mineral grains and form bridges at edges and apices. The prominence of bridges suggests preferential deposition of the clay in the menisci of a drying soil-water system.

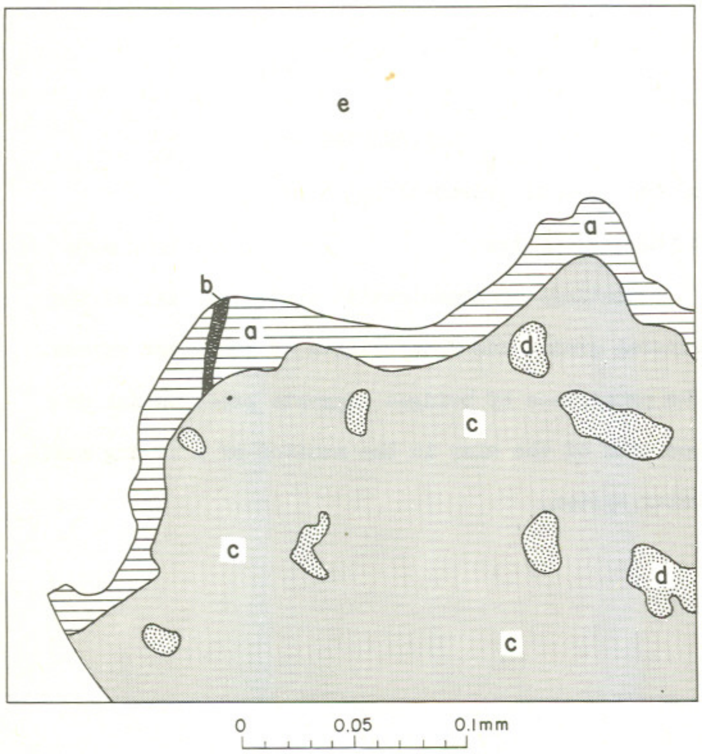
Figure 8.–Thin section of clay skins and bridges on sand.



A, Viewed under plain light



B, Viewed under crossed polarizers
+ Planes of polarization of light



C, Diagram

EXPLANATION

a Zone of preferred orientation

b Extinction band

c Soil matrix, lacking preferred orientation

d Mineral grains

e Voids between peds

Under crossed polarizers, transmission of light near the ped periphery indicates preferred alignment of clay and silt particles parallel to the ped surface. Such peripheries differ from coatings of translocated clay in having a diffuse boundary with the soil matrix and in having particle size distribution nearly identical to that of the soil matrix. In the micrograph taken under plain light, the periphery cannot be distinguished from the ped interior. Extinction bands are similar to those in coatings of translocated clay.

Figure 9.—Thin section of a ped surface in a cambic horizon that lacks clay skins.

Figure 10.–Thick clay skin in pore and thin clay skins on ped surface. (Scale is 2 mm.)

Figure 11.–Clay skins and bridges on sand. (Scale is 2 mm.)

a B horizon may be readily discernible. Conversely, a ratio of 1.2 would require an unreasonable amount of translocation in parent materials rich in clay. A difference of 8 percent ordinarily should be detectable in clayey soils in the field and is easily measured in the laboratory. Consequently, if the A contains more than 40 percent clay, an increase of 8 percent in the B horizon seems adequate for the recognition of an argillic horizon.

In sands and loamy sands, the argillic horizon often forms as a series of "fibers," or lamellae (fig. 12). These are spaced at intervals varying from a very few inches up to a foot or more. Only the lamellae are used for comparing textures. Obviously, a single lamella with a thickness of 2 mm. should not constitute an argillic horizon. It is too thin to be sampled for measurement of the clay content. Lamellae 1 cm. or more thick, and totaling something like 15 cm. or more in a given profile, should be present for the recognition of an argillic horizon in sands and loamy sands.

If the accumulation is not in lamellae, significant illuviation requires that the illuvial horizon have a reasonable thickness. An illuvial horizon 1 cm. thick underlying an eluvial horizon 50 cm. thick would not indicate a great deal of translocation. The illuvial horizon's thickness must be at least one-tenth that of the overlying horizons to indicate significant illuviation.

Detailed studies of the micromorphology of some soils with argillic horizons (i.e., class 7.34, Glossudalfs) show evidences that an argillic horizon may be formed and later destroyed. During the initial phases of destruction, the clay skins are removed from the ped surfaces, and bleached coatings of silt or sand are left. Oriented clays within the peds

Figure 12.–Argillic horizon in bands, or lamellae.

persist for a time. It is possible, therefore, to have an argillic horizon undergoing degradation that has few or no clay skins on ped surfaces but has many clay skins within the peds. Such horizons are still considered argillic horizons, so long as they retain the clay ratio of 1.2 with the overlying horizon, or if no A is present for comparison, have oriented clays in something like 10 percent of the cross section.

Soils that have been cultivated for many years may have lost their original eluvial horizons, and in these the plow layer may be in the argillic horizon. If cultivation is stopped and the soil remains undisturbed under grass or forest for a long period, a new A1 horizon may form in the old plow layer. In time, evidence of the plowing disappears and a profile is formed that has a thin A1 horizon containing as much clay as the B. In such soils and in severely eroded soils being cultivated, the clay skins and concentration of fine clays will be about the only reliable evidence that the B is an argillic horizon.

The argillic horizon may have more clay than the C, but this will not necessarily be so if the parent materials were stratified, or were very fine textured. The argillic horizon should, however, have relatively more fine clay than the parent material in which it developed. An argillic horizon developed in a medium-textured nonstratified parent material has more total clay and more fine clay than the underlying C horizon. If the parent material is fine textured, the C horizon at times has as much or more total clay than the argillic horizon. Data on the content of fine clay are relatively scarce, but for soils developed in clayey parent materials, it is reasonable to expect that either the content of fine clay will be maximum in the argillic horizon, or that the ratio of fine clay to coarse clay will be at a maximum in that horizon.

Profile 16 illustrates a soil developed in such material. It will be noted that there is as much or more clay in the C than in the argillic horizon, which starts at 11 inches and extends to 30 inches. In the argillic horizon the fine clay constitutes half of the total. In the A it is about one-quarter of the total, and in the C it is about one-third. The clay in the C is dominantly illite.

Another common situation is that found in soils developed from limestone, where the argillic horizon apparently has less clay or no more clay than the C. At this time data are not adequate to predict whether the ratio of fine clay to coarse clay will permit a clear distinction between the argillic horizon and the C horizon.

Stratified parent materials and truncated soils that have lost their A horizons present different problems in the recognition of argillic horizons. If the A horizon has not developed from the same material as the B, or if no A remains for comparison, the difference in clay content between the A and the B cannot be used to define the limits of the argillic horizon. It is common to find on floodplains recent deposits of sand lying on clay. The ratio of clay in the lower layer to the clay in the surface layer may exceed 3, but none of the clay is illuvial. On the other hand, in old stratified deposits, the illuvial horizon of clay accumulation may coincide with an originally finer textured stratum, but one does not want to assert that illuvial horizons cannot form in stratified materials.

It is therefore necessary to look in stratified materials or in truncated soils for the evidence of illuviation, the clay skins. When most of the ped surfaces have coatings that cover some 10 to 15 percent of the ped surfaces with clay skins thick enough to obscure fine sand grains, and have some pores with nearly continuous clay skins, or if thin sections show something like 10 percent of the ped interiors to be oriented clays, the horizon is considered to be an argillic horizon. It is desirable to recognize the argillic horizon at about the same stage of development in all soils; therefore, the development of clay skins in the soils formed from stratified parent materials should be equal to the development in the most weakly expressed but recognizable argillic horizons of soils that developed in uniform parent materials.

Another nearly universal feature of argillic horizons in soils without lithologic discontinuities is the nature of the transition from the A to the argillic horizon. The boundary may be abrupt or even gradual, but the clay content increases sharply enough that the limits for an argillic horizon are exceeded within a 12-inch vertical distance. To have an argillic horizon, the clay increase must occur within a 12-inch or thinner transition, and at least some clay skins must be present. It should be stressed that an increase in clay content with depth is not in itself evidence of an argillic horizon.

In summary, we can say that an argillic horizon forms below an eluvial horizon but may occur at the surface if a soil has been partially truncated. It meets the following requirements:

1. Where an eluvial A remains, and there is no lithologic discontinuity between the A and the argillic horizon, it contains more clay than the A as follows:
   a. If the A has less than 15 percent clay in the fine earth (less than 2 mm.) fraction, the argillic horizon must contain at least 3 percent more clay than the A. (13 percent versus 10 percent, for example.)
   b. If the A has more than 15 percent clay and less than 40 percent in the fine earth fraction, the ratio of the clay in the argillic horizon to that in the A must be 1.2 or more.
   c. If the A has more than 40 percent clay in the fine earth fraction, the argillic horizon must contain at least 8 percent more clay than the A. (50 percent versus 42 percent, for example.)

2. The argillic horizon must be at least one-tenth the thickness of the sum of all overlying horizons, or more than 15 cm. (6 inches) thick; and the clay increases required under item 1 must be reached within a vertical distance of 30 cm. (12 inches) or less.
3. If peds are present, an argillic horizon must show clay skins on some of both the vertical and horizontal ped surfaces and in the fine pores, or must show oriented clays in 10 percent or more of the cross section.
4. If a profile shows a lithologic discontinuity between the A and the argillic horison, or if only a plow layer overlies the argillic horizon, the argillic horizon need show only clay skins in some fine pores and, if peds exist, on some vertical and horizontal ped surfaces, or the clay skins must constitute approximately 10 percent of the cross section.
5. The argillic horizon does not necessarily have more clay than the C horizon, but it should have more fine clay than the C.

Agric Horizon

The argric horizon is an illuvial horizon of clay and humus formed under cultivation. When a soil is brought under cultivation, the vegetation is normally changed drastically; the surface material is mixed periodically by plowing and, in effect, a new cycle of soil formation is started. Even where the cultivated crops resemble the native vegetation, the stirring of the surface material and the use of amendments, especially lime and phosphate, normally produce significant changes in the soil flora and fauna. With long-continued cultivation, changes in the horizon immediately underlying the plow layer become apparent and cannot be ignored in the classification of the soil. Eluviation in the plow layer removes mixtures of humus and clay, and these may accumulate directly below the plow layer. Worm and root channels and ped surfaces become coated with dark-colored mixtures of organic matter and clay. The accumulation often takes the form of more or less horizontal lamellae or fibers that may vary in thickness from several millimeters to about a centimeter. If this illuvial material occupies less than about 15 percent of the volume of the horizon underlying the plow layer, the accumulation is considered too weak to be recognized as an agric horizon.

In summary, the agric horizon is a horizon immediately underlying a plow layer in which clay and humus have accumulated as thick, dark lamellae, or as coatings on ped surfaces and in wormholes, and occupy at least 15 percent of the horizon by volume.

Natric Horizon

The natric horizon is another special kind of argillic horizon. It has, in addition to the properties of an argillic horizon, (1) prismatic, or more commonly, columnar structure; and (2) more than 15 percent saturation with exchangeable sodium. If an underlying C horizon has more than 15 percent of exchangeable sodium in some part, an overlying argillic horizon that has more exchangeable magnesium plus sodium than calcium plus hydrogen is considered a natric horizon. The natric horizon is common to most soils that have been called solodized-Solonetz and Solonetz. Figure 13 shows the typical appearance of a natric horizon in a soil profile.

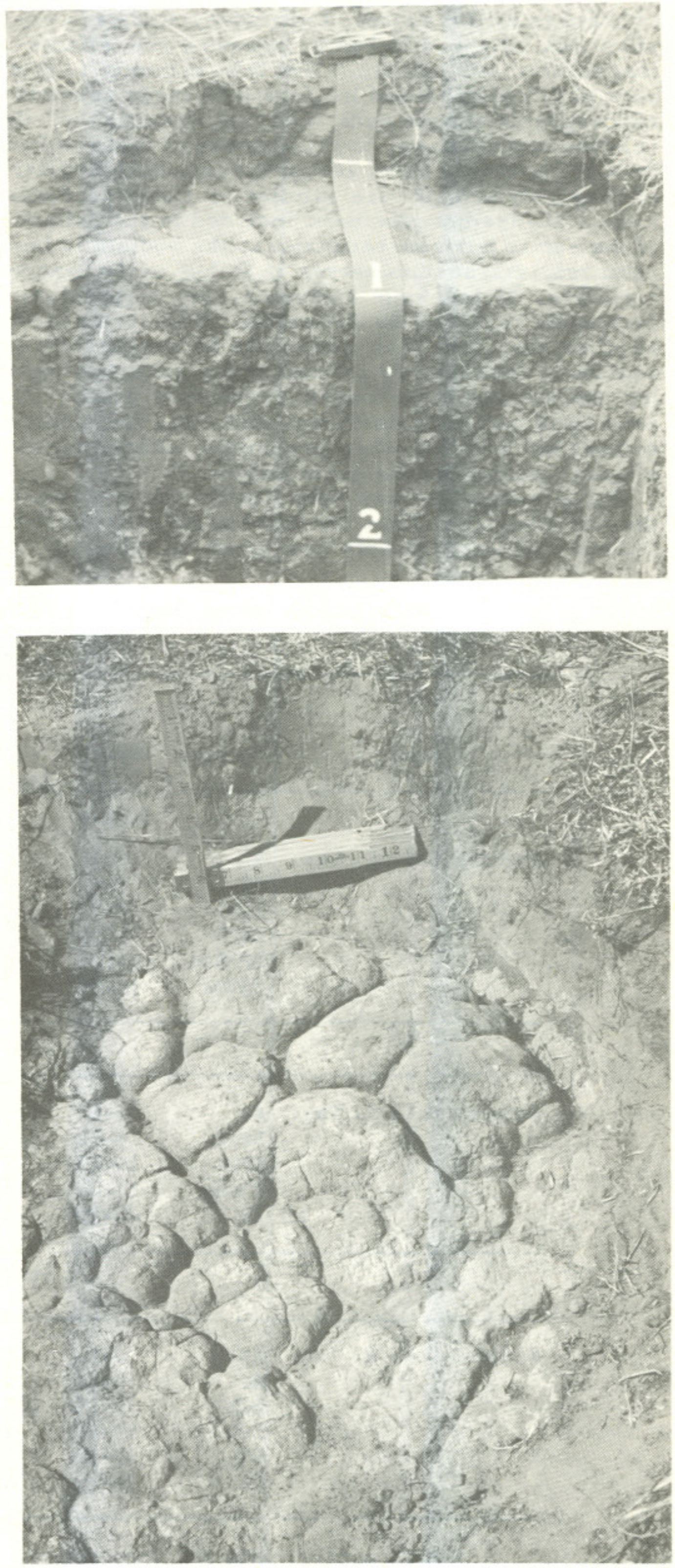


Figure 13.—Top, Natric horizon with columnar structure. Bottom, Bleached caps of columns.

The effect of the sodium on dispersion of clays and the formation of argillic horizons has been long recognized. The importance of special recognition of argillic horizons that have large amounts of exchangeable sodium has not been seriously questioned.

The effect of the magnesium ion on the dispersion of clays is still disputed. Laboratory studies seem to show but slight difference between the effects of magnesium and calcium. Yet it is common to find a poor physical condition in clays with large amounts of exchangeable magnesium, and the reasons for this relation are unknown. In the absence of more definite data, the authors cannot accept the idea that the effects of magnesium ions are similar to those of sodium ions. Magnesium has been included in the definition of the natric horizon because, as the sodium is being removed, magnesium seems to follow in the leaching sequence. If leaching continues, the magnesium is eventually replaced by hydrogen. When replacement reaches the point that saturation by magnesium and sodium is less than 50 percent of the exchange capacity, the horizon is no longer considered natric. One sees relicts of such horizons, with their form clearly evident but with all other properties altered because of great changes in the environment.

Some examples may help clarify the criteria for the natric horizon. Data for three profiles from North Dakota and South Dakota are given in table 12. All were developed under grass, have distinct prismatic or columnar argillic horizons, and have been considered by some soil scientists as solodized-Solonetz.

The first profile (17) has a natric horizon because the exchangeable sodium exceeds 15 percent of the exchange capacity. The second profile (18), from Sargent County, North Dakota, has a natric horizon because the magnesium and sodium exceed calcium (exchangeable hydrogen is very small in the montmorillonite clay of this soil) and because exchangeable sodium exceeds 15 percent of exchange capacity in the two lowest horizons. The third profile (19) has an argillic horizon, but not a natric horizon, because exchangeable sodium is less than 15 percent, and exchangeable calcium exceeds the sum of magnesium and sodium. In this last profile it is impossible to be sure that there was ever any significant amount of sodium. It should be noted that in this profile the B, or argillic horizon, has prismatic rather than columnar structure.

Spodic Horizon

The spodic horizon is an illuvial accumulation of free sesquioxides accompanied by appreciable amounts of organic carbon, an illuvial accumulation of free iron not accompanied by roughly equivalent amounts

TABLE 12.--Selected Properties of Soils with Natric and Argillic Horizons

Area	Horizon	Depth	pH (paste)	Clay	Extractable cations: Ca	Mg	Na	Exchange-able Na	$CaCO_3$
		Inches		Pct.				Pct.	Pct.
Profile 17									
Perkins Co., S. Dak.	A1	0-3	6.1	12.9	6.0	2.8	0.1	1	---
	A2	3-6	5.6	15.6	5.0	3.6	.9	7	---
	B21t	6-9	1/<u>7.1</u>	<u>44.3</u>	<u>16.7</u>	<u>13.8</u>	<u>5.4</u>	<u>15</u>	<u>1</u>
	B22t	9-11½	<u>7.8</u>	<u>37.7</u>	<u>25.2</u>	<u>13.2</u>	<u>5.4</u>	<u>18</u>	---
	B23tca	11½-15	8.1	28.5	---	---	3.9	17	4
	B3tca	15-21	7.7	20.8	---	---	2.7	13	2
Profile 18									
Sargent Co., N. Dak.	A1	0-6	7.2	26.0	17.5	8.3	0.2	1	---
	B21t	6-10	1/<u>7.4</u>	<u>30.3</u>	<u>11.0</u>	<u>12.3</u>	<u>1.1</u>	<u>5</u>	---
	B22t	10-17	<u>7.9</u>	<u>30.2</u>	<u>16.9</u>	<u>13.3</u>	<u>2.1</u>	<u>10</u>	<u>3</u>
	B3tca	17-24	8.2	39.3	---	---	2.3	16	26
	II C1	24-30	8.3	19.5	---	---	1.6	20	22
Profile 19									
Sargent Co., N. Dak.	Ap	0-6	6.6	29.8	20.8	7.4	0.1	---	---
	A2	6-11	6.0	23.6	10.7	5.1	.1	1	---
	B2t	11-19	2/<u>5.7</u>	<u>40.6</u>	<u>15.8</u>	<u>11.0</u>	<u>.1</u>	---	---
	B2t	19-27	<u>6.2</u>	<u>37.2</u>	<u>16.8</u>	<u>10.9</u>	<u>.2</u>	<u>1</u>	---
	B3	27-34	7.7	30.3	---	---	.1	1	6
	C1	34-45	7.8	27.8	---	---	.1	1	11

1/ Natric horizon data are underscored.

2/ Argillic horizon data are underscored.

of illuvial crystalline clay, or an illuvial accumulation of organic carbon usually if not always accompanied by an accumulation of aluminum combined in some form other than that of the crystalline silicate clays. It should be noted that aluminum is usually present in a form that meets the definition of allophane. The spodic horizon usually forms below an eluvial A horizon, though at times the A horizon is so thin, less than one-eighth inch, that the illuvial sesquioxides in the spodic horizon must have come in large part from some other source, perhaps from the leaf litter. The spodic horizon can occur at the surface, either as a result of soil truncation or of mixing of the surface by natural agents or by man.

The typical spodic horizon is easily recognized in the field because the lowest values, reddest hues, or strongest chromas occur in the upper part of the horizon. In addition, it shows rounded to subangular black or very dark brown pellets of silt size, usually between 20 and 50 microns in diameter. These are not visible to the naked eye, but they can be seen with a 40- to 60-power hand lens. The appearance of these pellets in a thin section is shown in figure 14.

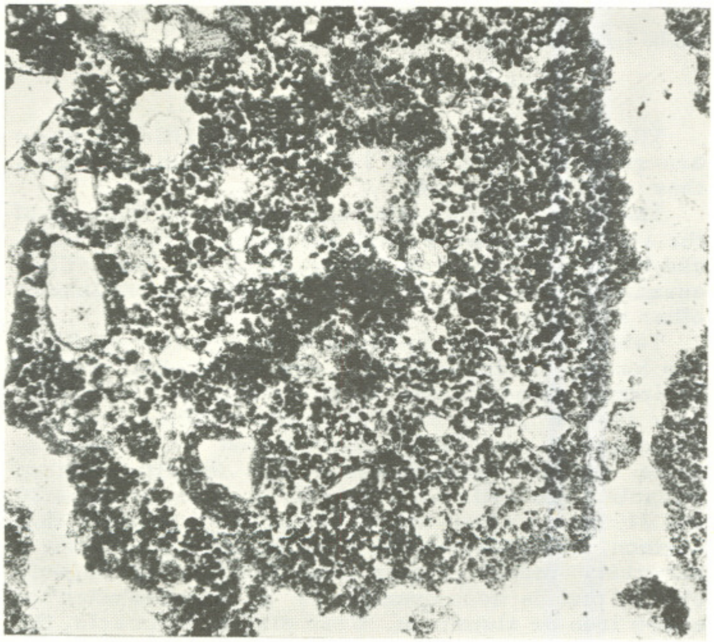
Some spodic horizons (ortsteins) are cemented by coatings of humus and sesquioxides. In these the pellets are not conspicuous under a hand lens, though they may be seen in thin sections. Figure 15 shows the appearance of a cemented spodic horizon in a thin section.

Rarely, there is a spodic horizon that shows few or no pellets and is not cemented. In this kind of spodic horizon the content of organic matter is very low but the content of free oxides is high.

Clay skins apparently are not found in spodic horizons, nor is a moderate or strong grade of blocky structure.

If a distinct, bleached eluvial horizon (albic horizon) overlies the spodic horizon, it is common, but not necessary, to find a second maximum of organic carbon in the spodic horizon. However, the presence of organic carbon in association with the free sesquioxides is a very common characteristic of the spodic horizon. It is the organic carbon and the pellets that distinguish an ortstein from the ironstone layers often found at lithologic discontinuities in deep layers below many soils. It should be pointed out that spodic horizons may occur at depths of more than 2 meters in some tropical and subtropical areas, and that buried spodic horizons can be found at even greater depths. Figure 16 shows a profile having a spodic horizon underlying an eluvial A2 horizon.

Horizons of sesquioxide and humus accumulation may be found in all degrees of development, ranging from a few millimeters to a meter or more in thickness, and with accumulations ranging from limits not detectable by ordinary laboratory methods to rather extreme concentrations. It seems essential to set some lower limits on the contents of organic carbon or free sesquioxides. These limits are set tentatively at 0.29 percent organic carbon (one-half percent organic matter) and 1 percent free sesquioxides. Horizons of accumulation with less than both this amount of organic carbon and this amount of free sesquioxides (one and the other) are not considered spodic horizons, though they may be recognizable as weakly developed B horizons. Similarly, horizons are

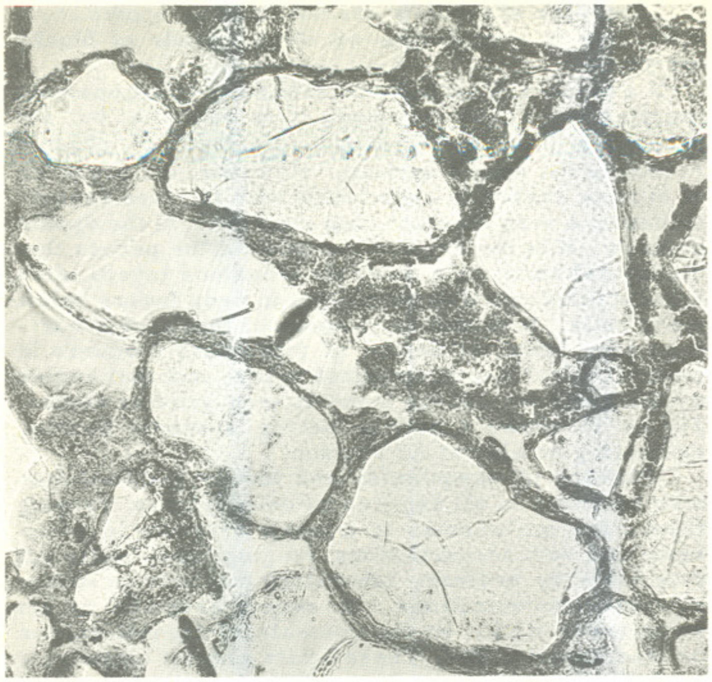


A, Thin section viewed under plain light. The fine pellets, 20 to 50 microns in diameter, are typical of spodic horizons. Some of the pellets have silt or clay particles as nuclei, but most of them do not. The ped periphery shows evidence of degradation, possibly the result of infringement of an albic horizon.

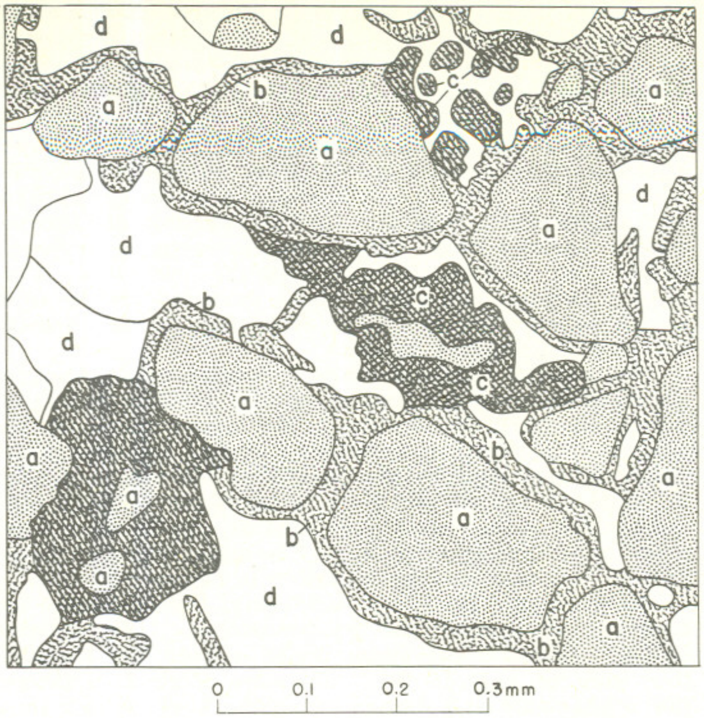
B, Diagram of thin section:

a Pellets
b Sand grains larger than very fine sand
c Small, diffuse pores within weakly developed structural units (weak, fine crumbs)
d Large pores between structural units

Figure 14.–Thin section of a spodic horizon with crumb structure.



A, Thin section viewed under plain light. Bridges between mineral grains, formed by connecting sesquioxide-organic matter coatings, are responsible for the hardness of the horizon. Cracked coatings (upper part of micrograph) seem to be first phase in the disintegration of ortstein.



B, Diagram of thin section
a Mineral grains (quartz)
b Coatings of organic matter and sesquioxides seen in cross section
c Coatings of organic matter and sesquioxides seen in sections parallel to grain surfaces
d Pores

Figure 15.–Thin section of a spodic horizon (ortstein).

not considered spodic horizons if they are so thin, are so near the surface, and are so weakly expressed that the cutting of a forest and plowing a few times to a depth of 6 to 7 inches obliterates all traces. A thin horizon of accumulation is considered a spodic horizon if, after plowing and mixing of the surface horizons to a depth of 6 to 7 inches, it is still possible to demonstrate a higher iron content than in the underlying horizons, to determine the presence of humus and sesquioxide pellets, or to recognize in the field or in thin sections the fragments of the spodic horizon.

Spodic horizons normally have little or no more crystalline clay than the overlying and underlying horizons. However, allophane is often if not always present, and mechanical analyses by the methods used for soils having crystalline clays are not always reliable. The clay that is present does not form well oriented coatings or clay skins.

It is common in argillic horizons to find a maximum of free iron oxides, and if the argillic horizon is strongly developed, a secondary maximum of organic carbon may coincide with the clay maximum. Normally such horizons are clearly distinguished from the spodic horizons by a blocky structure, crystalline clays, and an abundance of clay skins. The clear differences between spodic and argillic horizons in thin sections may be seen by comparing figures 6 and 14.

The accessory characteristics of the argillic and spodic horizons will help in the identification of horizons that are intermediate in the more common definitive characteristics.

The carbon-nitrogen ratios in argillic horizons are generally less than 14, but in spodic horizons they usually exceed 14.

The silica-sesquioxide ratio of the clay fraction of the argillic horizon is about the same as that of the A and the C. In spodic horizons, however, the silica-sesquioxide ratio of the clay fraction is lower than in other horizons.

Table 13 includes selected data from four profiles, two having spodic horizons, and two having argillic horizons. Descriptions of the profiles and additional data are on pages 85 to 88. All profiles have the bleached A2, or albic, horizons that were used in some earlier classifications for identification of Podzols. The soils with a spodic horizon, profiles 20 and 21, have a small accumulation of allophane in that horizon, as measured by alkaline dispersion, but a relatively much greater accumulation of organic carbon that is accompanied by an accumulation of either iron or aluminum. When dispersed in acid, the spodic horizons may show large clay accumulations. The spodic horizon of profile 20, from 4-1/2 to 23 inches, has approximately 14 percent clay that will disperse in acid. The spodic horizon of profile 21 has less than 1 percent clay that will disperse in acid.

The two profiles with an argillic horizon, profiles 22 and 23, show a large accumulation of crystalline clay in those horizons, with clay contents roughly proportional to the free iron oxides. A slight accumulation of nitrogen in the argillic horizons is suggested by the data, but carbon-nitrogen ratios are narrow compared to those of the spodic horizons.

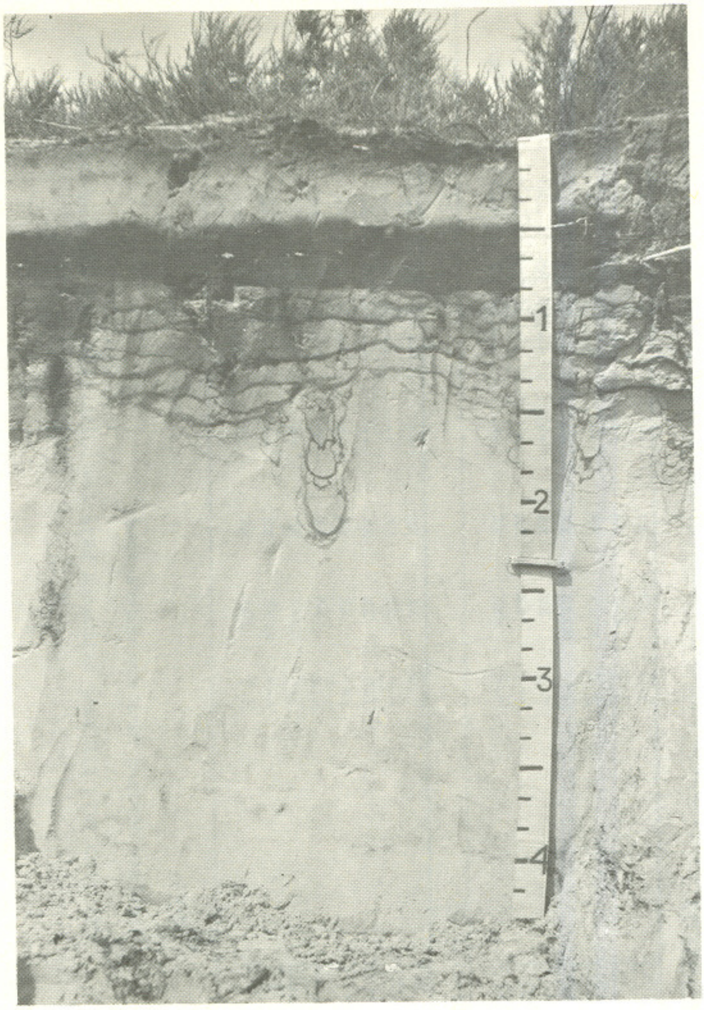


Figure 16.–Profile of a Humus Podzol showing a spodic horizon under an eluvial A2 horizon (albic horizon).

The properties of the clay fractions show more marked differences. The clays of the spodic horizon are largely amorphous and have a high loss on ignition, compared to the loss for all other horizons. The silica-sesquioxide ratios of the clays in the spodic horizon of these profiles differ greatly from those in their A2 horizon and are lower than in the C.

The clays in these profiles with an argillic horizon have more variability in their silica-sesquioxide ratios than is found in some soils with an argillic horizon (see table 10). Nevertheless, there is little variability detectable by x-ray and DTA analyses in the clays of the soils with argillic horizons. The clays in the argillic horizons have essentially the same loss on ignition as the clays in the A and C.

It should be pointed out that some soils have both a spodic horizon and an argillic horizon. Often these two are separated by an eluvial horizon. In some soils, particularly those with very low base saturation in the argillic horizon, the spodic horizon may rest directly on the argillic horizon, and may tongue into it along ped faces and thus make it difficult to sample the two horizons separately.

In summary, a spodic horizon is one which shows the following properties:

1. Amorphous coatings of humus and allophane or of humus, allophane, and free sesquioxides on particles of sand or silt; or rounded to subangular pellets of humus or of humus and sesquioxides between 20 and 50 microns in diameter; or both.

2. More than 0.29 percent organic carbon or 1 percent free sesquioxides in some part.

3. No clay skins; under crossed polarizers coatings in thin sections show slight or no birefringence and no extinction on rotation, which indicates substance forming the coatings are not both crystalline and oriented.

4. No structure; or structure other than blocklike; or blocklike structure only if the grade of structure is weak.

5. Carbon-nitrogen ratios of more than 14, if profile is virgin.

6. SiO_2/R_2O_3 ratio in clay fraction less than that in clay fraction of overlying A2 or albic horizon and less than that in clay fraction of parent material.

Cambic Horizon

The cambic horizon (L.L. cambiare, to change) is conceived to be a changed or altered horizon. Soil-forming processes have changed or altered the material enough to form structure if the texture is suitable; to liberate free iron oxides, form silicate clays, or both, and to obliterate most evidences of the original rock structure. The cambic horizon has not been altered enough to completely destroy volcanic glass, allophane, feldspars, micas, or similar weathered materials, nor has illuviation of iron oxides, humus, or clay reached a point that will permit classification of the horizon as argillic or spodic. The cambic horizon may be at the surface if a soil has been truncated. Otherwise, it is immediately below one of the diagnostic epipedons. It is considered a part of the solum and occurs within the zone normally reached by the roots of native plants. Thus, it lies in the position of a B horizon, and by many it is considered to be a B horizon. The concept appears much the same as that of the (B) of Laatsch.[5]

Below many B horizons (usually argillic and spodic horizons) there is a transition to the C in which there has been weathering and alteration. Free iron oxides may have been liberated in this horizon to much the same extent as in the cambic horizon. Yet, because there is an overlying argillic or spodic horizon, a transitional horizon of this kind is not considered a cambic horizon. Rather, it is considered a transition to the C horizon. This distinction, which may seem very fine, is primarily one of position; the cambic horizon occupies the position of a B horizon, between A and C, and not the position of a transition between a spodic or argillic horizon and the C.

Under the concept just explained, the cambic horizon may have more free iron, but little if any more total iron, than a underlying IC.[6] Ordinarily, it has less total iron than does the C.

Because considerable time is required for the partial destruction of iron-bearing minerals or the formation of clay, the cambic horizon in clayey and loamy materials normally has time to develop a granular, blocky, or prismatic structure.

[5]Laatsch, W. Dynamik der deutschen Aker-und Waldböden Steinkopff, Dresden.

[6]IC is used for C horizons presumed to be similar to the material from which the solum has developed, in contrast to IIC, material unlike that from which the solum developed. (See horizon designations.)

TABLE 13.--Chemical and Mineralogical Analyses of Soils with Spodic and Argillic Horizons

Depth	Whole soil (<2 mm.) Clay	Organic carbon	C/N	SiO_2 h	Al_2O_3 h	Fe_2O_3 h	Free Fe_2O_3	SiO_2/R_2O_3	Clay fraction SiO_2/R_2O_3 h	Mt	Mi	Vm	Chl	K	Gb	Loss on ignition
Inches	Pct.	Pct.		Pct.	Pct.	Pct.	Pct.									Pct.
								Profile 20								
0-1½	3.5	1.67	18	62.1	15.7	4.6	0.4	5.7	6.2	xx	--	--	--	5	--	7.6
1½-4½	1/ 4.1	2.71	27	54.6	19.7	5.5	1.2	4.0	1.6	--	--	--	--	(2/)	--	13.7
4½-13	5.1	2.31	20	56.7	20.1	5.6	1.6	4.1	1.1	--	--	x	--	(2/)	(3/)	18.2
13-23	4.8	1.71	18	59.0	19.2	5.5	1.8	4.4	1.1	--	--	--	--	(2/)	3	16.7
23-36	2.6	.66	18	64.1	15.5	5.9	.6	5.6		--	x	x	--	--	(3/)	--
36-48	2.3	.38	13	66.9	15.5	5.8	.4	5.9	1.7	--	--	x	--	--	(3/)	11.5
								Profile 21								
0-3	0.5	1.12	29	97.0	0.2	0.1	<0.1	621	---	--	--	--	--	--	--	---
3-16	.4	.03	--	99.8	.1	.1	< .1	1040	42.3	--	--	--	--	--	--	3.6
16-17	2.7	1.05	30	96.6	.4	.1	.1	357	---	--	--	--	--	--	--	---
17-18	1/ 4.6	2.54	69	92.3	2.1	.3	.1	68	2.6	--	--	--	--	(2/)	--	33.2
18-20	4.2	1.10	38	94.6	1.6	.2	< .1	93	2.7	--	--	x	--	(2/)	--	26.9
20-27	1.7	.10	--	97.6	.6	.2	< .1	226	3.3	--	--	xx	--	--	--	11.2
27-39	.7	.02	--	----	---	---	< .1	---	---	--	--	--	--	--	--	----
39-44	4.7	.07	--	----	---	---	.2	---	---	--	--	--	--	--	--	----
								Profile 22								
0-5	9.0	0.47	12	79.2	11.2	1.8	0.5	10.9	3.8	xx	xx	--	--	5/ 10	--	7.0
5-10	4/ 29.2	.38	8	73.0	13.5	4.0	1.0	7.7	3.2	xxx	xx	--	--	5/ 10	--	7.5
10-15	29.5	.30	6	72.2	12.8	4.2	1.0	7.9	3.2	xxxx	xx	--	--	5/ 10	--	7.3
15-23	13.4	.23	10	79.6	10.8	2.8	.8	10.7	---	xxxx	xx	--	--	5/ 10	--	---
23-29	8.8	.10		70.8	8.2	1.9	.5	12.8	4.7	xx	xx	--	--	5/ 10	--	6.1
29-45	9.2	.14	--	67.7	7.8	1.9	.5	12.7	---	xx	xx	--	--	5/ 10	--	---
45-55	10.1	.08	--	67.5	8.9	2.1	.4	11.2	4.2	xxx	xx	--	--	5/ 10	--	6.4
								Profile 23								
0-5	28.8	2.1	14	73.4	11.4	2.9	0.6	9.4	4.0	xx	xx	--	--	5/ 10	--	7.5
5-10	25.3	.7	12	76.7	11.3	2.5	.5	10.1	---	xxx	xx	--	--	5/ 10	--	---
10-17	19.7	.5	11	80.9	10.2	2.0	.4	12.0	4.4	xx	xx	--	--	5/ 10	--	7.0
17-22	16.8	.3	10	79.7	9.8	2.0	.4	12.2	---	xx	xx	--	--	5/ 10	--	---
22-31	4/ 31.1	.3	5	74.4	12.7	3.3	.4	8.5	3.5	xxx	xx	--	--	5/ 10	--	7.7
31-45	34.5	.3	7	72.5	14.0	3.6	.4	7.6	3.2	xxxx	xx	--	--	5/ 10	--	8.1
45-55	27.5	.2	--	73.5	12.4	3.1	.4	8.7	---	xxxx	xx	--	--	5/ 10	--	---
55-62	27.1	.3	8	72.4	12.1	3.5	.4	8.6	3.5	xxx	xx	--	--	5/ 10	--	7.7

1/ Spodic horizon data are underscored.

2/ DTA pattern shows strong endothermic peak at about 180°C., and this is attributed to allophane-like material.

3/ Trace.

4/ Argillic horizon data are underscored.

5/ DTA peak very diffuse; estimates have low reliability and are probably too high.

Since illuviation is negligible, the peds lack distinctive coatings and generally are weakly developed. Preferred alignment of plate-shaped particles parallel to the ped face can be demonstrated in thin sections (fig. 9) on smooth ped faces. If textures are too coarse to permit volume changes with wetting and drying, the cambic horizon may remain structureless. In soils of very high base status, the weak blocky structure of many cambic horizons may be absent and the soil fauna may have produced a granular or crumb structure.

The micro-fabric (fig. 9) of the cambic horizon resembles that of the argillic horizon in having random orientation of individual particles and little pore space in the maxtrix. It differs from an argillic horizon in lacking clay skins that are of distinctly finer material than the matrix. Under crossed polarizers, the birefringent faces of peds in a cambic horizon indicate a preferred orientation of particles. Although the ped faces show evidence of preferred alignment of plate-shaped particles, they differ from clay skins in that the particles are less perfectly arranged and are similar or identical to the ped interiors in particle size distribution.

Coarse textured materials, sands, and loamy sands coarser than loamy very fine sand, are excluded from cambic horizons. This is admittedly arbitrary, since sands can be altered by weathering. Nevertheless, recognition of alteration in sands is much more difficult. Normally structure cannot form. Decisions that a given sand does or does not show alteration are also apt to be arbitrary and inconsistent among different soil scientists. It was decided therefore to test a grouping into a single order of those sands and loamy sands that do not show the more easily defined diagnostic horizons. The mollic, umbric, and plaggen epipedons, and the argillic and spodic horizons all may occur in sands, and are used to place soils into appropriate groups. Cambic and, as discussed later, oxic horizons, are not to be recognized in sands, or in loamy sands coarser than loamy very fine sand.

Cambic horizons may form in the presence or absence of fluctuating ground water. If ground water is present in the horizon at some season, the free iron is generally partially removed from the individual particles of sand, silt and clay and is either lost from the horizon or is concentrated in the form of concretions or mottles. Mottling or gleying alone is not an evidence of alteration adequate for identification of a cambic horizon. One must find other evidences of alteration. Chemical weathering to form clay or to partially destroy weatherable minerals is difficult to recognize in the field. The presence of soil structure, the absence of rock structure, and evidences of leaching or of redistribution of carbonates may be recognized in the field and used where applicable for identification.

In the absence of ground water, cambic horizons normally have brownish colors; the chroma, because of liberation of free iron oxides, commonly is stronger or the hue redder in the cambic horizon than in the C. Feldspar minerals, and such easily weatherable minerals as glass, biotite, some pyroxenes, and some amphiboles, are all partly weathered; mica, if it is present, is at least partly weathered to 2:1 lattice clay. The minerals, however, have not been completely destroyed in a cambic horizon.

The hydrated oxide of iron removed from primary minerals may have formed coatings on individual soil particles and is considered to be responsible for the color of the horizon if it is brown or red. The free iron/clay ratio is constant among subhorizons of the cambic horizon.

The cambic horizon, however, may or may not contain more free iron than the material from which it was derived. The cambic horizon may have lost some iron, and furthermore, many soil parent materials, especially those derived from sedimentary rocks, contain amorphous forms of iron-bearing minerals that analytically, can not be distinguished from free iron-oxide coatings on soil particles.

The cambic horizon does not have the high content of organic matter and the dark colors definitive for mollic or umbric epipedons; it does not have the properties diagnostic for argillic or spodic horizons, nor does it have the cemented or brittle properties definitive of duripans and fragipans that will be given further on in this chapter.

The cambic horizon differs from the spodic horizon in lacking an accumulation of sesquioxides, in having a uniform silica-sesquioxide ratio in the clay fraction; and, if the clay fraction is not allophane, in having a relatively small loss on ignition. It also lacks the pellets diagnostic of spodic horizons.

Since cambic horizons grade imperceptibly to argillic and spodic horizons, some examples may help clarify the distinction between them.

Table 14 contains selected data on three profiles that have cambic horizons. In profile 24, the cambic horizon overlies a lower sequum containing an eluvial horizon and a fragipan. The profile description, profile No. 24, is on page 89. It will be noted that the cambic horizon, from 2 to 16 inches, contains more free iron but less total iron and less "lattice" iron than the underlying horizons. Lattice iron is not an entirely correct name, for it includes magnetite. Clay mineral analyses show some weathering of micas and chlorite to vermiculite. The cambic horizon in this profile has appreciably more clay than the overlying A2 or the underlying eluvial horizon, A'2. It could therefore be confused with an argillic horizon. This is an extreme example. More commonly the cambic horizon either has less clay or has at the most 2 or 3 percent more clay than the A. There are, however, no evidences of significant clay illuviation in profile 24. Clay skins are so few and so thin that they are not seen by field examination. Thin sections show the presence of a very few very small clay skins in pores. The total analyses indicate the clay has been largely formed in place, for the B is intermediate in its silica-sesquioxide ratio between the A and C. Both spodic and argillic horizons (table 13) have the minimum silica-sesquioxide ratio, on the basis of the fraction less than 2 mm. for the profiles in which they occur.

Profile 33 is a soil with a mollic epipedon above the cambic horizon. The data suggest the beginning of an argillic horizon, from 9 to 15 inches, in the mollic epipedon. The cambic horizon, from 15 to 34 inches shows no evidence of being an illuvial horizon, but does show evidences of formation of clay, as the clay content decreases steadily with depth.

Profile 34 is a soil with an ochric epipedon and a cambic horizon. The cambic horizon, from 2 to 13 inches, shows loss of both iron and aluminum, but no evidence of illuviation.

All these profiles, 24, 33, and 34, have significant amounts of weatherable minerals in the silt and sand fractions. Evidence may be seen in the appreciable contents of K_2O in all profiles, and the CaO in profiles 24 and 33.

In summary, a cambic horizon is one that contains feldspars, micas, or other weatherable minerals;

TABLE 14.--Chemical and Mineralogical Analyses of Soils with Cambic Horizons

Depth	Clay	Organic carbon	C/N	K_2O h	CaO h	SiO_2 h	Al_2O_3 h	Fe_2O_3 h	Free Fe_2O_3	"Lattice" Fe_2O_3	SiO_2/R_2O_3	SiO_2/R_2O_3 h	K_2O h	CaO h	Mt	Mi	Vm	Chl	K 1/	Gb	Loss on ignition
	Whole soil (<2 mm.)											Clay fraction									
Inches	Pct.	Pct.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.			Pct.	Pct.							Pct.
										Profile 24											
1/2-3/4	9.8	7.6	27	2.0	0.2	72.2	8.6	2.2	1.5	0.7	12.2	3.2	4.0	<0.2	--	xx	x	--	--	--	13.0
3/4-1	14.2	3.01	20	--		--	--	--	1.6	--	--	--	--	--	--	xx	xx	--	5	--	--
1-2	15.6	1.30	14	2.1	.2	78.4	8.8	2.7	1.5	1.2	12.6	2.7	4.0	<.2	--	xx	xx	--	5	--	9.0
2-16	2/ 23.7	.92	10	2.4	.2	73.9	12.5	4.8	2.4	2.4	8.1	2.1	3.6	<.2	--	xx	xxx	--	5	--	10.0
16-24	13.3	.26	5	2.6	.2	72.9	13.6	5.0	1.3	3.7	7.4	2.3	4.6	<.2	--	xxx	xx	x	5	--	8.4
24-34	19.6	.24	--	3.0	.2	70.1	14.1	5.5	1.6	3.9	6.8	2.3	5.1	<.2	--	xxx	xx	x	5	--	7.2
34-42	20.2	.14	--	3.0	.3	69.5	14.2	5.7	1.8	3.9	6.6	--	--	--	--	xxxx	xx	x	5	--	6.8
42-52	24.1	.19	--	3.2	.4	68.2	15.2	6.0	1.8	4.2	6.1	2.2	4.9	<.2	--	xxxx	xx	x	5	--	6.8
										Profile 33											
0-2 1/2	22.9	4.58	15	1.6	1.5	71.3	9.5	2.6	1.0	1.6	10.8	--	--	--	--	xx	xx	xx	5	--	--
2 1/2-9	23.1	2.38	12	1.7	1.3	73.3	10.0	3.0	1.0	2.0	10.4	3.2	1.9	0.2	--	xx	xx	x	5	--	8.0
9-15	24.3	1.29	11	1.7	1.0	74.5	10.9	3.5	1.1	2.4	9.6	3.2	1.6	.1	--	xx	xx	x	5	--	7.7
15-23	2/ 23.4	.59	9	1.8	1.1	77.6	10.7	3.7	1.4	2.3	10.1	3.5	1.7	.1	xxxx	x	--	x	5	--	7.1
23-28	19.4	.35	8	1.7	1.1	77.8	9.9	3.5	1.3	2.2	10.9	--	--	--	xxx	x	--	x	5	--	--
28-34	16.9	.27	8	1.7	1.2	75.9	9.7	3.3	1.2	2.1	10.9	4.1	1.8	.2	xxx	x	--	x	5	--	6.3
34-37	14.6	.23	--	1.6	2.7	75.3	9.3	3.0	1.0	2.0	11.4	3.9	1.7	.4	xxxx	x	--	x	5	--	7.5
										Profile 34											
0-2	16.0	5.48	22	1.2	0.3	69.2	9.6	4.3	2.3	2.0	9.5	2.1	2.4	<0.1	--	x	xxx	--	10	--	11.2
2-7	2/ 18.2	1.13	16	1.4	<.1	73.6	11.4	4.3	2.6	1.7	8.8	2.1	2.8	<.1	--	x	xxx	--	15	--	9.0
7-13	23.2	.33	7	2.3	<.1	68.3	15.5	5.8	3.2	2.6	6.0	2.2	3.7	<.1	--	xx	xx	--	10	--	8.0
13-23	20.2	.14	--	2.5	<.1	64.5	16.1	7.1	4.0	3.1	5.3	2.2	4.0	<.1	--	xxx	xx	--	20	--	7.4

1/ DTA peak very diffuse; estimates have low reliability and are probably too high.

2/ Cambic horizon data are underscored.

shows little of the original rock structure; has structure if the texture permits volume changes on wetting and drying; and shows other evidences of alteration--formation of clay, loss of "combined" or lattice iron, or redistribution of carbonates. It cannot have all of the properties diagnostic for a mollic or umbric epipedon, an argillic or spodic horizon, or a duripan or fragipan, nor can it have textures coarser than loamy very fine sand.

Oxic Horizon

The concept of the oxic horizon presented here is very tentative, as it has had little testing. The limits used may need to be modified considerably or some may be dropped. The oxic horizon is one from which weathering has at some time removed or altered a large part of the silica that is combined with iron and aluminum, but not necessarily the quartz or 1:1 lattice clays. The result of the weathering is concentration of clay-size minerals consisting of sesquioxides mixed with varying amounts of silicate clays having a 1:1 lattice. The clays rarely can be completely dispersed by normal laboratory methods. Among the evidences of this resistance to dispersion is the lack of relationships among data on the determined clay percentages and exchange capacities, on free iron, and on moisture tension.[7] Textures usually are dominated by the sand and clay fractions, and there is very low content of primary silt particles. Primary minerals--quartz or crystalline grains other than free sesquioxides and kaolinite--between 2 and 20 microns in size ordinarily account for less than one-tenth of the total clay fraction, and this clay fraction includes the bulk of the silt and clay reported here in the laboratory analyses. The horizon is porous and structureless, or has weak blocky structure. Coatings and pore fillings of 1:1 lattice silicate clays and sesquioxides may be present or absent. The content of free sesquioxides is high, usually more than 12 percent of the total clay fraction. The boundary of the oxic horizon with the overlying horizon that is darkened by organic matter is clear or diffuse if not plowed, and the boundary with the horizon below is normally diffuse. Micas, feldspars, ferro-magnesian minerals, and glass are absent. Allophane and 2:1 lattice clays are normally absent, but if they are present, the amounts are small.

The oxic horizon often contains more clay than the overlying horizon, particularly if quartz sand is abundant, but the increase in the content of clay with depth is so gradual that comparisons made at depth intervals of less than 12 inches normally show differences smaller than those required for an argillic horizon. The reasons for lower clay content in the overlying surface horizons are obscure. They have been attributed to destruction of clay by weathering, and to differential movement of the clay to the surface by termites, ants, and small animals, with subsequent loss in water running off the surface. But clay skins are sometimes present in an oxic horizon, and this indicates movement of clay. It should be pointed out that an oxic horizon may occur in the same profile with an argillic horizon, and that an oxic horizon may contain an argillic horizon.

Oxic horizons are very common in transported sediments. A great many of them are underlain by stone lines. Where no constituent of the parent rock can form a stone line, it is common to find that there is no evidence of the original rock structure in thin sections.

Colors of oxic horizons may vary widely. In soils with fluctuating water tables, the iron and manganese may have been lost and gibbsite and kaolin left as the main components of the clay. Such oxic horizons may be gray to white. Oxic horizons formed from basic igneous rocks under free drainage tend to have dark-red to dark-brown colors, but those that formed from more acid rocks vary widely in hue and tend to have strong chromas and moist values of 5 to 6. Color therefore is not diagnostic of oxic horizons.

Profile 27, page 92, illustrates a soil with a very strongly weathered oxic horizon. The oxic horizon extends from about 18 inches to about 70 inches. This soil has been called Nipe clay. No pores were described when the profile was sampled, but this is presumed to be an oversight, as other descriptions of the same series mention the pores.

In the lower horizons the pH in a solution of KCl is higher than the pH in water. This influence is thought to be due to a net or excess positive charge in these horizons. The net positive charge has been demonstrated by electrophoretic measurements. This difference of pH is characteristic of very strongly weathered oxic horizons, but not of all oxic horizons. The content of both silt and of clay is high. The high silt content recorded here indicates incomplete dispersion, not the actual amount of primary mineral grains that are of silt size, for thin sections of this profile show very few crystals of silt size.

Profile 28, page 93, illustrates a soil with an oxic horizon from a depth of about 7 inches down to 28 inches. This has a negative charge, and pH values in a solution KCl are lower than in water. The data show large amounts of silt. Some of this silt is probably kaolinite. But, the reported percentages of clay are not in accord with the water held at 15 atmospheres nor in accord with the exchange capacities, and this indicates incomplete dispersion.

Chemical and mineralogical analyses of these profiles are summarized in table 15. It will be noted that the horizons in profile 27 that have higher pH values in KCl than in water also have extremely low silica-sesquioxide ratios.

The resistance of its clays to dispersion seems to be one of the properties most definitive of an oxic horizon, but it should be noted that allophane produces similar problems of dispersion. It seems likely that the resistance of the clays to dispersion is the result of mutual attraction of negatively charged 1:1 lattice clay and positively charged free sesquioxides. Since the clays cannot be readily dispersed in the laboratory, it is not surprising that they do not seem to move readily in the soil. Commonly, the peds in an oxic horizon exhibit no clay skins or have only a small part of their surfaces covered with translocated clays. The same property that inhibits dispersion may contribute to the notable resistance of oxic horizons to erosion. Unless the content of sand is very great, roadbanks and cuts in oxic horizons remain vertical for many years without significant erosion or sloughing.

Figure 17 shows a highway cut through oxic horizons on the island of Kauai in Hawaii. The surface of the cut has formed a thin, very slightly hardened crust that may contribute to the stability.

Because the clays of oxic horizons are dominantly kaolinite and oxides, the cation-exchange capacities are low, normally less than 20 milliequivalents per

[7]The nondispersed clay most commonly shows up in the fine silt fraction after mechanical analysis.

TABLE 15.--Chemical and Mineralogical Analyses of soils with Oxic Horizons

Profile 27

			Whole soil (less than 2 mm.)								Clay Fraction							
Depth	Organic carbon	C/N	SiO_2 h	Al_2O_3 h	Fe_2O_3 h	Free Fe_2O_3	SiO_2/R_2O_3	K_2O 1/	CaO 1/	Loss on ignition	G 2/	Mt	Mi	Vm	Chl	K	Gb	Q 2/
Inches			Pct.	Pct.	Pct.	Pct.		Pct.	Pct.									
0-11	6.34	17	23.7	25.3	29.7	15.3	0.91	0.1	0.1	16.8	x	--	--	--	--	10	20	xx
11-18	2.04	18	21.1	27.8	30.2	14.3	.76	.2	<.1	15.2	x	--	--	--	--	15	20	xx
18-28	3/ 1.33	17	----	----	----	17.5	--	--	--	----	xx	--	--	--	--	15	15	xx
28-38	.86	--	14.4	29.0	36.2	20.4	.47	.1	<.1	16.0	xx	--	--	--	--	15	15	x
38-48	.72	--	----	----	----	21.5	--	--	--	----	xx	--	--	--	--	20	20	x
48-62	.56	--	10.0	25.6	44.1	22.8	.31	<.1	<.1	15.8	xx	--	--	--	--	15	25	--
62-70+	.19	--	4.8	26.8	51.7	28.4	.14	<.1	<.1	16.1	xxx	--	--	--	--	5	40	--

Profile 28

			Whole soil (less than 2 mm.)								Clay Fraction							
Depth	Organic carbon	C/N	SiO_2 h	Al_2O_3 h	Fe_2O_3 h	Free Fe_2O_3	SiO_2/R_2O_3	SiO_2/R_2O_3	K_2O 1/	CaO 1/	G	Mt	Mi	Vm	Chl	K	Gb	Loss on ignition
Inches			Pct.	Pct.	Pct.	Pct.			Pct.	Pct.								
0-4	5.16	16	45.9	20.3	13.5	6.8	2.7	1.5	<0.3	0.1	--	--	--	--	--	45	--	13.0
4-7	3.05	11	45.7	22.3	15.5	9.4	2.4	1.5	<.3	.1	--	--	--	--	--	40	--	13.0
7-14	3/ .59	14	45.3	27.4	12.5	10.7	2.2	1.6	<.3	<.1	--	--	--	--	--	45	--	12.8
14-19	.53	12	39.8	29.5	13.5	11.0	1.8	1.5	<.3	<.1	--	--	--	--	--	60	--	13.7
19-28	.25	12	43.1	29.1	13.0	10.6	2.0	1.4	<.3	<.1	--	--	--	--	--	65	--	13.5
28-34	.13	--	42.0	30.5	11.6	7.9	1.9	1.6	<.3	<.1	--	--	--	--	--	60	--	13.9
34-44	.16	--	46.3	26.8	10.2	8.0	2.4	1.6	<.3	.1	--	--	--	--	--	65	--	13.6

1/ Approximate figure, estimated by spectrographic analysis.

2/ Goethite and quartz are estimated from powder patterns.

3/ Oxic horizon data are underscored.

100 grams of clay. The cation-exchange capacity per 100 grams of clay is difficult to compute because the amount of clay is not known precisely. It is known, however, from examination of thin sections and from other evidences, that primary silt particles are few, so that the sum of the silt and the clay approximates the clay percentage. Exchange capacities measured by the NH_4OAC method approximate 7 to 12 milliequivalents per 100 grams of clay, and as measured by the sum of extractable cations, the exchange capacities are approximately 14 to 25 milliequivalents per 100 grams of clay.

The oxic horizon can conceivably include an argillic horizon consisting of 1:1 lattice clay and free oxides. The oxic and the argillic horizons are not necessarily mutually exclusive, though additional studies are needed to be sure that some oxic horizons do contain significant amounts of translocated kaolin.

At times it may be difficult to distinguish the oxic horizon from a cambic horizon, and from C or parent material. The clearest distinction between an oxic horizon and a cambic horizon is mineralogic. The cambic horizon should contain allophane, 2:1 lattice clays, glass, micas, feldspars, or ferro-magnesian minerals. The oxic horizon should not. The limits, or amounts, of these minerals that can be tolerated in an oxic horizon can only be approximated with present information. Very tentatively, this limit is set at 1 percent in the silt and the sand fractions. The clay fraction should have no detectable montmorillonite, illite, or allophane, and only traces of vermiculite. Spectographic analyses of profiles 27 and 28 show only traces of Ca and K, which suggests that there are no weatherable minerals in the silt and the sand fractions. The virtual absence of allophane is indicated by the low exchange capacities. X-ray analyses of the clays show traces of vermiculite but no montmorillonite or illite. Differential thermal analyses give no indication of allophane.

Whatever the cause, there are oxic horizons in which there has been some accumulation of secondary carbonates. The cause may be a change in environment. Oxic horizons may be preserved for long periods of time, during which climate can change drastically. Calcite is normally considered an easily weatherable mineral, but it is permitted to occur in oxic horizons.

Perhaps the most troublesome boundary to place is that between soils with oxic horizons and the Entisols, which lack an oxic horizon. It has been pointed out that the oxic horizons consist primarily of mixtures of sand and clay. The soils of the tropics

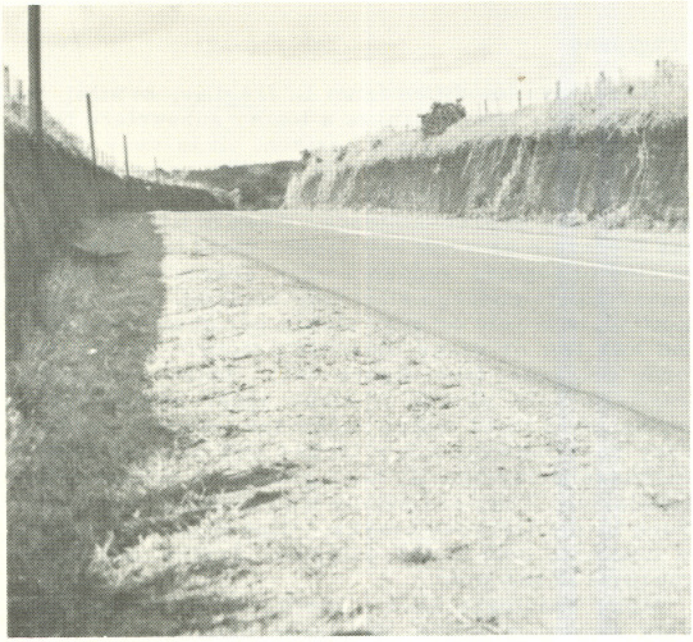


Figure 17.—Vertical roadcut in oxic horizons, Lihue, Hawaii.

Figure 18.—Fragment of a duripan probably cemented with both lime and silica; thin, dark, extremely hard crust on upper surface is absent in some places. (Scale in inches.)

are often thought of as being dominantly clays, but geographically vast areas of the soils in the tropics are sands and sandy loams. A horizon having one-half percent clay and 99-1/2 percent sand would seem to have too little clay to qualify as an oxic horizon, even though the clay were all free sesquioxides. But with no clear distinctions, the sands grade to the loamy sands, to sandy loams, and finally to clays. At this moment we can only suggest that the oxic horizon should have a sandy loam texture or a finer texture. Because the soils in question have essentially no silt their clay content, if it can be determined, should approximate 15 percent or more. If clay content cannot be determined the combined content of 1:1 lattice clays plus fine silt (less than 20 microns) and free sesquioxides should be at least 15 percent.

At times an oxic horizon can be distinguished from parent material, or C, by the presence of root pores in the oxic horizon and by absence of rock structure or of stratification indicating the original rock structure. A basic igneous rock may be completely altered to silicate clay and free oxides but still retain all or most of the original rock structure. Such altered material would be best considered as C material rather than an oxic horizon. However, if in that material the rock structure has been largely lost during soil genesis, it is considered a part of the oxic horizon. Finely stratified alluvium, with stratifications of a few centimeters or less, regardless of its composition, is considered C material; but if the fine stratification in the alluvium has been destroyed by soil genesis, the alluvium may be considered part of an oxic horizon if it meets the other requirements of an oxic horizon.

In summary, an oxic horizon is a horizon occurring below an epipedon in virgin profiles but at the surface of some truncated soils; it has:

1. Blocky structure, or common to many visible pores if it is structureless.
2. Little or no original rock structure.
3. 15 percent or more of clay-size minerals, of which 90 percent or more is a mixture of free sesquioxides and 1:1 lattice clays that is difficult to disperse.
4. A ratio of free sesquioxides to 1:1 lattice clays of 12 percent or more.
5. No more than about 1 percent micas, feldspars, or ferro-magnesian minerals in the sand and silt fraction; the clay fraction should have no detectable montmorillonite, illite, or allophane, and no more than detectable traces of vermiculite.

PANS

Duripans

Duripans (L. durus, hard, and pan, meaning hardpan) have more than one probable genesis and they vary in morphology. They are indurated horizons, cemented in part by an agent that is soluble in concentrated alkali. This cement is presumed to be silica or an aluminum silicate, but it has not been identified.

The duripans often contain cementing agents other than those thought to be silica. One kind is partially cemented by $CaCO_3$ and can be softened only by first treating it with acid to remove the lime, and then treating with concentrated NaOH. Duripans having $CaCO_3$ as one of the cementing agents are massive or platy, and nearly nonporous. Often they have a thin, extremely hard crust on the upper surface. Figure 18 shows a fragment of such a duripan.

Duripans cemented in part by $CaCO_3$ are commonly associated with high concentrations of replaceable sodium. pH valves commonly exceed 9. Where the pH values are below 9, there is often reason to think that pH values were higher when the duripan was being formed.

In early or weak stages of development, duripans of the kind just described may be massive, platy, or concretionary. The cementation is very weak and gives rise to a porous fabric. If moist, the weakly cemented horizons can be penetrated by hand augers, but perhaps with some difficulty. Horizons in such stages are so weakly cemented they are not considered to be duripans.

Another kind of duripan is free or nearly free of carbonates and can be broken down only by repeated alternate treatments with acid and alkali. These pans are presumed to be cemented with thin alternating layers of iron and silica. Thin sections viewed under crossed polarizers show structures identical with the structures of clay skins, alternating light and dark birefringent bands in the pores and as a crust on the surface of the peds. The extreme hardness of the cement precludes its being a clay skin. Figure 37, page 212, shows photographs of thin sections of one of these duripans.

In the United States the duripans nearly free of carbonates and presumably cemented by alternate layers of iron and silica are restricted to areas with a Mediterranean climate. Profile 31, page 96, illustrates a profile with a duripan of this character. The soil has a thin, strongly developed argillic horizon extending from a depth of 19-1/2 inches to 22 inches and it rests abruptly on the duripan. Duripans of the kind in this profile commonly have gross polygons that are 3 to 20 or more feet in diameter and are 1 to 4 feet thick. The sides of the polygons are coated with a grayish, very hard crust that may extend a few feet below the base of the duripan. These crusts are commonly only 1/4 to 1/2 centimeter thick. Figure 19 is a photograph of a soil profile comparable to profile 31. The argillic horizon in figure 19 is the dark horizon 20 to 24 inches from the surface. The duripan begins at 24 inches and extends below the bottom of the photograph.

A third kind of duripan is sometimes found in albic horizons that overlie spodic horizons. So far as is known now, these duripans are restricted to soils with spodic horizons in which humus or humus and aluminum have accumulated (Humus Podzols). The albic horizon (A2) becomes indurated but remains nearly white. The cement is presumed to be silica, or alumina and silica, though it has not been identified.

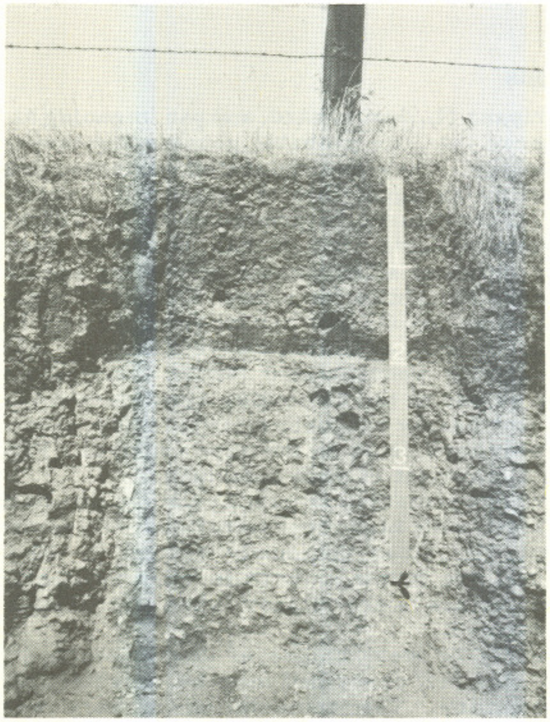


Figure 19.—Soil profile with a duripan; dark material between depths of 20 and 24 inches is an argillic horizon; the duripan begins at 24 inches and extends below the bottom of the excavation.

Fragipans

A fragipan (modified from L. fragilis, brittle; and pan, meaning brittle pan) is a loamy subsurface horizon, often underlying a B horizon. It is very low in organic matter, has high bulk density relative to the solum above, is seemingly cemented when dry, having hard or very hard consistence. When moist, a fragipan has moderate or weak brittleness (tendency for a ped or clod to rupture suddenly when pressure is applied rather than to undergo slow deformation). It is usually mottled, is slowly or very slowly permeable to water, and has few or many bleached fracture planes that form polygons (see figure 20). Most commonly, fragipans have abrupt or clear upper boundaries at depths of 15 to 40 inches below the original surface. They vary between a few inches and several feet in thickness and ordinarily have gradual or diffuse lower boundaries. They are nearly free of roots, except for those in the bleached cracks. Clay skins are scarce to common, both in the polygonal cracks and in the interiors of the peds.

Many fragipans have a moderate to strong thick platy structure within the large prisms. In some,

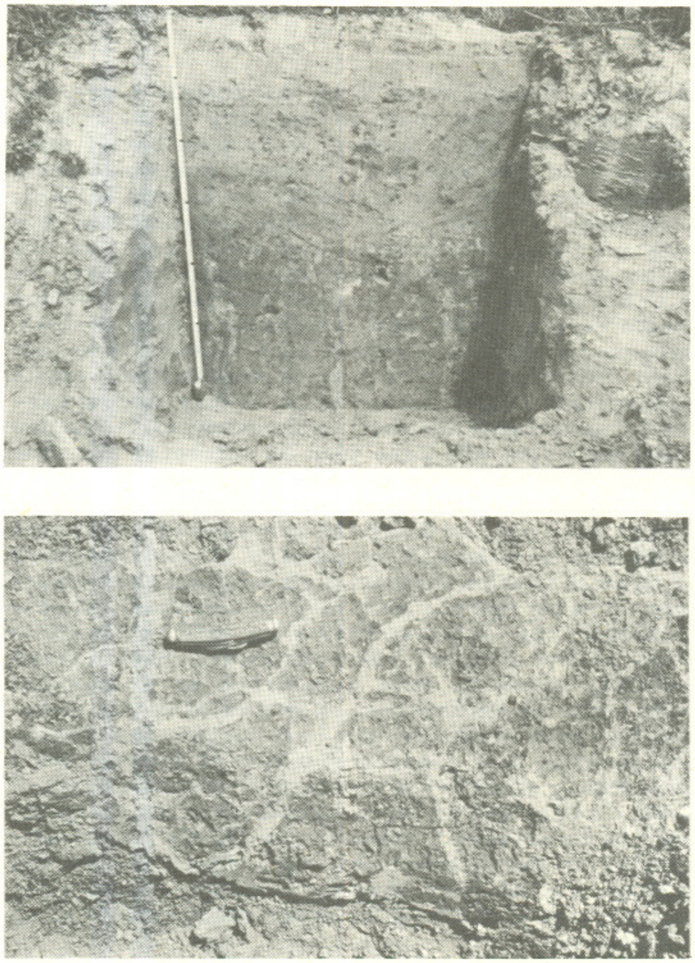


Figure 20.—Vertical and horizontal views of a fragipan: Top, Vertical view; ruler ticks are 6 inches (15 cm.) apart and upper boundary of fragipan is at 20 inches. Bottom, Horizontal view; knife is 3.5 inches (9 cm.) long.

however, the structure within the prisms is more nearly blocky than platy, and there are varying stages between platy and blocky. In some fragipans the prisms are massive and without secondary structure.

The genesis of fragipans is obscure. With more knowledge, their definition can be improved. Their presence has been attributed to the weight of glaciers, to permafrost, and other events in the Pleistocene. The authors, however, consider them to be soil horizons on the following evidences:

1. The fragipan, within its range of occurrence, is roughly parallel to the soil surface.

2. The majority of the fragipans have their upper boundary about 18 to 24 inches below the surface. This seems true whether the soil occurs in northern Michigan, in southern Mississippi, or in New Zealand, Scotland, or Italy. The extreme range in depth from the surface in soils that have not been eroded under cultivation seems to be from about 10 to 40 inches. This would be a remarkable accident if the fragipans were not soil horizons.

3. The pans occur in alluvium, in loess, in residuum from bedrock, in glacial till, and in solifluction materials. The common denominators in parent materials are a loamy texture, a low carbonate content or no carbonates, and an appreciable content of silt or very fine sand.

4. The pans may underlie a variety of horizons--spodic, argillic, cambic, or albic horizons. In all instances the morphology of the pan may be very similar. However, the pans do not occur in materials that are still calcareous, nor do they underlie ca, cs, or sa horizons, however weakly developed they may be. If the pans were not soil horizons, the failure to find them under any one of the ca, cs, or sa horizons would be another remarkable accident.

5. In bisequum profiles, the fragipan may be formed in the lower argillic horizon or even in the eluvial horizon that separates the two B horizons.

The authors believe that the polygonal network of bleached fracture planes is formed by water moving into desiccation cracks. Other things being equal, the polygons are smallest in the finer textured materials. For a given texture, polygons tend to be larger as the dry season becomes shorter or less intense. The bleached fracture planes are rare or absent in the coarsest textured materials and in the most humid climates.

If an argillic horizon overlies the pan, movement of clay down the fracture planes usually is indicated by relatively thick clay skins. If a spodic horizon overlies the fragipan, clay skins in the bleached fracture planes are often scarce or absent.

Examination of interiors of the polygons shows close packing of the mineral grains. This is in line with the high bulk density of the pans relative to the density of the overlying part of the solum. Figure 21 shows a thin section of a fragipan that has typical close packing of the particles.

The hardness of the pans when dry may be largely attributed to the close packing and to cementation by clay. But cementation by clay does not account for the brittleness of the pans when they are moist or wet. At this time, the cause of the brittleness is not understood.

Where pans formed in glacial till, their relative high bulk density may be attributed partly to the weight of the glaciers. Yet, in many if not all of the pans, there seem to be other factors. One factor is presumed to be pressures generated by the very slight shrinking and swelling. When dry, the pans normally have very fine cracks between the polygons; and very fine sands, silts, and clays might be washed into these cracks when the dry season ends. Roots growing along the sides of the polygons add to the bulk. Then, when the pan remoistens it swells slightly. The force of swelling, however, is opposed by the materials that have moved into the cracks between the polygons. The internal pressures thus generated may be responsible for part of the compaction. Among other factors are hydration of primary minerals that leads to an increase in volume, the movement of small amounts of clay, or the weak cementing action caused by silica or by alumino silicates.

Repeated core measurements to determine permeability show that these pans are very slowly permeable.

Descriptions of soils with fragipans are included to illustrate something of the range of properties among the fragipans. Profile 24, page 89, is typical of a soil that has a fragipan underlying a cambic horizon. The fragipan, at depths between 24 and 42 inches, is immediately overlain in most places by what appears to be an eluvial horizon that is relatively low in both clay and free iron oxides. Water has been observed to move laterally over the surface of pans such as that in profile 24, page 89, and the eluviation therefore may have been lateral as well as vertical.

Profile 29, page 94, is typical of a soil that has a fragipan underlying a spodic horizon. The upper boundary of the fragipan is at a depth of 16 inches. The lower boundary is very diffuse, but below a depth of 64 inches there seems to be no evidence that the till has been altered.

Profile 30, page 95, is typical of a hydromorphic soil with a fragipan. The textures of this soil are about as coarse as any in which distinct fragipans can be found. The pan, beginning at 20 inches, underlies a cambic horizon. Determinations for free iron and free aluminum show the lowest contents in the bleached polygonal cracks, the highest contents in the thin yellowish-red bordering strips, and intermediate contents within the main part of the pan. In the three parts of the pan, the free iron contents were, respectively, 0.08, 2.01, and 0.62. Free aluminum contents were 0.08, 0.52, and 0.26, respectively.

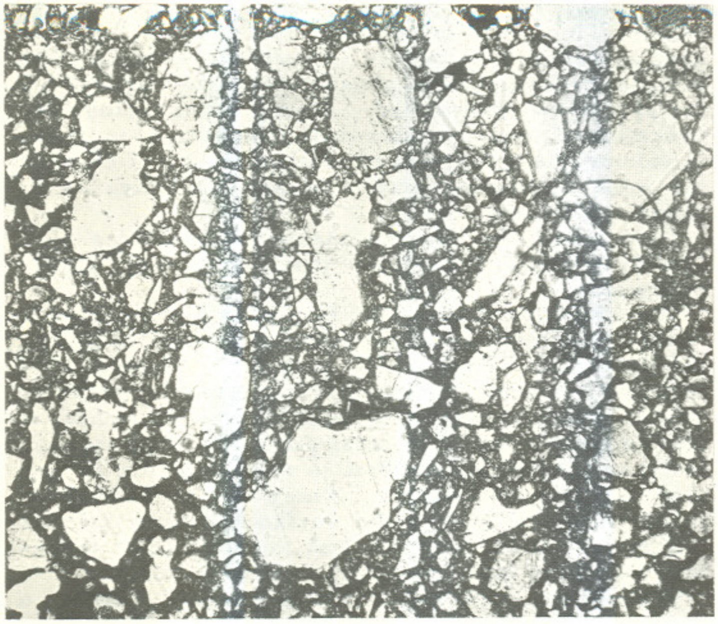
OTHER HORIZONS

Calcic Horizon

The letter designation ca is used to indicate accumulations of calcium carbonate or of calcium and magnesium carbonates. The accumulations may be in the C horizon, but they may also be found in mollic epipedons, or in argillic, natric, and other horizons.

The calcic horizon is a horizon of secondary carbonate enrichment that is more than 6 inches thick, has a calcium carbonate equivalent content of more than 15 percent, and has at least 5 percent more calcium carbonate equivalent than the C. If no C is present, the calcic horizon is one that is more than 6 inches thick, has a calcium carbonate equivalent content of more than 15 percent, and contains more than 5 percent, by volume, of identifiable secondary carbonates in concretions or soft powdery forms.

Sometimes it is difficult or even impossible to distinguish calcic horizons in soils from calcareous parent materials. Limestones like ca horizons are formed by precipitation of calcium carbonate or calcium and magnesium carbonates. In dry regions



A, Thin section viewed under plain light. Fines, predominantly of silt size, fill all the interstices between grains of sand. No pores visible in the photograph; very small pores may be present, but if so, are smaller than the thickness of the thin section (0.03 mm.)

B, Diagram of thin section

a Mineral grains the size of fine and medium sand

b Matrix consisting mainly of very fine sand and silt

Figure 21.—Thin section of a fragipan showing very close packing of particles and absence of pores.

very thick beds may be formed in lakes, and these may later become the parent material of soils. Such deposits of carbonates may be recognized as unrelated to the modern soils if they contain aquatic fossils. However, a modern ca horizon formed in such materials is difficult if not impossible to identify at present, and any distinction is, of necessity, arbitrary to some degree.

If the parent material of a soil is a hardened caliche, or croute calcaire, it is common to find a fractured surface layer. The upper surfaces of the fragments often show solution pitting. The lower surfaces of the fragments commonly are covered with redeposited lime that differs from the lime on fragments in the parent material in color, or hardness, or both. Where the percentage, by volume, of the redeposited lime exceeds 5 percent in a layer more than 6 inches thick, the horizon should be considered a calcic horizon.

Commonly, calcic horizons are developed in unconsolidated materials of more or less mixed mineralogic composition. In these the secondary lime is generally easy to recognize, for it occurs as a white powdery filling, as concretions, as pseudo mycelia, as pendants or crusts below pebbles and stones, or as thin sheets at lithologic discontinuities where there are breaks in the size of the pore spaces. If, in such situations, the carbonate content of a layer 6 inches or more thick exceeds 15 percent by weight, and the layer has at least 5 percent more calcium carbonate equivalent than the next underlying layer, the horizon is considered a calcic horizon. Such horizons are generally thickest in gravels, other things being equal, but they rarely exceed 2 to 3 meters in thickness. Such a horizon is illustrated in figure 22. In this soil the pebbles cemented by lime form a horizon impervious to water and roots. Other calcic horizons are soft and friable. The categoric level at which distinctions should be made between cemented and soft calcic horizons is still undetermined.

The genetic implications of a calcic horizon are variable. In desert regions, if the parent materials contain considerable amounts of calcium, the very limited rainfall seems unable to remove lime completely from even the surface few inches of the soil. About the only significant horizon that can develop in such a soil is a calcic horizon. In areas transitional from the desert to the steppes, an A1 horizon, or mollic epipedon, may develop in addition to the calcic horizon. Apparently no other horizons ordinarily develop. Such soils are the arid and semiarid equivalents of the Rendzinas of humid regions.

In soils that have, near the surface, ground waters that contain appreciable amounts of calcium bicarbonate, the capillary rise and evaporation, plus transpiration, cause precipitation of large amounts of lime. Depending on the height of the capillary fringe, the deposition of lime may take place in the very surface, or in the soil at depths of a foot or two. In such soils, the accumulation of lime is comparable to the accumulation of more soluble salts in the desert playas. One might think of such soils as the humid equivalents of the Solonchaks. Profile 1, page 66, is a soil with such a calcic horizon.

In the situation just discussed, one might attach a high genetic significance to a calcic horizon. In other circumstances, however, one can attach no genetic significance to a calcic horizon. Deposition from ground water at depths of 10 feet or more is more nearly a geologic than a pedologic process. In soils formed from calcareous materials on the steppes, the amount of accumulation of lime may be extremely erratic, and, in fact, may vary from one foot to the next. One might consider the presence or absence of a ca horizon to be significant at a low categoric level, but one might not be concerned at any categoric level with the absolute amount of accumulation that makes the distinction between a ca and a calcic horizon.

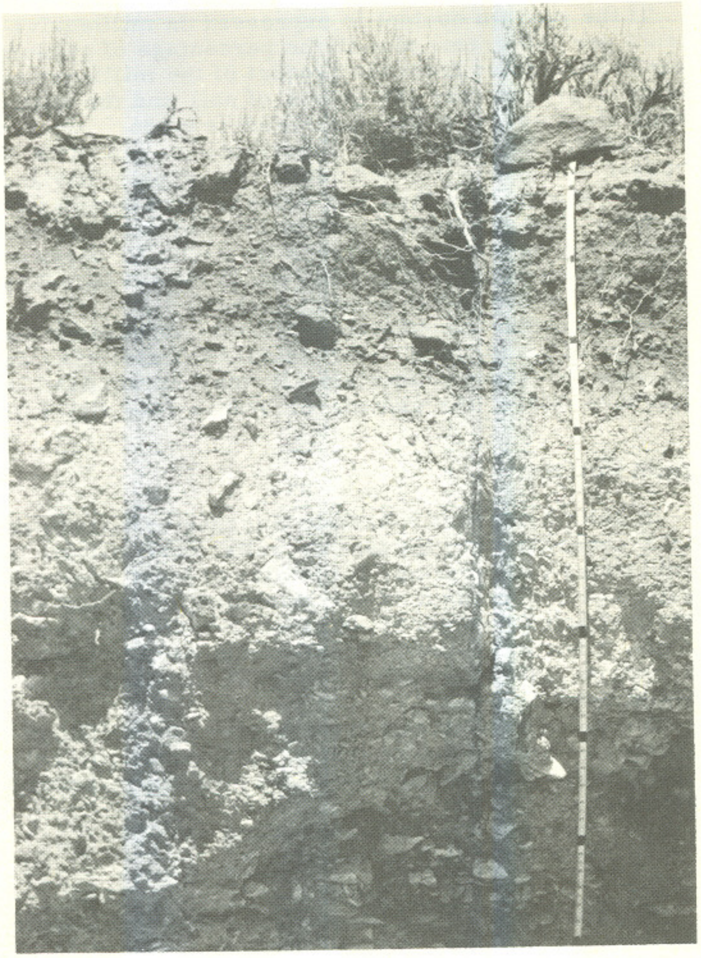


Figure 22.—Calcic horizon in an Argid (Sierozem). Ticks on scale are spaced at 6 inches. The calcic horizon is indurated at depths between about 14 inches and 40 to 48 inches.

Profile 3, page 68, is typical of a soil in which there is a calcic horizon of no apparent genetic or other significance. The mollic epipedon and the argillic horizon are significant to the classification of this soil. The presence of a ca horizon is also significant, but the absolute amount of lime accumulation has no known significance.

Gypsic Horizon

The gypsic horizon is a horizon of secondary calcium sulfate enrichment that is more than 6 inches thick, has at least 5 percent more gypsum than the C or the underlying stratum, and in which the product of the thickness in inches and the percent gypsum is equal to or greater than 60 percent-inches. Thus, a horizon 12 inches thick that is 5 percent gypsum would qualify if gypsum were lacking in the underlying horizon. A layer 12 inches thick that is 6 percent gypsum would qualify if the gypsum content of the underlying horizon did not exceed 1 percent.

If the gypsum content is expressed in milliequivalents per 100 grams of soil, the percentage of gypsum can be calculated from the product of the milliequivalents of gypsum per 100 grams of soil and the milliequivalent weight of gypsum, which is 0.086.

Profile 25, page 90, illustrates a soil with a gypsic horizon. In this soil, the gypsic horizon begins at one half inch and extends to a depth of 27 inches. The gypsum content in this horizon exceeds that of the underlying horizons by about 30 percent. The product of percent gypsum and thickness in inches for this horizon is 945 percent-inches.

Gypsum may accumulate uniformly throughout the matrix of sands and finer textured materials. In gravels or stony materials, it may accumulate in pendants below the gravels or stones (see fig. 23).

Salic Horizon

A salic horizon is a horizon 6 inches or more thick with secondary enrichment of salts more soluble in cold water than gypsum. It contains at least 2 percent salt, and the product of the thickness in inches and percent salt by weight is 24 percent-inches or more. Thus, a horizon 8 inches thick would need to contain 3 percent salt to qualify; a horizon 12 inches thick would need 2 percent.

If data on soluble salt are expressed in milliequivalents per liter of the saturation extract, the percentage of salt, on a weight basis, may be approximated as follows:

$$\frac{\text{meq per liter soluble cations} \times 0.058 \times \text{percent } H_2O \text{ at saturation}}{1{,}000}$$

Profile 26, page 91, illustrates a soil with a salic horizon. The salic horizon extends from 2 to 23 inches, and the product of thickness and percent salt is 64 percent-inches.

Albic Horizon

The albic (L. albus, white) horizon is one from which clay and free iron oxides have been removed,

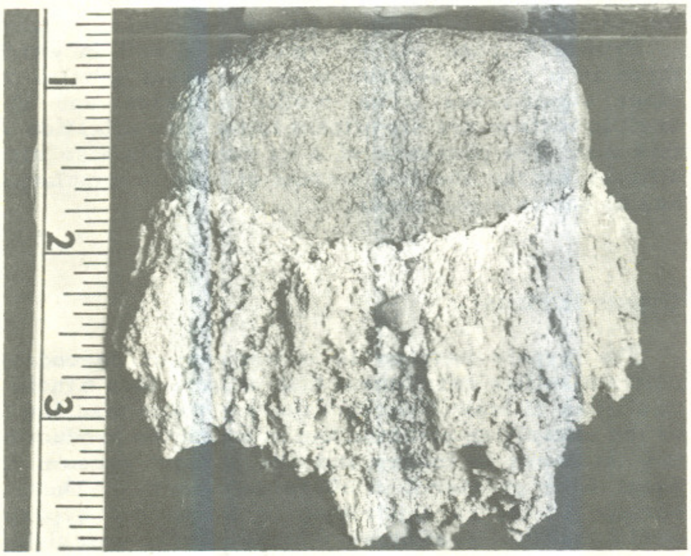


Figure 23.–Gypsum pendant formed below a small stone in a gypsic horizon.

or in which the oxides have been segregated, to the extent that the color of the horizon is determined primarily by the color of the primary sand and silt particles rather than by coatings on these particles. It is typified by the bleicherde of Podzols and the bleached A2 horizons of Planosols. An albic horizon may be found at the surface of the mineral soil; it may lie just above an argillic or a spodic horizon; it may lie between a spodic horizon and either a fragipan or an argillic horizon; or it may lie between an argillic horizon and a fragipan. It is usually underlain by an illuvial B horizon of some sort, a fragipan, or a relatively impervious layer that can produce a perched water table with either stagnant or moving water.

Chemical data on several albic horizons are included in table 13. The albic horizons in profiles 20 and 21 overlie spodic horizons. In profiles 22 and 23, the albic horizons overlie argillic horizons. Profile descriptions of these soils are on pages 85 to 88. The albic horizons in these profiles are designated as A2 horizons. In each soil, total iron and free iron are at or near a minimum in the albic horizon. The total iron of the clay fraction is at a minimum, though differences are small in profiles 22 and 23, where the albic horizon overlies an argillic horizon. The data suggest that the albic horizons have all lost iron, and that the losses have been relatively greater if the underlying horizon is spodic rather than argillic. In all of these profiles, the horizon underlying the albic horizon is illuvial and has a higher chroma, a lower value, or both.

Deep deposits of pure white sand can be formed by wind or wave action. While these deposits have the apparent morphology of an albic horizon, they are in fact a parent material. The white sand in these soils does not overlie a B horizon or any other soil horizon except, in some cases, a buried soil.

In summary, an albic horizon is a surface or lower horizon having such thin coatings on the sand or silt particles that the hue and chroma of the horizon are determined primarily by the color of the sand and silt particles. Especially in soils rich in quartz, moist chromas of albic horizons are 3 or less, and dry chromas less than 3. Chromas are lower than those of an underlying argillic horizon, unless the chroma of the argillic horizon is 2 or less. Dry values are higher and moist values usually higher than those of an underlying argillic horizon, and always are higher than those of any underlying spodic horizon. An albic horizon usually lies on an argillic horizon, spodic horizon, or on a fragipan or an equally impervious horizon or layer.

Other Soil Characteristics

A number of the characteristics used for classification in the higher categories cannot be considered horizons. Rather they are diagnostic features of horizons or of soils. These are discussed in the following section.

Abrupt textural change.--This is an abrupt change from an albic (eluvial A) horizon to an argillic horizon, with a very appreciable increase in the clay content in a very short distance in depth. If the clay content of the albic horizon is less than 20 percent, the clay content should double within a distance, in depth, of 3 inches or less. If the clay content in the albic horizon exceeds 20 percent, the increase should be at least 20 percent within a 3-inch vertical distance, and the clay content in some part of the argillic horizon should be at least double that of the albic horizon. Transitional horizons are normally lacking, though there may be a layer a few inches thick that, if sampled as a layer, includes portions of both the albic horizon and the argillic horizon. The horizon boundary in such cases is irregular, and there may even be disconnected inclusions of the argillic horizon in the albic horizon. Thus, the sampling of such a mixture of albic and argillic horizons as a single horizon might create the appearance, after analyses, of a relatively thick transitional horizon.

Crusty.--This term refers to the tendency of some soils to form thin surface crusts under the beating action of raindrops. The opposite term used here is "self-mulching." Crusts are thin, massive or platy surface horizons. Usually the thickness is less than a centimeter and depends on the number and intensity of rains that have fallen since the last tillage of the soil. A more detailed discussion of crusting is included in the definition of Mazaquerts.

Dry.--This refers to soil moisture contents below permanent wilting point, 15 bars (atmospheres) tension. A plant can wilt permanently in a soil saturated with water if the water is salty enough. Such soils should be considered salty rather than dry. Usually dry means that the soil is dry more than half of the time that it is not frozen. This term carries the implication that the period of dryness is nearly continuous. If, during a 7-month period a soil is dry except for a few brief periods of about 2 weeks or less following showers, when the surface few inches have some available moisture, the soil is considered usually dry. During this entire period, normally there are dry horizons in the soil at all times. The use of soil moisture to classify soils creates a problem when soils that are naturally dry are being irrigated. It is possible to change the classification when the soil is irrigated, for its moisture regime is changed by irrigation. For the present however, an attempt is being made to classify the soil as though it were not being irrigated, at least at the level of the series and all higher categories. This requires that we determine what the moisture regime would be if irrigation were discontinued. It is believed that this is generally feasible. If experience proves otherwise it may become necessary to change the classification of some soils when irrigated or to find other criteria that will not be affected by irrigation.

Gilgai.--A microrelief of clays that have high coefficients of expansion with changes in moisture is called gilgai. Such microrelief consists of either a succession of enclosed micro-basins and micro-knolls in nearly level areas, illustrated in figure 24, or of micro-valleys and micro-ridges that run with the slope. The micro-ridges commonly range from a very few inches to 1 or 2 feet. Rarely, they appear to approach 5 or 6 feet.

Figure 24.--Gilgai micro-relief in India. The micro-relief shown here is considerably greater than average.

Moist.--Moist refers to soil moisture contents above permanent wilting point or, if the soil is salty, moisture held at tensions of less than 15 bars. Usually moist means moist for more than half of the time that the soil is not frozen, either as a continuous period, or in interrupted periods if the periods exceed a few weeks.

Mineral soils.--These are soils that, to a depth of 30 centimeters (12 inches) have less than 17.4 percent organic carbon (30 percent organic matter) if the mineral fraction has more than 50 percent clay, or less than 11.6 percent organic carbon (20 percent organic matter) if the mineral fraction has no clay. An intermediate clay content requires a proportional content of organic matter.

Mottles.--The word "mottled" means marked with spots of color. If a soil horizon has a matrix color of gray, with a few spots of red and brown, the mottles technically are the spots of red and brown. In other soil horizons, there may be so many red and brown spots that the gray colors occupy a small volume and are considered mottles. Throughout the keys and the text, many references will be found to "mottles with chromas of 2 or less." For clarity of writing it is impossible to spell out in each reference a full definition of the meaning of this phrase. It refers to colors of horizons in which portions have chromas of 2 or less. If the minor or major part has chromas of 1 to 2, with spots of higher chroma, it is included in the meaning of "mottles with chromas of 2 or less." It is excluded from the meaning if all of the horizon has chromas of 2 or less, or none of the horizon has these chromas.

N value.--The N value refers to combinations of organic-matter, water, and clay contents of the soil that seriously reduce its bearing value, usually to the point where grazing by livestock is impossible and serious subsidence will occur following drainage. The N value may be calculated by the formula:

$$N = \frac{A - 2}{L + 3H}$$

where A = percentage of water in soil in field condition, calculated on a dry soil basis;
L = percent clay, and
H = percent organic matter (organic carbon x 1.724).

Few data are available for these calculations, but the critical N value of 0.5 can be approximated closely in the field by the simple test of squeezing the soil in the hand. If the soil flows with difficulty between the fingers, leaving the hand empty, the N value is a little above 0.5. If the soil flows easily between the fingers, the N value is considerably above 0.5. If a ball of soil remains in the hand, the N value is less than 0.5.

Soils that are periodically reduced in moisture content below field capacity seldom or never have N values of 0.5 or more. Only those that have been permanently saturated are apt to have high N values. Consequently, high N values are apt to be found only in soils of tidal marshes, swamps, or shallow lakes; the sediments have never been above the capillary fringe during drought cycles.

Organic soils.--Organic soils are those which, to a depth of at least 30 cm. have more than 17.4 percent organic carbon (30 percent or more organic matter) if the mineral fraction is more than 50 percent clay, or more than 11.6 percent organic carbon (20 percent or more organic matter) if the mineral fraction has no clay. Intermediate clay content requires a proportional content of organic carbon.

Permafrost.--Layers with temperatures permanently at or below 0° C., whether consistence is very hard or loose (dry permafrost).

Plinthite.--(Gk. plinthos, brick) is the sesquioxide rich, humus poor, highly weathered mixture of clay with quartz and other diluents, which commonly occurs as red mottles, usually in platy, polygonal, or reticulate patterns; plinthite changes irreversibly to hardpans or irregular aggregates on repeated wetting and drying, or it is the hardened relicts of the soft red mottles. The lower boundaries of plinthite are often diffuse or gradual, but they may be abrupt at a lithologic discontinuity.

Plinthite may occur as a constituent of a number of horizons, including ochric and umbric epipedons, argillic horizons, oxic horizons, and C horizons. It is a form of the material which has been called laterite, renamed to obtain a better combining form for the new nomenclature. It normally forms in horizons below the surface, though it is commonly exposed at the surface, and may, under some conditions, form at the surface.

From a genetic viewpoint, plinthite represents segregation of iron with probable additions in many cases from other horizons or from higher lying adjacent areas.

The original segregation of the iron is normally in the form of soft, more or less clayey, red mottles. It is possible that at times the original formation may be hard. Generally, the plinthite forms in horizons that are, at some season, saturated with water.

When present in small amounts, the plinthite generally forms a discontinuous phase in the soil; that is, the individual mottles or aggregates are not connected with each other. If present in large amounts, the plinthite may form a continuous phase. In this case, on hardening, a massive layer is formed that has irregular somewhat tubular inclusions of yellowish, grayish or white, soft, clayey material. If exposed, these inclusions may be washed out, and thus an ironstone with many coarse tubular pores is left. Figure 25 shows such an exposure of hardened plinthite.

The lower boundaries of plinthite are normally diffuse. The upper boundary may be abrupt if it is at the soil surface or if it has been truncated and later buried by another material. The segregations of iron may continue down for several tens of feet. The amount of iron in the mottles may gradually decrease with depth until the point is reached where the content is too low to permit hardening.

Self-mulching.--This term refers to the tendency of many clays to form a loose granular surface mulch as a result of freezing and thawing, or wetting and drying. If the granules are destroyed by plowing when wet, they reform, usually on a single drying. Figure 26 shows an undisturbed surface of a self-mulching clay.

Sequum.--A sequence of an eluvial horizon and its related illuvial horizon, if present, is a sequum. An albic horizon and a spodic horizon immediately underlying it would constitute a sequum. Two sequa may be present in a single soil and can be called a bisequum. Profile 32, page 97, formed in a single deposit of glacial till in Maine, illustrates a soil with an upper sequum that has a spodic horizon and a lower sequum that has an argillic horizon. This soil has been cultivated, and the albic horizon is now discontinuous. Where the albic horizon is missing, the upper part of the spodic horizon probably has been mixed into the plow layer.

Slickensides.--Slickensides are polished and grooved surfaces produced by one mass sliding past

Figure 25.—Hardened, exposed plinthite. Large, rounded, tubular holes to left of scale presumably were at one time filled with clayey material that did not harden with rest of matrix. (Scale in feet.)

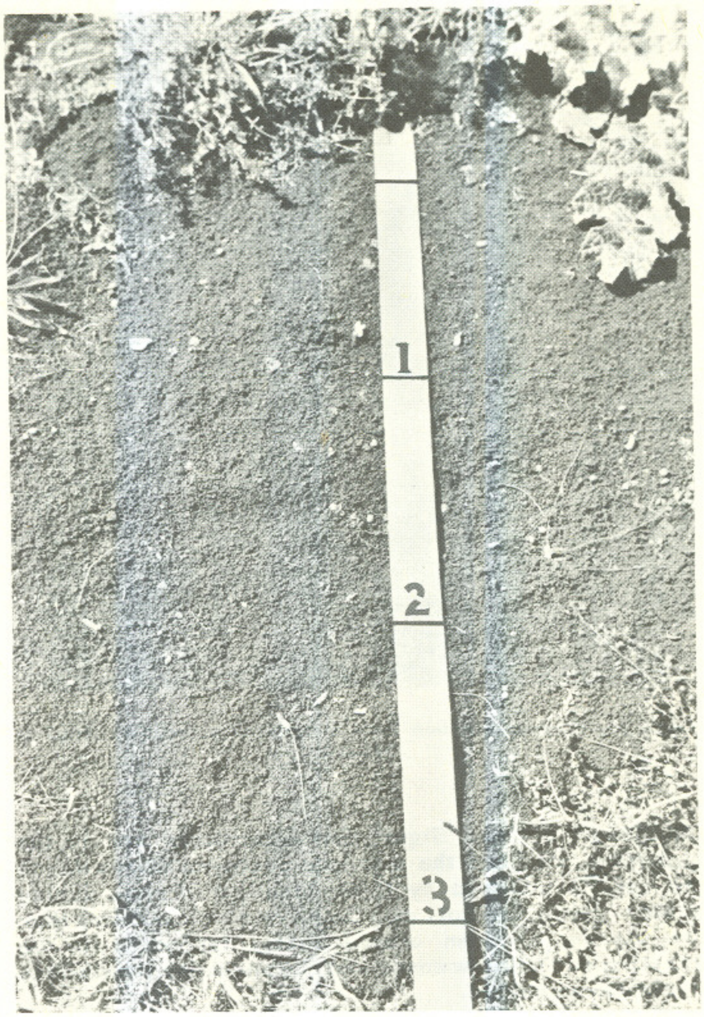


Figure 26.—Surface of the granular mulch that is typical of self-mulching clays.

another. In soils, slickensides may be found at the base of slip surfaces on relatively steep slopes. They are also common in swelling clays that have marked changes in moisture content. A photograph of such a slickenside is shown in figure 27.

Soil temperature.--Soil temperature, though varying with daily and seasonal cycles, is a characteristic of any soil, that can be measured. While the temperature of a soil usually cannot be expressed by a single figure, it can be described by the mean annual value and by the seasonal and daily fluctuations from the mean.

Some soil morphologists have neglected soil temperature and soil moisture as soil characteristics. Rather, they have been considered as soil-forming factors. In fact, they are both.

Soil temperatures take on extreme importance when they are too low to permit the growth of roots. While a soil temperature of 1° C. does not affect the movement of soil water appreciably, it will completely inhibit the root growth of most plants. Roots of most plants require a temperature of 5° C. or more for growth. Thus, a cold horizon is a kind of thermal pan, as important to plants as a fragipan, and is considered in the classification at the same categoric level as other kinds of pans. As an example, alfalfa (Medicago sativa) with pronounced symptoms of sulfur deficiency, has been seen growing on soils that have abundant gypsum at 18 to 20 inches. But, the soils are too cold for the roots to reach the gypsum.

In the absence of thermal waters that can supply heat, the mean annual temperature of all horizons of a soil is the same, though at any moment the temperature of the various horizons is apt to differ. Seasonal temperature fluctuations, in the latitudes of the United States, penetrate to a depth of about 30 feet, though they are of minor importance below 20 feet. The mean annual temperature of a soil in the United States therefore can be measured by a single reading of the temperature at 30 feet and closely approximated by a reading at 20 feet.

Mean annual temperatures seem to be relatively independent of soil texture, color, and drainage. They are influenced locally by the direction of slope, and by the presence of an O horizon, formerly A_0. Data are too few to permit generalizations about the influence of these factors on the mean annual soil temperatures.

In the absence of direct measurements of soil temperature in the United States, the mean annual temperature can be very closely approximated by adding 1° C. (2° F.) to the mean annual air temperature. This relation holds rather closely for most of

Figure 27.–Slickenslides from lower horizons of a Vertisol. (Scale in inches.)

the United States. Significant departures are in the high mountains and the extreme northern States where the soil is covered by thick blankets of snow during winter. Here, the soil may be up to 5° C. warmer than the air on a mean annual basis, depending on the duration of the snow cover and the seasonal differences in air temperature.

Seasonal variations from the mean annual temperature may be highly significant to plant growth. The mean summer temperature as used in this system refers to the months of June, July and August in the northern hemisphere.

The air and soil temperatures during any 3-month period may differ significantly. When the air temperature is rising, the soil is colder than the air, but when the air temperature is falling, the soil is warmer than the air. The summer temperature of the soil is influenced not only by the air temperature but also by direction of slope, the soil moisture content, and the presence and nature of an O horizon. Thus, in high latitudes during the summer, a freely drained soil is warmer than one saturated with water. A plowed soil is warmer than a soil under forest with a thick O. And if plowed, south-facing slopes are warmer than north-facing slopes.

It is a principle of this classification to keep arable soils and related soils under natural vegetation in the same classes until some of the diagnostic horizons or features have been permanently altered. The clearing of a forest in Alaska may raise both the mean annual and the summer soil temperature, but the change is not permanent. Limits on soil temperature for the arable land therefore must be different from those under forest. Otherwise, the classification of a soil is changed by the cutting of a forest and the burning of the O. Then, if the land reverts to forest, the classification is again changed.

Tongues of albic horizons.--Tongues of albic horizons consist of penetrations of bleached material, as defined for an albic horizon, into an argillic horizon along ped surfaces, if peds are present. The penetrations must have greater depth than width, have horizontal dimensions of 5 mm. or more in fine textured argillic horizons (clay, silty clay and sandy clay) 10 mm. or more in moderately fine textured argillic horizons, and 15 mm. or more in medium or coarser textured argillic horizons (very fine sandy loams, loams, and silt loams, or coarser), and must occupy more than 15 percent of the mass of the upper part of the argillic horizon before they are considered tongues. Figure 28 shows a moderately fine textured argillic horizon with tongues of an albic horizon.

Figure 28.–Tongues of an albic horizon extending into an argillic horizon; gray tongues in the thin section show incomplete but very substantial stripping of the clay. (Scale in inches.)

Profile Descriptions for Chapter 5

(Colors for moist soil unless otherwise stated)

Profile No. 1

Area: Cass County, North Dakota.
Vegetation: Small grain; (natural) tall grasses.
Parent material: Lacustrine materials.
Topography: Level; 1/2 percent slope.

Ap 0 to 8 inches, black (10YR 2/1) silty clay loam, very dark gray (10YR 3/1) when dry; compound strong, fine, granular and very fine, blocky structure; slightly hard, friable; calcareous; abrupt boundary.

C1ca 8 to 15 inches, light brownish-gray (2.5Y 6/2) silty clay loam, light gray (2.5Y 7/2) when dry; streaks of dark gray (10YR 4/1), gray (10YR 5/1) when dry; strong, very fine, granular and very fine, subangular blocky structure; soft, very friable; calcareous; clear boundary.

C2ca 15 to 22 inches, light olive-brown (2.5Y 5/4), light silty clay loam, pale yellow (2.5Y 7/3) when dry; streaks of dark grayish brown (2.5Y 4/2), gray (2.5Y 5/1) when dry; strong, very fine, subangular blocky structure; soft, very friable; calcareous; clear boundary.

C3g 22 to 31 inches, light olive-brown (2.5Y 5/4) silty clay loam, light gray (2.5Y 7/2) and pale yellow (2.5Y 7/3) when dry; many fine mottlings of light brownish gray (2.5Y 6/2), white (10YR 9/1) and brownish yellow (10YR 6/8) when dry; moderate, very fine, subangular blocky structure; slightly hard, friable; a moderate amount of segregated lime in threads and a few small, soft, round concretions; calcareous; clear boundary.

C4g 31 to 40 inches, grayish-brown (2.5Y 5/2) silty clay loam, light gray (2.5Y 7/2) when dry; many, fine mottlings of yellowish brown (10YR 5/6), brownish yellow (10YR 6/8) when dry; moderate, medium, platy, breaking to very fine, blocky structure; slightly hard, friable; few lime segregations; calcareous; gradual boundary.

C5g 40 to 48 inches, olive-gray (5Y 5/2) silty clay loam, light gray (5Y 7/2) when dry; many, medium mottles of strong brown (7.5YR 5/6), brownish yellow (10YR 6/8) when dry; moderate, medium, platy, breaking to strong, very fine blocky structure; slightly hard, friable; calcareous; gradual boundary.

C6g 48 to 60 inches, colors as in the horizon above; silty clay; strong, platy structure or varved; hard, friable; calcareous.

Climatic data (Fargo, N. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F)	7	11	25	42	55	65	71	69	59	46	28	13	41
Mean precipitation, 1921-50 (inches)	0.6	0.7	0.9	1.9	2.2	3.0	2.3	2.7	1.7	1.3	0.9	0.6	18.7

Annual precipitation more than 9.4 and less than 28.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-8	Ap	0.5	0.9	1.1	3.8	13.4	50.0	30.3	42.5	23.8			3.23	12
8-15	C1ca	.1	.4	.5	1.9	6.6	57.1	33.4	37.9	27.2			.81	9
15-22	C2ca	.1	.3	.4	1.6	3.2	65.6	28.8	33.4	36.5			.53	9
22-31	C3g	.1	.3	.4	.8	1.1	59.9	37.4	19.7	41.9			.28	7
31-40	C4g	.3	.4	.4	.6	.8	63.1	34.4	17.6	46.8			.25	7
40-48	C5g	.1	.4	.4	.8	.8	59.0	38.5	13.4	46.9			.23	6
48-60	C6g	.1	.1	.2	.7	1.0	49.3	48.6	11.2	39.6			.22	6

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	$CaCO_3$ % v
						7.8	3
						8.2	24
						8.2	26
						8.2	13
						8.2	21
						8.1	18
						7.9	16

Profile No. 2

Area: Washington County, Nebraska.
Vegetation: Small grain; (natural) tall grasses.
Parent material: Loess.
Topography: 9 percent slope facing east; relief 50 feet.

Ap 0 to 6 inches, very dark brown (10YR 2/2) silty clay loam; weak, very fine, granular structure; slightly hard, friable; lower part very compact as the result of tillage; many fine roots; common wormcasts and small pores; clear, smooth boundary.

B1 6 to 10 inches, very dark grayish-brown (10YR 3/2) silty clay loam; dark grayish brown (10YR 4/2 dry) when crushed; moderate, fine and very fine, granular structure; hard, friable; ped faces coated with organic or colloidal material; many wormcasts; clear, wavy boundary.

B21 10 to 22 inches, dark-brown (10YR 3/3) silty clay loam; moderate, coarse, prismatic, breaking to moderate, fine and very fine, subangular blocky structure; hard, firm; shiny ped faces may be clay films; patchy dark stains of organic matter on faces of peds; many wormcasts and very fine pores; gradual, wavy boundary.

B22 22 to 32 inches, dark grayish-brown (2.5Y 4/2) silty clay loam; weak, coarse, prismatic, breaking to weak, medium and fine, subangular blocky structure; hard, firm; many, medium mottles of gray (10YR 5/1) and yellowish brown (10YR 5/4); common wormcasts and fine pores; common iron stains and small specks of manganese; gradual, wavy boundary.

B3 32 to 42 inches, mottled gray (10YR 5/1) and yellowish-brown (10YR 5/4) silty clay loam; weak, coarse, prismatic, breaking to weak, coarse and medium, subangular blocky structure; slightly hard, friable; continuous clay films on faces of peds; many fine pores; many, fine and medium-sized manganese and iron stains; many soft, dark-brown iron concentrations; gradual, wavy boundary.

C1 42 to 60 inches, light olive-brown (2.5Y 5/4), light silty clay loam or heavy silt loam, light yellowish brown (2.5Y 6/4) when dry; many yellowish brown and gray mottles; weak, coarse prismatic structure to massive; slightly hard, very friable; many pores and fine channels; many dark-brown iron stains; common, very dark gray or black manganese stains and concretions.

C2 60 to 90 inches, generally similar in morphology to C1 horizon but many soft iron concretions; calcareous below a depth of 73 inches.

Climatic data (Fremont, Nebr.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	23	27	38	52	63	73	78	76	67	56	39	28	52
Mean precipitation, 1931-52 (inches)	1.2	1.2	1.8	2.4	3.5	4.6	3.3	3.6	2.7	1.5	1.2	0.9	27.9

Annual precipitation more than 17.2 and less than 38.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-6	Ap	0.2	0.1	0.1	0.2	3.4	59.9	36.1	43.3	20.1			2.01	11
6-10	B1	---	---	---	---	3.2	58.6	38.2	41.4	20.4			1.13	11
10-22	B21	---	---	---	.1	3.1	62.3	34.5	43.7	21.8		1.34	.63	10
22-32	B22	---	---	---	.1	3.3	64.7	31.9	43.6	24.5			.31	8
32-42	B3	---	.1	---	.1	2.8	65.1	31.9	41.9	26.2			.21	
42-60	C1	---	---	---	.3	3.6	66.6	29.5	46.6	23.8		1.31	.14	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1
27.0	15.9	6.0	10.3	---	1.0	85	6.1
29.0	17.5	7.2	7.6	0.1	.7	88	6.3
26.2	16.9	7.6	6.8	.1	.5	96	6.5
24.8	16.2	7.2	5.6	.1	.5	97	6.7
25.1	16.8	7.5	3.6	.2	.5	100	6.8
24.5	16.4	7.3	3.6	.2	.5	100	6.8

*Exchange acidity.

Profile No. 3

Area: Hand County, South Dakota.
Vegetation: (natural) mid and short grasses.
Parent material: Loess
Topography: Less than 5 percent slope.

- A1 — 0 to 3½ inches, very dark brown (10YR 2/2) silt loam, very dark grayish brown (10YR 3/2) when dry; weak, fine, granular structure; clear, smooth boundary.
- B21t — 3½ to 8 inches, very dark grayish-brown (10YR 3/2) silty clay loam, dark grayish brown (10YR 4/2) when dry; weak to moderate, medium and fine, prismatic, breaking to medium and fine, subangular blocky structure; slightly hard, friable; thin, patchy clay films on faces of prisms; gradual, smooth boundary.
- B22t — 8 to 14 inches, very dark grayish-brown (10YR 3/2) silty clay loam, dark grayish brown (10YR 4/2) when dry; moderate, medium, prismatic, breaking to medium and fine, subangular blocky structure; slightly hard, friable; prisms coated with very dark brown (10YR 2/2); thin, continuous clay films on faces of prisms; clear, smooth boundary.
- B3ca — 14 to 19 inches, olive-brown (2.5Y 4/4), heavy silt loam, grayish brown (2.5Y 5/2) when dry; few, fine mottles of dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/8) when dry; weak to moderate, coarse and medium, prismatic, breaking to weak, coarse and medium subangular blocky structure; slightly hard, friable; thin, continuous clay films on faces of prisms; common, medium and small, soft segregations of lime; calcareous; clear, smooth boundary.
- C1ca — 19 to 26 inches, olive-brown (2.5Y 4/4), heavy silt loam, light olive brown (2.5Y 5/4) when dry; few, fine, dark yellowish-brown mottles, yellowish brown (10YR 5/8) when dry; weak, coarse, prismatic, breaking to coarse and medium, subangular blocky structure; slightly hard, friable; patchy clay films on prism faces; common, medium and small lime segregations; calcareous; clear, irregular boundary.
- IIC2ca — 26 to 35 inches, mottled olive-brown (2.5Y 4/4), grayish-brown (2.5Y 5/2), and dark yellowish-brown (10YR 4/4) clay loam, olive brown (2.5Y 4/4), light brownish gray (2.5Y 6/2), and yellowish brown (10YR 5/8) when dry; weak, coarse and medium, prismatic structure; hard, firm; thin, patchy clay films on vertical faces of peds; many soft, and common hard, small and medium lime segregations; calcareous; clear, irregular boundary.
- IIC3ca — 35 to 42 inches, light olive-brown (2.5Y 5/4), heavy silty clay loam, light yellowish brown (2.5Y 6/4) when dry; common, fine, dark yellowish-brown (10YR 4/4) and black (10YR 2/1) mottles, yellowish brown (10YR 5/8) and very dark gray (10YR 3/1) when dry; weak, coarse and medium, prismatic structure; hard, firm; few, medium and small lime segregations; calcareous; clear, irregular boundary.
- IIC4ca — 42 to 60 inches, dark grayish-brown (2.5Y 4/2) clay loam, grayish brown (2.5Y 5/2) when dry; common, fine mottles of light olive brown (2.5Y 5/4) and gray (N 5/), pale yellow (2.5Y 7/4) and light gray (N 6/) when dry; few, very fine mottles of yellowish red (5YR 5/8), yellowish brown (10YR 5/8) when dry; massive to weak, very thick, platy structure; few, medium and small, hard and soft lime segregations; calcareous.

Climatic data (Miller, S. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	16	19	31	47	59	68	76	73	63	50	33	22	46
Mean precipitation, 1931-52 (inches)	0.6	0.5	1.2	2.1	2.5	3.9	2.1	1.9	1.4	1.3	0.6	0.4	18.2

Annual precipitation more than 10.3 and less than 26.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
0-3½	A1	0.6	0.8	0.9	2.5	6.2	62.6	26.4	46.3	24.1	Tr.		4.62	13
3½-8	B21t	.2	.7	.8	2.0	5.7	56.3	34.3	40.8	22.4	--		2.31	11
8-14	B22t	.1	.5	.5	1.5	6.5	59.5	31.4	42.8	24.1	--		1.50	10
14-19	B3ca	.3	.6	.6	1.9	7.8	63.1	25.7	42.6	29.6	--		.99	9
19-26	C1ca	.9	1.2	1.1	3.4	10.2	57.2	26.0	44.1	25.5	2.3		.54	8
26-35	IIC2ca	1.4	2.7	3.0	7.8	9.7	44.0	31.4	31.6	27.3	2.4		.33	
35-42	IIC3ca	.8	1.6	1.6	4.5	4.4	47.0	40.1	15.4	38.9	Tr.		.36	
42-60	IIC4ca	2.3	3.7	3.3	9.6	8.5	38.4	34.2	26.3	26.0	5.8		.30	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Exch. Na %	pH sat. paste	E. C. mmhos. per cm. at 25° C.	$CaCO_3$ equiv. % v
27.5	20.0	5.8	5.9	--	1.7	--	6.8	0.9	1
27.0	17.4	7.1	5.0	--	1.3	--	6.1	.6	1
24.6	18.3	6.8	3.0	0.1	.7	--	6.9	.7	1
18.2				.1	.4	--	7.9	.6	16
17.9				.2	.4	1	7.9	.7	15
21.0				1.4	.4	6	8.0	.8	15
23.4				3.4	.4	12	8.4	.8	21
22.2				5.2	.6	20	8.6	1.0	12

*Exchange acidity.

Profile No. 4

Area: Dickey County, North Dakota.
Vegetation: Small grain; (natural) tall and mid grasses.
Parent material: Glacial lacustrine materials.
Topography: $\frac{1}{2}$ percent slope; glacial lake plain.

Ap 0 to 6 inches, very dark gray (10YR 3/1) fine sandy loam, dark gray (10YR 4/1) when dry; weak, fine, granular structure; slightly hard, very friable; clear boundary.

A2 6 to 7 inches, very dark gray (10YR 3/1) fine sandy loam, light gray (10YR 7/1) when dry; weak, thin, platy structure; hard, very friable; abrupt boundary.

B21t 7 to $9\frac{1}{2}$ inches, black (10YR 2/1) sandy clay loam, dark gray (10YR 4/1) when dry; strong, medium, columnar structure; rounded tops of peds have discontinuous coatings that are $\frac{1}{4}$ inch thick and are gray (10YR 5/1) when dry; extremely hard, very firm.

B22t $9\frac{1}{2}$ to 12 inches, black (10YR 2/1) sandy clay loam, dark gray (10YR 4/1) when dry; interiors of peds very dark brown (10YR 2/2); strong, medium, columnar structure; extremely hard, very firm; clear boundary.

B23t 12 to 17 inches, black (10YR 2/1) sandy clay loam, dark grayish brown (2.5Y 4/2) when dry; interiors of peds very dark brown (10YR 2/2), very dark grayish brown (2.5Y 3/2) when dry; compound, weak, medium, prismatic and moderate, fine, subangular blocky structure; very hard, firm; very few lime segregations; clear, irregular boundary.

C1ca 17 to 24 inches, grayish-brown (2.5Y 5/2) clay loam, white (2.5Y 8/2) when dry; olive-brown (2.5Y 4/4) and light-gray (N 6/) mottles; compound, weak, coarse, prismatic and fine, subangular blocky structure; friable; common segregations of lime; calcareous; gradual boundary.

C2ca 24 to 36 inches, mottled olive-yellow (2.5Y 6/6), light yellowish-brown (2.5Y 6/4), and light brownish-gray (2.5Y 6/2) silt loam, pale yellow (2.5Y 7/4) when dry; compound weak coarse prismatic and fine subangular blocky structure; friable; calcareous; clear boundary.

C4g 36 to 49 inches, light-gray (5Y 6/1) silt loam, white (5Y 8/1) when dry; strong-brown (7.5YR 5/8) and dark-brown (7.5YR 3/2) mottles; weak, thin, platy (laminated) structure; friable; calcareous; gradual boundary.

C5g 49 to 60 inches, colors as in the horizon above; silt loam; moderate, thin, platy (laminated) structure; friable; a few, soft segregations of lime.

Climatic data (Oakes, N. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	9	12	26	43	56	65	72	70	59	47	29	15	42
Mean precipitation, 1931-52 (inches)	0.4	0.6	1.0	1.7	2.2	3.7	2.5	2.1	1.2	1.2	0.7	0.5	17.7

Annual precipitation more than 10.8 and less than 24.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-6	Ap	0.4	6.3	10.1	30.3	8.2	27.1	14.7		17.4			2.71	14
6-7	A2	.3	5.8	9.8	27.4	12.3	30.4	10.8		19.0			2.11	12
7-$9\frac{1}{2}$	B21t	0	4.7	7.5	28.1	5.6	28.2	20.0		19.4			1.25	13
$9\frac{1}{2}$-12	B22t	0	4.1	7.6	32.7	1.9	23.2	26.1		13.1			1.09	13
12-17	B23t	0	4.0	5.8	37.5	2.1	23.1	24.8		14.0			.61	13
17-24	C1ca	0	2.0	3.1	19.7	1.4	36.9	36.4		27.4			.14	
24-36	C2ca	0	2.5	1.6	11.1	.8	59.2	25.9		54.8			.30	
36-49	C4g	0	.9	.8	3.6	.8	70.9	23.8		70.5			.30	
49-60	C5g	0	0	.8	5.0	.7	69.3	23.6		68.2			.28	

Cation exch. cap.[b]	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	Exch. Na %	pH sat. paste	$CaCO_3$ % v
19.3	13.7	4.8		0.62	0.95	3.2	7.2	
15.4	9.6	4.6		1.81	.48	11.8	7.7	
20.5	10.0	8.1		4.9	.67	2.40	8.1	
23.2	11.0	10.8		10.0	.74	43.0	8.5	
19.7	11.6	12.5		8.1	.72	41.0	8.9	1.6
14.7	17.2	12.9		6.0	.52	40.7	9.4	30.1
14.9	15.6	10.7		4.8	.55	32.2	9.1	26.7
18.9	16.7	12.9		6.0	.47	31.7	8.9	20.0
20.0	18.2	12.3		5.4	.53	27.0	8.6	14.8

Profile No. 5

Area: Clallam County, Washington.
Vegetation: Brackenfern.
Parent material: Alluvium from basic volcanic ash.
Topography: Gently undulating terraces.

A11 — 0 to 8 inches, black (10YR 2/1) silt loam, very dark gray (10YR 3/1) when dry; strong, fine, granular structure; friable, plastic, slightly sticky; abundant roots, many of them fern roots as much as ½ inch in diameter; diffuse boundary.

A12 — 8 to 16 inches, black (10YR 2/1) silt loam, very dark gray (10YR 3/1) when dry; strong, medium, granular structure; friable, plastic, slightly sticky; abundant roots; gradual, wavy boundary.

A13 — 16 to 23 inches, very dark brown (10YR 2/2) silt loam, dark grayish brown (10YR 4/2) when dry; moderate, medium, granular structure; friable, plastic, slightly sticky; plentiful roots; diffuse, wavy boundary.

A14 — 23 to 32 inches, similar to horizon just above, but ¼ to ½ unit higher in color value; clear, wavy boundary.

B21 — 32 to 48 inches, dark-brown (10YR 4/3) silt loam, pale brown (10YR 6/3) when dry; weak to moderate, fine, subangular blocky structure; friable to firm, plastic, slightly sticky; few roots; many fine, tubular pores; numerous krotovinas; very thin, patchy clay films in pores and vertical fractures; diffuse, wavy boundary.

B22 — 48 to 70 inches, dark yellowish-brown (10YR 4/4) silt loam; very pale brown (10YR 7/4) when dry; massive with vertical fractures 3 to 6 inches apart; firm, plastic, slightly sticky; few roots; common fine pores; colloidal staining on fractures and in pores; few, fine, yellowish red (5YR 4/8) mottles on surfaces of fractures and in some root channels; numerous krotovinas; diffuse, wavy boundary.

B23 — 70 to 80 inches, very similar to horizon just above, but fractures are 3 to 12 inches apart; occasional pebbles ¼ inch in diameter; diffuse, wavy boundary.

C — 80 to 96 inches, dark yellowish-brown (10YR 4/4) silt loam, very pale brown (10YR 7/4) when dry; massive; firm, slightly sticky, slightly plastic; few roots; common fine pores; few krotovinas; few, fine, yellowish red (5YR 4/8) mottles in root channels; occasional fine pebbles.

Comments: The entire profile has a very smeary feel; the longer the soil is rubbed between the fingers, the finer it becomes.

Climatic data (Forks, Wash.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	39	40	43	47	52	56	60	60	58	52	44	40	49
Mean precipitation, 1931-52 (inches)	16.7	14.4	12.6	8.2	5.1	3.6	2.6	2.1	5.0	11.3	14.6	19.7	115.9

Annual precipitation more than 92.5 and less than 139.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C %[w]	C/N[k]
0-8	A11	0.4	0.6	0.3	1.0	3.4	74.8	19.5	38.7	40.2	0		16.32	21
8-16	A12	.7	.7	.3	1.5	4.2	75.5	17.1	41.7	39.1	0		13.80	21
16-23	A13	.1	.8	.8	2.3	4.5	80.7	10.8	43.4	43.3	0		9.42	20
23-32	A14	.0	.4	.4	1.9	9.1	82.6	5.6	50.7	42.4	0		6.52	20
32-48	B21	.1	.1	.2	4.6	9.7	80.9	4.4	56.7	37.7	0		1.63	13
48-70	B22	.1	.7	.5	1.2	4.0	88.9	4.6	49.1	44.6	0		.80	10
70-80	B23	.6	1.6	.8	1.2	1.8	88.4	5.6	38.3	52.6	2		.71	8
80-96	C	.7	1.5	1.1	1.6	2.5	86.7	5.9	38.6	51.8	3		.96	11

Cation exch. cap.[f]	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. %[b]	pH sat. paste	Moisture tensions 1/3 atmos.	15 atmos.	Air-dry moisture %
80.8	3.0	2.1	52.5	0.3	0.0	9	5.3	59.2	28.9	10.4
65.0	1.0	.9	52.2	.3	.3	5	5.1	53.4	24.2	10.2
59.2	.6	.6	47.2	.3	.1	3	5.2	48.4	20.9	8.6
42.1	.4	.4	41.4	.2	.0	2	5.5	44.8	19.0	7.4
23.4	.2	.3	22.5	.1	.0	3	5.7	36.8	14.9	5.3
19.4	.2	.1	15.8	.1	.0	2	5.8	36.7	11.6	4.2
17.0	.2	.1	15.5	.1	.0	3	5.8	37.7	11.2	3.9
21.3	.2	.1	17.2	.2	.0	3	6.0	38.3	12.7	4.6

*Exchange acidity.

Profile No. 6

Area: Craven County, North Carolina.
Vegetation: Mainly pine forest.
Parent material: Acid Coastal Plain materials.
Topography: Level, less than 1 percent slope; elevation about 35 feet.

All 0 to 6 inches, mainly black (10YR 2/1) sandy loam, but mixed with white, which results in a salt and pepper effect; granular structure; very friable; many large, medium and fine roots growing parallel to the ground surface.

A12 6 to 12½ inches, black (10YR 2/1) sandy loam; granular structure; friable; many fine roots; wavy boundary.

B21tg 12½ to 22 inches, grayish-brown (10YR 5/2) to dark grayish-brown (10YR 4/2) sandy clay loam; coarse, subangular blocky, breaking to fine, subangular and angular blocky structure; sticky, plastic; tongues of black (10YR 2/1) materials extending along root channels from horizon above.

B22tg 22 to 32 inches, gray (10YR 5/1) sandy clay loam; many brownish-yellow (10YR 6/8) mottles; coarse, prismatic, breaking to fine, subangular blocky structure; clay films on both horizontal and vertical faces of peds, but more prominent on the vertical faces; sticky, plastic; a number of large root channels filled with black material from the A1 horizon; plentiful roots.

IIA1b 32 to 40 inches, very dark grayish-brown (10YR 3/2) sandy loam; granular structure; firm.

IICb 40 to 50 inches, light brownish-gray (10YR 6/2) to grayish-brown (10YR 5/2) loamy sand; small lenses of white sand; very friable.

Climatic data (New Bern, N. C.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	47	47	54	63	71	78	80	79	75	65	55	47	64
Mean precipitation, 1931-52 (inches)	3.4	4.0	3.9	3.4	4.0	4.6	8.8	6.8	6.3	3.0	3.8	4.2	56.1

Annual precipitation more than 43.6 and less than 68.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N b
0-6	A11	1.3	9.6	26.4	24.8	4.5	20.1	13.3	17.4	13.2	0		5.3	27
6-12½	A12	.2	8.3	27.4	25.9	4.8	16.1	17.3	15.8	11.4	0		1.61	26
12½-22	B21tg	.4	7.8	23.9	21.5	4.5	16.9	25.0	15.0	12.0	0		.42	8
22-32	B22tg	.4	7.4	24.0	21.1	4.0	16.4	26.7	13.9	11.6	0		.30	
32-40	IIA1b	.3	9.7	31.2	27.0	4.6	12.1	15.1	14.5	8.5	-		.61	
40-50	IICb	.3	8.4	35.8	34.4	6.0	8.5	6.6	16.8	5.2	0		.05	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1
26.2	0.4	0.4	24.9	0.2	0.3	5	3.9
15.0	.1	.1	14.8	<.1	<.1	1	4.4
11.7	.1	.1	11.4	<.1	.1	3	4.2
12.1	<.1	<.1	12.0	<.1	.1	1	4.2
9.0	.1	<.1	8.8	<.1	.1	2	4.3
2.6	<.1	<.1	2.6	<.1	<.1	<1	4.6

*Exchange acidity.

Profile No. 7

Area: Columbia County, Oregon
Vegetation: Coniferous forest; fir, cedar, and hemlock.
Parent material: Residuum from basalt, with some volcanic ash.
Topography: 8 percent slope; upland; elevation 1,200 feet.

O1 1 to 0 inch, litter of needles with a thin fermentation layer.

A1 0 to 3 inches, dark reddish-brown (5YR 3/2) silt loam, dark brown (7.5YR 4/2) when dry; strong, coarse to fine, granular structure; very friable, slightly sticky, slightly plastic; many medium pellets; abundant roots; clear, smooth boundary.

3 to 10 inches, dark reddish-brown (5YR 3/2) silt loam, reddish brown (5YR 4/4) when dry; strong, fine and very fine, subangular blocky structure; very friable, slightly sticky, slightly plastic; common, medium pellets; abundant roots; gradual, smooth boundary.

B1 10 to 15 inches, dark reddish-brown (5YR 3/3) silt loam, reddish brown (5YR 5/3) when dry; moderate to strong, fine and very fine, subangular blocky structure; friable, slightly sticky, slightly plastic; few thin, patchy clay films; few rock fragments or pellets; abundant roots; diffuse, smooth boundary.

B2 15 to 23 inches, dark reddish-brown (5YR 3/4) silt loam, reddish brown (5YR 5/3) when dry; moderate; fine and very fine, subangular blocky structure; friable, slightly sticky, slightly plastic; few thin, patchy clay films on vertical and horizontal ped surfaces and in pores; few rock fragments or pellets; abundant roots; gradual, smooth boundary.

B3 23 to 31 inches, dark reddish-brown (5YR 3/3) loam, reddish brown (5YR 5/3) when dry; moderate, fine, subangular blocky structure; friable, slightly sticky, slightly plastic; few thin, patchy clay films on vertical and horizontal ped surfaces and in pores; many roots; gradual, smooth boundary.

R&C 31 to 44 inches, dark-brown (10YR 4/3) silt loam, brown (10YR 5/3) when dry; massive; friable, slightly sticky, plastic; weathered rock fragments make up more then 50 percent by volume of the soil mass; gradual, smooth boundary.

R 44 to 50 inches, fragmented, weathered, basic igneous rock.

Climatic data (Vernonia, Oreg.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1938-52 (Deg. F.)	36	40	43	48	53	57	62	62	59	51	43	39	49
Mean precipitation, 1938-52 (inches)	6.5	6.7	4.8	2.7	2.0	1.3	0.5	0.6	1.6	4.4	6.8	7.5	45.4

Annual precipitation more than 32.1 and less than 58.7 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-3	A1	9.0	5.3	2.0	4.3	7.3	55.2	16.9	32.3	32.7	44.3		4.50	22	4.0
3-10	A3	4.4	4.3	2.0	4.7	8.4	60.2	16.0	36.2	35.2	36.9		1.60	16	4.4
10-15	B1	2.7	3.5	2.1	5.0	9.5	60.5	16.7	39.1	34.0	22.8		.71	12	3.8
15-23	B2	2.9	3.4	2.3	5.1	8.4	61.3	16.6	40.7	32.3	16.5		.41	11	4.1
23-31	B3	2.5	10.8	9.2	17.4	9.9	33.0	17.2	31.9	21.1	----		.54	20	5.4
31-44	R and C	1.0	3.7	3.5	9.1	10.7	52.8	19.2	41.1	28.4	----		.45	18	4.0
44-50+	R	3.3	9.0	7.2	15.8	12.4	33.7	18.6	35.5	20.2	----		.54	34	8.9

Cation exch. cap. b	Extractable cations, meq./100 gm. Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1
42.7	20.2	2.7	18.2	0.2	1.4	57	5.9
27.7	8.8	2.6	15.6	.1	.6	44	5.5
21.2	5.8	1.8	13.0	.2	.4	39	5.4
21.2	7.4	2.0	11.4	.1	.3	46	5.3
45.0	21.3	7.9	14.9	.4	.5	67	4.8
31.2	13.1	4.5	13.0	.2	.4	58	5.0
42.5	19.3	9.1	13.3	.3	.5	69	4.8

*Exchange acidity.

Profile No. 8

Area: Prineville Area, Oregon.
Vegetation: Small sage, cheatgrass, big sage, rabbitbrush.
Parent material: Pumice and water-laid materials.
Topography: Level basin; 3,130 feet elevation.

A1 0 to 2 inches, dark grayish-brown (10YR 4/2) silt loam, gray (10YR 5/1) when dry; vesicular where undisturbed, grading with depth to weak, thin, platy structure; slightly hard, friable, sticky, slightly plastic; silt flows in vesicles; small amount of fine and medium grains of pumice; clear, smooth boundary.

A2 2 to 5 inches, gray (10YR 5/1) silt loam, light gray (10YR 7/1) when dry; moderate, thin and very thin, platy structure; slightly hard, firm, sticky, slightly plastic; abrupt, irregular boundary.

B21t 5 to 13 inches, very dark grayish-brown (2.5Y 3/2), light clay or silty clay, light brownish gray (10YR 6/2) to grayish brown (2.5Y 5/2) when dry; moderate, medium columnar, breaking to strong, fine, blocky structure; hard, very firm, very sticky, plastic; thick, continuous clay films on ped faces; bleached, gray (10YR 5/1) silt coatings on tops of columns and on ped faces in vertical cracks between columns; neutral; clear, wavy boundary.

B22t 13 to 22 inches, dark grayish-brown (2.5Y 4/2), light clay or silty clay, grayish brown (2.5Y 5/2) when dry; moderate, medium and coarse, prismatic, breaking to strong, fine and medium, blocky structure; hard, firm to very firm, sticky, plastic; thick, continuous clay films; gradual, smooth boundary.

B3 22 to 32 inches, dark grayish-brown (2.5Y 4/2), light clay or silty clay, grayish brown (2.5Y 5/2) when dry; angular and subangular blocky structure; hard, firm to very firm, sticky, plastic; continuous, moderately thick clay films on peds and in pores; a higher proportion of pumice than in horizon just above; gradual, smooth boundary.

C1 32 to 44 inches, dark grayish-brown (2.5Y 4/2), light clay or silty clay, grayish brown (2.5Y 5/2) when dry; moderate, fine and medium, blocky structure; hard, firm to very firm, sticky, plastic; gradual, smooth boundary.

C2 44 to 60 inches, very dark grayish-brown (2.5Y 3/2), light clay or silty clay; dark grayish brown (2.5Y 4/2) when dry; massive to weak, platy structure; hard, firm to very firm, sticky, plastic; lacustrine sediments mixed with some pumice.

Climatic data (Prineville, Oreg.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	30	34	40	46	52	57	63	62	56	48	38	33	47
Mean precipitation, 1931-52 (inches)	0.9	0.7	0.7	0.7	1.1	1.3	0.3	0.3	0.5	0.9	1.1	1.0	9.5

Annual precipitation more than 5.9 and less than 13.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C %[w]	C/N[k]
0-2	A1	0.4	2.0	2.3	9.2	10.5	62.7	12.9	47.6	31.6	0		1.39	12
2-5	A2	.1	1.6	2.1	7.6	9.1	61.5	18.0	39.5	36.2	0		.66	11
5-13	B21t	.1	.6	1.0	2.4	1.9	31.3	62.7	17.8	16.8	0		.48	10
13-22	B22t	.1	.9	1.2	2.7	1.9	31.4	61.8	12.7	22.1	1		.28	8
22-32	B3	.1	.8	1.1	2.4	1.9	35.1	58.6	13.9	24.4	0		.20	8
32-44	C1	.1	.6	.8	1.9	2.1	36.9	57.6	15.0	25.2	0		.17	8
44-60	C2	.0	.5	1.0	2.6	2.5	39.7	53.7	21.2	22.5	0		.17	8

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. %[b]	pH sat. paste
18.8	7.0	3.8	5.5	0.4	1.7	70	6.2
16.9	6.8	4.2	2.7	.8	1.2	83	6.6
58.7	25.1	16.6	4.2	2.8	2.6	92	6.6
54.0	24.6	16.8	3.2	3.0	2.5	94	6.9
47.1	22.5	17.0	2.0	2.6	2.6	96	7.4
50.0	19.8	14.2	1.4	4.1	4.2	97	7.6
49.5	26.3	11.6	1.5	3.3	2.8	97	7.7

*Exchange acidity.

Profile No. 9

Area: Erath County, Texas.

Vegetation: Deciduous forest; moderately dense.

Parent material: Sandy clay or soft sandstone and clay.

Topography: Plane surface; 2 percent slope facing southeast; upland.

A1 0 to 3 inches, very dark grayish-brown (10YR 3/2) loamy very fine sand, dark grayish brown (10YR 4/2) when dry; weak, fine, granular structure; very friable; plentiful roots, uniformly distributed; gradual boundary.

A2 3 to 15 inches, light yellowish-brown (10YR 6/4) loamy very fine sand, very pale brown (10YR 7/3) when dry; structureless; nearly loose; plentiful roots, uniformly distributed; a transitional layer of very friable fine sandy loam to light sandy clay loam, ½ to 1 inch thick, at bottom of this horizon is actually an interfingering of the two horizons.

B21t 15 to 23 inches, yellowish-red (5YR 4/8) sandy clay, yellowish red (5YR 4/6) when dry; moderate, medium and coarse, blocky structure; very hard, very firm, plastic to strongly plastic; crushed surfaces are slightly less dark than when uncrushed; dark streaks along common root and worm channels; gradual boundary.

B22t 23 to 33 inches, yellowish-red (5YR 4/6) sandy clay loam, yellowish red (5YR 5/8) when dry; few mottles of light yellowish brown (10YR 6/4) and reddish yellow (7.5YR 6/6); medium and coarse, blocky structure; very hard, very firm, plastic to strongly plastic; uncrushed surfaces are slightly darker than when crushed; dark streaks along a few worm and root channels; gradual boundary.

B3 33 to 40 inches, mottled red (2.5YR 4/8) and reddish-yellow (7.5YR 6/8) sandy clay with thin lenses of sandy loam or loam, red (2.5YR 4/6) and reddish yellow (7.5YR 6/6) when dry; mottles are fine; weak, coarse, prismatic, breaking readily to weak, coarse, blocky structure; hard, firm, plastic; uncrushed surfaces are darker than when crushed; gradual boundary.

C1 40 to 51 inches, reddish-yellow (7.5YR 6/8) sandy clay with lenses and pockets of sandy loam and sandy clay loam, reddish yellow (7.5YR 6/6) when dry; medium mottles of red (2.5YR 5/6) and light red (2.5YR 6/8) red (2.5YR 4/6) when dry; weak, coarse, prismatic, breaking readily to weak, fine and medium, blocky structure; hard, friable, plastic; gradual boundary.

C2 51 to 62 inches, finely mottled light-red (2.5YR 6/8), light-brown, and brown, stratified sandy clay or clay and sandy clay loam with little or no structure.

Climatic data (Dublin, Tex.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	45	48	55	64	71	80	83	84	77	68	55	48	65
Mean precipitation, 1931-52 (inches)	2.3	2.5	2.0	3.3	5.5	3.1	1.9	1.8	3.6	2.3	2.1	2.4	32.7

Annual precipitation more than 18.8 and less than 46.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C %	C/N
0-3	A1	0	0.3	3.2	56.6	21.5	14.0	4.4		3.9			0.79	
3-15	A2	.1	.3	3.2	62.4	21.4	9.4	3.2		3.1			.16	
15-23	B21t	0	.2	2.3	41.3	15.1	6.1	35.0		2.2			.49	
23-33	B22t	0	.1	1.8	35.8	15.1	26.2	21.0		20.6			.41	
33-40	B3	0	.1	1.4	31.4	17.4	13.4	36.3		3.4			.30	
40-51	C1	0	.1	1.4	33.0	18.4	17.4	29.7		3.8			.15	
51-62	C2	0	.1	1.6	39.6	17.1	20.1	21.5		5.1			.20	

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. %	pH 1:1
5.6	1.9	0.6	2.6		0.4	54	5.6
1.9	1.0	.2	.5		.2	74	5.7
18.6	8.4	3.7	6.1		.4	67	5.2
21.1	9.1	4.2	7.3		.5	65	5.0
19.9	8.9	4.2	6.3		.5	68	5.1
17.1	8.3	3.9	4.5		.4	74	5.3
11.2	7.0	.8	3.0		.4	73	5.4

*Exchange acidity

Profile No. 10

Area: Yugoslavia.

Vegetation: Small grain; (probable natural) open-park forest; Mediterranean oak and grass.

Parent material: Residuum from limestone, probably mixed with eolian or other sediments.

Topography: About 2 percent slope; facing northwest.

Ap 0 to 6 inches, dark reddish-brown (between 5YR 3/3 and 2.5YR 3/3) silty clay; strong, fine, granular structure; friable, sticky, plastic; abrupt, smooth boundary.

B11 6 to 9 inches, dark reddish-brown (5YR 3/3) silty clay, reddish brown (5YR 4/3) when dry, (a weak plowpan), strong, coarse, prismatic, breaking with slight pressure to fine, blocky structure; very hard, very firm, sticky plastic; patchy clay films; a few ½- to 1-inch fragments of limestone; diffuse boundary.

B12 9 to 16 inches, dark reddish-brown (5YR 3/3) silty clay, reddish brown (5YR 4/3) when dry; moderate clay skins on 40 to 60 percent of ped faces, and thin clay skins on the remainder; clay skins are dusky red (2.5YR 3/2) to dark reddish-brown (2.5YR 2/4) when dry; strong, coarse, prismatic, breaking with slight pressure to fine, blocky structure; very hard, very firm, sticky, plastic; diffuse boundary.

B21 16 to 22 inches, dark reddish-brown (between 5YR 3/3 and 2.5YR 3/3) silty clay, reddish brown (5YR 4/3) when dry; continuous clay skins on ped faces; clay skins dusky red (2.5YR 3/2) to dark reddish brown (2.5YR 2/4) when dry; moderate, coarse, subangular blocky, breaking to fine, blocky structure; very firm, sticky, plastic; plentiful roots; many medium pores 1 to 2 millimeters in diameter.

B22 22 to 36 inches, dark reddish-brown (between 2.5YR 2/4 and 2.5YR 3/4) silty clay, dark reddish brown (2.5YR 3/4) when dry; crushed colors are dark reddish brown (between 5YR 3/4 and 2.5YR 3/4), reddish brown (between 5YR 4/4 and 2.5YR 4/4) when dry; weak, coarse, prismatic, breaking to medium and fine, subangular blocky structure; continuous thick clay skins, wavy boundary; depth to rock varies from about 20 to 80 inches within a field.

R 36 to 44 inches, fractured limestone with penetrations of clay and calcite between fragments; rock fragments 2 to 5 inches in diameter, irregular, some edges rounded by solution.

Climatic data (Pula, Yugoslavia)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 44 years (deg. F.)	40	42	47	53	61	69	74	73	66	58	50	44	57
Mean precipitation, 1931-40 (inches)	2.0	1.7	2.2	1.5	2.1	1.6	1.8	1.5	3.5	3.1	4.2	2.3	27.5

Annual precipitation more than 16.2 and less than 38.8 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	C/N c	Free iron oxides Fe_2O_3 %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-6	Ap	0.5	0.4	0.1	0.3	1.6	51.3	45.8	25.3	27.8		1.66	1.68	10	5.0
6-9	B11	.5	.3	.1	.3	1.5	51.5	45.8	26.8	26.4		1.71	1.57	10	5.1
9-16	B12	.4	.2	.1	.3	1.3	50.9	46.8	22.6	29.8		1.64	1.34	9	5.0
16-22	B21	.2	.2	.1	.3	1.1	48.1	50.0	20.2	29.2		1.63	1.20	10	5.2
22-36	B22	<.1	.1	<.1	.2	.8	23.1	75.8	9.9	14.1		1.67	.84	8	7.5

Cation exch. cap. b	Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Cation exch. cap. s	Base sat. % b
	Extractable cations, meq./100 gm.								
14.7	15.8	1.5	6.6	0.1	0.4	73	6.9	24.4	121
17.3	13.8	1.4	7.0	.1	.3	69	6.7	22.6	90
17.4	12.2	1.2	9.0	.2	.2	60	6.6	22.8	79
18.0	11.7	1.2	9.5	.2	.2	58	6.4	22.8	74
27.4	18.8	2.0	13.0	.2	.3	62	6.2	34.3	78

*Exchange acidity.

Profile No. 11

Area: Knox County, Indiana.
Vegetation: Small grain; (natural) oak-hickory forest.
Parent material: Loess.
Topography: 2 percent slope.

Ap 0 to 6 inches, dark grayish-brown (10YR 4/2) to brown (10YR 4/3) silt loam; weak, medium, granular structure; friable; abrupt, smooth boundary.

A2 6 to 9 inches, brown (10YR 5/3) to dark grayish-brown (10YR 4/2) silt loam; penetration of material from Ap horizon into top of layer along root channels and wormcasts; moderate, thin, platy structure; friable; clear, wavy boundary.

B21t 9 to 13 inches, brown to dark-brown (7.5YR 4/4), heavy silt loam; very few peds coated with brown (10YR 5/3) to pale brown (10YR 6/3); a few very thin coatings of very dark brown (10YR 2/2); moderate, fine, subangular blocky structure; firm; clear, wavy boundary.

B22t 13 to 22 inches, brown (7.5YR 4/4), heavy silt loam to light silty clay loam; moderate to strong, coarse subangular blocky, breaking to fine subangular blocky structure; firm; numerous thin, dark reddish-brown (5YR 3/4 to 3/3) clay films; common coatings of very dark brown (10YR 2/2); clay films; gradual, wavy boundary.

B23t 22 to 32 inches, brown (7.5YR 4/4) light silty clay loam to heavy silt loam; moderate to weak, coarse and very coarse, subangular blocky structure; dark reddish-brown (5YR 3/4) clay films are less numerous than in the above horizon; numerous very dark-brown (10YR 2/2) coatings and streaks that become more conspicuous with increasing depth; firm; gradual, wavy boundary.

B3 32 to 48 inches, brown (7.5YR 4/4) silt loam; weak to very weak, very coarse, subangular blocky structure; friable; a few dark reddish-brown (5YR 3/3 - 3/4) clay films; very few coatings and streaks of light brownish gray (10YR 6/2), pale brown (10YR 6/3), and very dark brown (10YR 2/2); gradual, wavy boundary.

C 48 to 55 inches plus, brown (7.5YR 4/4) silt loam; an occasional thin crack filled with light brownish-gray (10YR 6/2) material; massive; friable.

Climatic data (Edwardsport, Ind.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	32	34	43	54	65	75	79	77	69	58	43	34	55
Mean precipitation, 1931-52 (inches)	3.9	2.5	4.1	4.0	3.9	4.4	3.6	3.3	3.4	2.5	3.3	2.9	41.7

Annual precipitation more than 27.8 and less than 55.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) u	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-6	Ap	0.2	0.4	0.3	0.5	1.6	84.2	12.8	44.9	41.2	Tr.	1.49	0.86	10	1.4
6-9	A2	---	.3	.4	.6	1.6	84.7	12.4	44.5	42.1	---	1.38	.85	10	1.2
9-13	B21t	.1	.4	.2	.4	1.1	76.1	21.7	35.3	42.1	---	1.45	.33	7	1.8
13-22	B22t	---	---	---	.2	1.0	69.3	29.5	35.2	35.2	---	1.45	.17	5	2.4
22-32	B23t	---	---	---	.1	1.4	71.3	27.2	39.6	33.2	---	1.46	.12	4	2.5
32-48	B3	---	---	---	---	1.3	76.2	22.5	43.7	33.8	---	1.48	.10		2.5
48-55+	C	---	---	---	---	.8	79.3	19.9	44.8	35.3	---		.08		2.4

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1	Base sat. % s	Cation exch. cap. s	Moisture tensions: 1/3 atmos.	15 atmos.
8.2	6.7	1.6	4.4	---	0.4	100	6.7	66	13.1	24.9	5.2
8.6	5.6	1.8	3.2	---	.3	90	6.3	71	10.9	25.9	5.2
10.4	7.0	2.6	4.1	0.1	.3	96	6.5	71	14.1	27.3	8.2
15.6	8.2	4.6	5.8	.1	.4	85	6.5	70	19.1	31.4	12.1
14.4	5.4	4.3	8.2	.1	.4	71	5.6	55	18.4	32.2	11.1
12.0	3.6	3.4	8.2	.1	.3	62	4.8	47	15.6	28.8	9.3
11.5	3.5	3.7	7.4	.1	.3	66	4.8	51	15.0	29.5	8.6

*Exchange acidity.

Profile No. 12

Area: Prentiss County, Mississippi.
Vegetation: (natural) mixed deciduous and pine forest.
Parent material: Thinly stratified, glauconitic, acid clay, sandy clay, and sand.
Topography: Rolling; relief 50 to 100 feet; Coastal Plain.

Ap 0 to 5 inches, grayish-brown (2.5Y 5/2) very fine sandy loam with very weak, granular structure; coarse mottles of yellowish brown (10YR 5/4), dark grayish brown (10YR 4/2), and very dark grayish brown (10YR 3/2) indicating uneven distribution of organic matter; matted with fine roots.

A2 5 to 7 inches, brownish-yellow (10YR 6/6) to yellowish-brown (10YR 5/4), heavy very fine sandy loam; very weak, coarse, granular structure; few roots.

B21t 7 to 14 inches, yellowish-red (5YR 5/6) clay; strong, medium, subangular blocky structure.

B22t 14 to 19 inches, yellowish-red (5YR 5/8) clay; scattered, small, yellow (10YR 7/8) mottles; strong, medium, subangular blocky structure; a few mica flakes.

B23t 19 to 31 inches, predominantly yellowish-red (5YR 5/8), heavy clay loam; intricately mottled with pale yellow (2.5Y 8/4) and gray; proportions of pale yellow and gray mottles increase and red decreases with depth; at bottom, layer is highly mottled red, pale yellow, and gray; strong, medium, blocky structure; hard; fine mica.

B3 31 to 37 inches, predominantly pale-olive (5Y 6/4) sandy clay loam; mottled with yellowish red (5YR 5/8); strong, medium, blocky structure; hard; common fine mica.

C1 37 to 47 inches, predominantly pale-olive (5Y 6/3) to light olive-gray (5Y 6/2) sandy clay loam; fine and medium mottles and streaks of yellowish red (5YR 5/8); strong, coarse, blocky structure; weak, prismatic; hard; fine mica flakes; glauconitic material evident.

C2 47 to 60 inches, same color as layer just above; micaceous sandy clay loam; less hard, slightly more friable than material in C1 horizon; largely glauconitic material.

Climatic data (Booneville, Miss.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	43	45	52	61	69	78	80	79	74	64	51	44	62
Mean precipitation, 1931-52 (inches)	6.2	5.7	6.3	4.5	4.1	3.6	4.1	3.8	3.3	3.1	4.7	5.8	55.1

Annual precipitation more than 32.3 and less than 77.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-5	Ap	0.1	0.3	0.3	11.6	53.9	22.4	11.4					1.6	24	0.6
5-7	A2	0	.1	.1	10.1	44.0	25.3	20.4					.58	12	1.4
7-14	B21t	0	.1	.1	3.6	31.5	14.9	49.8					.23	8	4.2
14-19	B22t	0	.1	.1	3.4	33.0	19.0	44.4					.17	6	3.4
19-31	B23t	0	.1	.1	3.8	37.5	21.1	37.4					.12	6	2.3
31-37	B3	0	.1	.1	6.4	40.4	18.7	34.3					.35	14	2.2
37-47	C1	0	.1	.1	6.7	42.6	18.9	31.6					.12	6	2.4
47-60	C2	0	.1	.2	8.3	43.5	15.6	32.3					.06	3	2.2

Cation exch. cap. a	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % a	pH 1:1
11.9	4.6	0.8	6.1	0.1	0.3	49	5.5
12.8	1.3	1.8	9.2	.1	.3	28	4.7
26.0	.7	3.6	21.2	<.1	.5	18	4.9
24.0	.6	3.4	19.7	<.1	.3	18	4.4
25.0	1.8	2.9	19.9	.1	.3	20	4.4
23.2	1.3	2.8	18.8	.1	.2	19	4.3
22.4	1.9	2.7	17.4	.1	.3	22	4.3
23.3	3.0	3.0	17.0	.1	.2	27	4.3

*Exchange acidity.

Profile No. 13 (Lab. data by Ohio Agr. Expt. Sta.)
Area: Allen County, Ohio.
Vegetation: Meadow; (natural) deciduous forest.
Parent material: Calcareous glacial till.
Topography: 3 percent slope; elevation 820 feet; till plain.

Ap1 0 to 7 inches, dark grayish-brown (10YR 4/2) loam, light brownish gray (10YR 6/2) when dry; weak, fine, granular structure; slightly hard, slightly sticky; abundant roots.

Ap2 7 to 10 inches, dark-brown (10YR 4/3) loam, pale brown (10YR 6/3) when dry; moderate, fine, subangular blocky structure; slightly hard, slightly sticky; abundant roots.

B21t 10 to 14 inches, dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/6) clay; many fine to medium mottles of yellowish brown (10YR 5/8); strong, medium and coarse, blocky, breaking to strong, fine, blocky structure; hard, firm; coatings on faces of peds, dark grayish brown (10YR 4/2); few small fragments, less than ½ inch in diameter, of sandstone, shale, limestone, chert, and granite; plentiful roots.

B22t 14 to 23 inches, dark grayish-brown (10YR 4/2) clay; common fine to medium mottles of yellowish brown (10YR 5/8); strong, medium and coarse, blocky structure; very hard, plastic; plentiful roots; many small stones.

C1 23 to 29 inches, mottled dark-brown (10YR 4/3) and yellowish-brown (10YR 5/6) clay loam; weak, medium to coarse, blocky structure; very hard; very compact, slightly plastic; small chips and pebbles of limestone, shale, and chert; few roots; calcareous.

C2 29 to 35 inches, calcareous clay loam till.

Climatic data (Lima, Ohio)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	29	30	38	49	60	71	74	72	65	54	41	31	51
Mean precipitation, 1931-52 (inches)	2.6	2.0	3.3	3.4	3.6	4.4	3.2	3.3	3.2	2.7	2.7	2.2	36.5

Annual precipitation more than 25.1 and less than 47.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Total sand	Fine clay <.0002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
0-7	Ap1	2.5	4.7	6.5	10.5	6.2	47.0	22.6	30.4	6.8			1.25	
7-10	Ap2	1.7	4.3	5.7	9.8	6.9	45.4	26.2	28.4	7.4			1.08	
10-14	B21t	1.7	3.4	3.9	6.3	5.1	34.3	45.3	20.4	20.2			.45	
14-23	B22t	1.5	3.0	3.3	6.2	5.9	37.3	42.8	19.9	16.2			.45	
23-29	C1	2.4	3.7	3.5	6.5	7.4	41.8	34.7	23.5	9.5				
29-35	C2	1.8	4.1	3.8	6.1	7.1	44.2	32.9	22.9	8.9				

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH 1:1	$CaCO_3$ equivalent %
						6.2	
						5.9	
						5.3	
						6.9	
						7.6	15.4
						7.7	19.2

Profile No. 14 (Lab. data by Ohio Agr. Expt. Sta.)
Area: Van Wert County, Ohio.
Vegetation: Small grain; (natural) deciduous forest.
Parent material: Stratified very fine sand and silt.
Topography: Less than 1 percent slope; elevation 800 feet; (drift) outwash plain.

Ap 0 to 7 inches, very dark gray (10YR 3/1) and very dark brown (10YR 2/2) silty clay loam; crushed color is dark grayish brown (10YR 4/2) to very dark grayish brown (10YR 3/2), grayish brown (2.5Y 5/2) when dry; weak to moderate, very fine and fine, blocky and some fine, granular structure; firm; abundant roots; abrupt boundary.

A12 7 to 10 inches, very dark gray (10YR 3/1) and very dark brown (10YR 2/2) silty clay loam; crushed color is very dark grayish brown (10YR 3/2); few, fine, brown (7.5YR 5/4) mottles; weak, fine and medium, subangular blocky structure; firm, sticky, slightly plastic; abundant roots; abrupt, wavy boundary.

B21tg 10 to 16 inches, dark-gray (10YR 4/1) to very dark-gray (10YR 3/1) silty clay; common, fine, mottles of yellowish brown (10YR 5/4) on about 20 percent of exposed faces of peds; strong, very fine and fine, blocky structure; many peds less than 3 millimeters in diameter; structure slightly weaker in upper 2 inches of the horizon than in lower part; firm, slightly sticky, plastic; plentiful roots; clear, wavy boundary.

B22tg 16 to 21 inches, mottled yellowish-brown (10YR 5/4, 5/6), dark grayish-brown (2.5Y 4/2), and grayish-brown (2.5Y 5/2) silty clay; few, very dark gray (10YR 3/1) mottles; moderate, very fine and fine, blocky structure; firm, slightly sticky, plastic; plentiful roots; gradual, wavy boundary.

B23tg 21 to 28 inches, mottled yellowish-brown (10YR 5/6) and light brownish-gray (2.5Y 6/2) silty clay; moderate, very fine, fine, and medium, blocky structure, coarser in lower part of horizon than in upper part; dark-gray (10YR 4/1) clay films on about 50 percent of ped faces; firm, slightly sticky, plastic; plentiful roots; clear, smooth boundary.

B24tg 28 to 47 inches, mottled yellowish-brown (10YR 5/4), light brownish-gray (2.5Y 6/2), and light-gray (5Y 6/1) silty clay loam; gray colors follow old root channels and cracks; compound moderate, fine and medium prismatic and medium and coarse subangular blocky structure; firm, slightly sticky, plastic; nearly continuous very dark gray (10YR 3/1) to gray (10YR 5/1) clay films up to 2 millimeters thick; roots common on faces of peds.

C1 47 to 56 inches, mottled yellowish-brown (10YR 5/4) and light-gray (5Y 6/1) silt loam; pattern of mottling is coarse and irregular; gray color has slightly pinkish cast in places; massive; firm; many black fragments of shale and granite; calcareous.

C2 56 to 80 inches, brown (10YR 5/3) to dark-brown (10YR 4/3) silt loam; coarse, irregular mottles of yellowish brown (10YR 5/6), grayish brown (2.5Y 5/2), and light gray (5Y 6/1); massive, firm; many black fragments of shale; calcareous.

IIC3 80 to 100 inches, grayish-brown sandy loam, single grain; loose; calcareous.

Climatic data (Van Wert, Ohio)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	29	30	39	49	61	71	75	73	66	55	41	30	52
Mean precipitation, 1931-52 (inches)	2.6	1.9	3.4	3.5	4.3	4.4	3.3	2.4	3.2	2.7	2.4	2.3	36.4

Annual precipitation more than 24.9 and less than 47.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Total sands 0.2-0.02	Fine clay <.0002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N
0-7	Ap	1.1	1.3	1.9	4.7	6.3	51.6	33.1	15.3	8.5			2.09	
7-10	A12	.9	1.1	1.6	4.2	6.7	53.1	32.4	14.5	9.2			2.04	
10-16	B21tg	.7	1.0	1.3	3.1	5.6	47.9	40.4	11.7	15.8			1.08	
16-21	B22tg	.6	1.0	1.3	2.8	4.1	45.2	45.0	9.8	20.0			.57	
21-28	B23tg	.3	1.0	1.1	2.8	4.9	48.5	41.4	10.1	18.1				
28-47	B24tg	.5	1.3	1.6	3.2	4.7	50.7	38.0	11.3	14.7				
47-56	C1	1.7	3.5	3.8	7.9	8.6	54.0	20.5	25.5	.4.9				
56-80	C2	2.0	3.1	3.3	6.1	7.8	57.4	20.3	22.3	5.0				
80-100	IIC3	26.7	14.6	6.2	6.3	3.8	30.1	12.3	57.6	2.8				

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH 1:1	$CaCO_3$ equivalent % a
						6.3	
						6.2	
						6.5	
						6.8	
						7.0	
						7.3	
						8.0	18.2
						8.0	19.8
						8.0	14.9

Profile No. 15

Area: Williams County, North Dakota.
Vegetation (Natural): Mid and short grasses.
Parent material: Friable, calcareous till.
Topography: Near crest of low hill; 3 percent slope facing west; local relief 10 to 20 feet.

A11 — 0 to 1½ inch, very dark brown (10YR 2/2) loam, dark grayish brown (10YR 4/2) when dry; moderate, fine, granular structure; soft, very friable; clear boundary.

A12 — 1½ to 3 inches, very dark brown (10YR 2/2) loam, dark grayish brown (10YR 4/2) when dry; weak, medium, prismatic, breaking to weak, fine, granular structure; slightly hard, very friable; clear boundary.

A13 — 3 to 8 inches, very dark brown (10YR 2/2) clay loam that is very dark grayish brown (10YR 3/2) when crushed, dark grayish brown (10YR 4/2) when dry, or a slightly browner color when crushed; moderate, medium prismatic, breaking to moderate or strong, fine and medium, angular and subangular blocky structure; hard, friable; gradual boundary.

B — 8 to 11 inches, dark grayish-brown (10YR 4/2) clay loam, grayish brown (10YR 5/2) when dry; compound moderate, medium, prismatic, breaking to moderate, medium, angular and subangular blocky structure; hard, friable; clear, irregular boundary.

C1ca — 11 to 23 inches, light olive-brown (2.5Y 5/4) clay loam, grayish brown (2.5Y 5/2) when dry; dark grayish brown (2.5Y 4/2) and light brownish gray (2.5Y 6/2) mottlings, light brownish gray (2.5Y 6/2) and white (2.5Y 8/2) when dry; weak, coarse, prismatic, breaking to weak, medium, blocky structure; hard, friable; large amount of segregated lime in threads and films; calcareous; clear, very irregular boundary.

C2ca — 23 to 39 inches, light olive-brown (2.5Y 5/4) clay loam, light brownish gray (2.5Y 6/2) mottled with white (2.5Y 8/2) when dry; weak, medium, blocky, breaking to moderate, very fine, blocky structure; hard, friable; small amount of segregated lime in threads and films; calcareous; clear, very irregular boundary.

C3 — 39 to 60 inches, light olive-brown (2.5Y 5/4) clay loam, light brownish gray (2.5Y 6/2) when dry; weak, medium, blocky, breaking to moderate, fine, blocky stuucture; hard, friable; calcareous.

Climatic data (Epping, N. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	8	11	23	43	55	63	71	68	58	45	27	15	40
Mean precipitation, 1931-52 (inches)	0.3	0.4	0.5	0.7	1.6	3.0	2.1	1.6	1.0	0.7	0.3	0.3	11.5

Annual precipitation more than 6.3 and less than 16.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
0-1½	A11	3.6	4.1	4.9	11.6	10.6	43.5	21.7	38.0	22.7	---		4.68	14
1½-3	A12	2.2	4.1	5.2	13.1	11.9	39.2	24.3	38.6	20.2	1.6		2.60	11
3-8	A13	2.3	4.7	6.0	13.9	11.5	32.3	29.3	35.0	16.8	1.6		1.26	11
8-11	B	3.7	4.5	5.8	13.8	10.9	33.0	28.3	33.6	18.0	1.3		1.20	10
11-23	C1ca	3.1	4.2	4.7	11.3	10.7	34.5	31.5	30.6	21.2	2.7		.77	
23-39	C2ca	3.8	3.8	4.3	11.7	12.0	36.6	27.8	33.7	22.1	2.4		.44	
39-60	C3	3.3	3.9	4.0	10.5	10.6	37.7	30.0	30.9	23.5	3.0		.35	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	E.C mmhos. per cm. 25° C.	$CaCO_3$ equivalent v	Moisture tensions 1/3 atmos. %	15 atmos. %
27.9	18.7	5.4		0.1	1.3	6.6	0.8	---	30.5	12.8
20.8	12.0	4.1		.1	.9	6.2	.6	---	23.3	11.3
22.6	14.5	5.7		.1	.5	6.3	.6	---	22.2	11.6
21.8				.1	.3	7.3	.7	3	20.8	11.5
16.0				.1	.2	7.9	.6	19	21.1	10.0
14.8				.2	.2	8.1	.7	15	20.5	9.4
17.2				1.2	.3	8.5	.7	12	22.3	11.0

Profile No. 16 (Lab. data by Ohio Agr. Expt. Sta.)
Area: Union County, Ohio
Vegetation: Oak-hickory forest.
Parent material: Calcareous clay till.
Topography: Lowland; less than 1 percent slope; elevation 1,030 feet; morainic area.

O1 2 to 0 inch, leaf litter.

A1 0 to 3 inches, very dark grayish-brown (between 10YR 3/2 and 2.5Y 3/2) silty clay loam, gray (N 5/) when dry; strong, medium and coarse, granular structure; hard, friable, nonsticky, nonplastic; abundant roots; clear boundary.

A2 3 to 7½ inches, light brownish-gray (2.5Y 6/2) clay loam, light gray (2.5Y 7/2) to white (2.5Y 8/2) when dry; weak, platy, breaking to weak, very fine, subangular blocky or medium, granular structure; hard, friable, slightly sticky, slightly plastic; many black, very fine, rounded nodules (shot) that are moderately hard; clear boundary.

B1g 7½ to 11 inches, light brownish-gray (2.5Y 6/2) clay, light gray (2.5Y 7/2) to white (2.5Y 8/2) when dry; many, medium mottles of brownish yellow (10YR 6/6) and reddish yellow (7.5YR 6/6), brownish yellow (10YR 6/6) and gray (N 6/) when dry; moderate, fine, subangular blocky structure; very hard, firm, plastic, sticky; discontinuous clay films; roots plentiful; common, fine, rounded, moderately hard nodules; gradual boundary.

B2tg 11 to 17 inches, light brownish-gray (2.5Y 6/2) clay, light gray (N 7/) when dry; yellowish brown (10YR 5/6), medium and coarse mottles, light yellowish brown (10YR 6/4) and brownish yellow (10YR 6/6) when dry; weak, medium and coarse, subangular blocky structure; very hard, very firm, sticky, plastic; light brownish-gray, discontinuous clay films; few roots; gradual boundary.

B2t 17 to 30 inches, dark grayish-brown (2.5Y 4/2) clay, gray (10YR 6/1 and N 6/) when dry; mottles of olive brown (2.5Y 4/3) to brown (10YR 4/3), yellowish brown (10YR 5/6) when dry; fewer mottles in lower part; massive to weak very coarse, prismatic structure; there are a few cracks as much as 3/4 inch across; extremely hard; extremely firm, sticky, plastic; thin clay films along root channels; few roots; fine, black concretions; clear, wavy boundary.

C1 30 to 40 inches, dark grayish-brown (2.5Y 4/2) clay, a few, gray (N 5/) mottles, moderate, medium and coarse, subangular blocky structure; interiors of peds olive brown (2.5Y 4/4); extremely hard, very firm, sticky, plastic; few roots; fragments of limestone, coated or stained with yellowish brown, and igneous cobbles common; calcareous.

C2 40 to 57 inches, dark grayish-brown (2.5Y 4/2) clay, weak, prismatic, breaking to medium and coarse, angular blocky structure; interiors of peds olive brown (2.5Y 4/3); extremely hard, sticky, plastic; many white, calcareous splotches on the vertical and horizontal faces of peds; fragments of limestone and igneous rock; calcareous.

IIC3 57 to 82 inches, light olive-brown (2.5Y 5/4) clay; angular blocky structure; very hard to extremely hard, sticky, plastic; gray (N 5/) films on faces of peds; a few white, calcareous splotches.

IIC4 82 to 96 inches, like IIC3 but films on peds are grayish brown (2.5Y 5/2) and become fewer with increasing depth.

Climatic data (Marysville, Ohio)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	30	30	39	49	61	71	74	72	65	54	41	31	51
Mean precipitation, 1931-52 (inches)	3.2	2.3	3.4	3.6	3.6	4.5	3.2	3.7	2.9	2.3	2.4	2.7	37.7

Annual precipitation more than 27.0 and less than 48.4 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Fine clay <.0002	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % d	C/N k
0-3	A1	4.4	5.7	3.4	3.2	2.8	52.3	28.9	7.6				6.5	14
3-7½	A2	13.9	9.4	3.5	3.0	.7	39.1	30.4	6.6				1.11	12
7½-11	B1g	2.9	2.2	1.2	1.9	1.9	38.0	51.9	20.4				.63	8
11-17	B2tg	.9	1.3	.8	1.4	1.5	32.7	61.4	29.8				.69	9
17-23	B2t	.5	1.2	1.0	1.7	1.7	32.9	61.0	30.0				.64	10
23-30	B2t	.7	1.1	1.0	1.8	1.7	34.9	58.8	26.6				.69	11
30-40	C1	1.5	1.3	.8	1.1	1.3	39.0	55.0	19.3					
40-57	C2	.5	.6	.6	.1	1.9	38.4	57.9	19.4					
57-82	IIC3	.2	.2	.1	.2	.1	39.2	60.0	17.0					

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	Sum exch. cations meq./100 gm.	Base sat. % s	$CaCO_3$ equivalent % a
	8.6	4.3	24.3	0.0	0.62	5.4	37.8	35.7	
	1.3	1.1	17.1	.1	.21	4.8	19.8	13.6	
	2.0	3.9	20.8	.1	.35	4.6	27.2	23.5	
	2.0	8.2	21.8	.1	.45	4.6	32.6	33.1	
	4.7	15.7	13.1	.3	.50	4.8	34.3	61.8	
	6.9	20.6	6.3	1.0	.42	6.4	35.2	82.1	
						7.5			10.9
						7.6			12.7
						7.8			19.8

*Exchange acidity

Profile No. 17

Area: Perkins County, South Dakota
Vegetation: Native grasses (western wheatgrass, June-grass and blue grama, green needle and needle-and-thread grasses) and sage.
Parent material: Stratified sand and clay residuum.
Topography: Upland; midway on slope ½ mile long; 3 percent gradient; local relief 10 to 30 feet.

A1 — 0 to 3 inches, very dark grayish-brown (10YR 3/2) very fine sandy loam, brown (10YR 5/3) when dry; weak, thin, platy, breaking to weak, very fine, granular structure; soft, very friable; clear, smooth boundary.

A2 — 3 to 6 inches, very dark grayish-brown (10YR 3/2) very fine sandy loam, grayish brown (10YR 5/2) and light brownish gray (10YR 6/2) when dry; moderate, medium, prismatic, breaking to moderate, medium, platy structure; hard, friable; abrupt, smooth boundary.

B21t — 6 to 9 inches, very dark grayish-brown (10YR 3/2) clay, grayish brown (10YR 5/2) when dry; strong, medium and fine, columnar structure; extremely hard, firm; clear, smooth boundary.

B22t — 9 to 11½ inches, very dark grayish-brown (10YR 3/2), heavy clay loam, brown (10YR 5/3) when dry; compound, moderate, medium and fine prismatic, breaking to strong, fine, blocky structure; extremely hard, firm; clear, smooth boundary.

B23tca — 11½ to 15 inches, olive-brown (2.5Y 4/4) sandy clay loam, brown (10YR 5/3) when dry; compound, weak, medium, prismatic, breaking to strong, fine, blocky structure; prisms are coated very dark grayish brown (10YR 3/2), grayish brown (10YR 5/2) when dry; very hard, friable; contains a large amount of segregated lime in small, soft concentrations and in threads; clear, smooth boundary.

B3tca — 15 to 21 inches, olive-brown (2.5Y 4/4) sandy clay loam, light yellowish brown (2.5Y 6/4) when dry, with a few spots of very dark grayish-brown (2.5Y 3/2) coatings; weak, coarse, prismatic, breaking to coarse, blocky structure; hard, friable; contains a layer of dark reddish-brown, very hard, angular pebbles; common concentrations of carbonates in threads, films, and small, soft, round concretions; calcareous; gradual boundary.

C1 — 21 to 39 inches, olive (5Y 4/3) fine and very fine sand, pale olive (5Y 6/3) when dry; moderate, very coarse, prismatic, breaking to coarse, blocky structure; slightly hard, very friable; few, very fine lenses of clay less than 1/16 inch thick; segregated carbonates in common, vertical and horizontal threads and films 1/8 to 1/36 inch thick; gradual boundary.

C2 — 39 to 56 inches, olive (5Y 4/3) fine sand, pale olive (5Y 6/3) when dry; moderate, very coarse, prismatic, breaking to coarse, blocky structure; slightly hard, very friable; few, very fine lenses of clay less than 1/16 inch thick; segregated carbonates in common, vertical and horizontal threads and films 1/8 to 1/36 inch thick; clear boundary.

Climatic data (Faith, S. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	18	21	31	47	58	67	77	74	63	51	34	24	47
Mean precipitation, 1931-52 (inches)	0.4	0.5	1.0	1.5	2.4	3.6	1.6	1.4	1.1	0.9	0.4	0.3	15.0

Annual precipitation more than 7.6 and less than 22.4 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Exch. Na %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-3	A1	0.5	0.6	1.4	24.8	25.8	34.0	12.9	63.7	14.2	--		1.36	12	1
3-6	A2	.8	.4	1.0	24.9	23.7	33.6	15.6	60.2	15.3	--		.78	8	7
6-9	B21t	.3	.3	.6	14.6	14.6	25.3	44.3	37.0	13.3	--		1.06	13	15
9-11½	B22t	.4	.3	.7	17.3	17.1	26.5	37.7	41.1	14.7	0.5		.77	9	18
11½-15	B23tca	.5	.7	1.5	25.3	18.7	24.8	28.5	48.5	12.4	.5		.60	10	17
15-21	B3tca	1.1	.8	2.5	37.3	20.1	17.4	20.8	50.1	10.1	4.1		.29		13
21-39	C1	--	.1	.4	38.4	38.5	10.5	12.1	77.9	6.1	--		.03		23
39-56	C2	--	.2	1.2	61.7	18.8	8.3	9.8	72.7	5.3	--		.02		26

Cation exch. cap. b	Extractable cations, meq./100 gm. Ca	Mg	H	Na	K	pH sat. paste	pH 1:10	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Moisture tensions 1/3 atmos. %	15 atmos. %	Sat. ext., sol. (meq./l.) Na	K	H_2O at sat. %
12.2	6.0	2.8		0.1	0.9	6.1	6.9	0.6	--	18.7	6.1	2.0	0.6	36.9
13.0	5.0	3.6		.9	.4	5.6	7.2	.7	--	16.7	6.3	4.5	.1	31.4
36.6	16.7	13.8		5.4	.7	7.1	8.7	1.0	1	44.4	20.4	8.3	--	79.1
29.7	25.2	13.2		5.4	.5	7.8	9.4	1.3	--	39.0	18.0	11.1	--	74.1
23.0				3.9	.4	8.1	9.6	1.9	4	32.3	13.8	15.4	.1	66.5
20.7				2.7	.3	7.7	8.6	6.4	2	19.2	10.2	47.0	.3	49.7
16.8				3.8	.2	8.3	9.8	1.4	1	20.7	8.0	12.4	--	63.8
16.2				4.2	.3	8.4	9.8	1.2	1	15.7	7.3	9.7	--	50.4

Profile No. 18 Area: Sargent County, North Dakota.
Vegetation: Meadow; (natural) tall and mid grasses.
Parent material: Glacial lacustrine deposits.
Topography: Nearly level; lake plain.

A1 0 to 6 inches, black (10YR 2/1) clay loam, very dark gray (10YR 3/1) when dry; fine, granular structure; sticky, plastic; smooth boundary.

B21t 6 to 10 inches, very dark gray (5Y 3/1) clay loam, dark gray (5Y 4/1) when dry; strong, medium, columnar structure; very firm, very sticky, very plastic; clear, wavy boundary.

B22t 10 to 17 inches, very dark grayish-brown (2.5Y 3/2) clay loam; strong, medium, columnar structure; very firm, very sticky, very plastic; calcareous segregations on exteriors of columns and in the larger root channels.

B3tca 17 to 24 inches, light-gray (5Y 7/2) to pale-yellow (5Y 7/3) clay loam with tongues of olive (5Y 4/3); fine and very fine, blocky structure; friable, slightly sticky, slightly plastic; calcareous; abrupt, smooth boundary.

IIC1 24 to 30 inches, light olive-brown (2.5Y 5/6) loam; friable, slightly sticky, slightly plastic; calcareous; abrupt, smooth boundary.

IIC2 30 to 40 inches, olive (5Y 5/3) silt loam; weak, blocky structure; sticky, plastic; calcareous; clear, smooth boundary.

IIC3 40 to 48 inches, light olive-brown (2.5Y 5/4) silt loam; weak, angular, blocky structure; sticky, plastic; common, white (5Y 8/2) lime concretions and dark reddish-brown (5YR 3/4) iron concretions; calcareous; smooth boundary.

IIC4g 48 to 60 inches, gray (5Y 5/1) silt loam; nonsticky, nonplastic; dark reddish-brown (5Y 2/2 and 3/4) iron concretions that are nearly round with a long, vertical axis; calcareous.

Climatic data (McLeod, N. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	9	12	26	43	57	65	72	69	60	47	29	15	42
Mean precipitation, 1931-52 (inches)	0.5	0.5	1.1	1.7	2.4	3.5	2.7	2.7	1.6	1.2	0.7	0.4	19.1

Annual precipitation more than 12.5 and less than 25.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) r	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-6	A1	0.1	0.6	1.4	20.0	20.0	31.9	26.0	50.5	15.9	--		2.43	11	--
6-10	B21t	---	.4	1.2	19.4	19.3	29.4	30.3	48.3	14.7	--		1.03	10	--
10-17	B22t	.1	.4	1.2	20.3	19.1	28.7	30.2	49.3	14.4	--	1.40	.82	10	3
17-24	B3tca	.1	.3	1.2	18.1	16.7	24.3	39.3	40.4	14.9	--		.62	9	26
24-30	IIC1	---	.1	.5	20.2	29.4	30.3	19.5	63.5	13.1	--	1.52	.20		22
30-40	IIC2	---	---	.2	6.5	20.7	51.6	21.0	51.3	26.4	--		.19		24
40-48	IIC3	.2	.1	.2	5.2	12.8	64.6	16.9	50.5	30.9	Tr.		.15		18
48-60	IIC4g	---	.1	.1	.9	26.9	60.8	11.2	73.9	14.5	--	1.53	.08		9

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	pH 1:10	E. C. mmhos. per cm. 25°C.	Exch. Na %	Sat. ext., sol. (meq./l.) Na	Ca	Mg	Moisture at sat. %
22.9	17.5	8.3		0.2	1.3	7.2	8.3	1.0	1	1.8	4.6	4.4	56.2
23.7	11.0	12.3		1.1	1.0	7.4	8.6	1.0	5	7.3	1.2	2.8	60.2
21.1	16.9	13.3		2.1	.7	7.9	8.9	3.2	10	23.1	4.9	10.2	64.2
14.6				2.3	.3	8.2	8.9	10.4	16	79.4	19.4	50.5	53.2
7.9				1.6	.2	8.3	9.3	5.9	20	47.2	5.9	18.7	40.6
11.8				1.9	.2	8.0	9.2	7.1	16	45.7	34.8	43.8	46.4
12.4				1.8	.2	7.9	9.1	6.9	14	35.9	31.4	36.6	46.6
10.0				1.8	.2	8.1	9.2	2.0	18	14.6	1.8	4.3	42.4

Profile No. 19

Area: Sargent County, North Dakota.
Vegetation: Corn; (natural) sedges, rushes, and reeds.
Parent material: Glacial till.
Topography: Large, flat depression in upland.

Ap 0 to 6 inches, black (10YR 2/1), heavy silt loam; fine, granular structure; friable, slightly sticky, slightly plastic; wavy boundary.

A2 6 to 11 inches, very dark grayish-brown (10YR 3/2) silt loam; moderate, medium, platy structure; very friable, slightly sticky, slightly plastic; wavy boundary.

B21t 11 to 19 inches, very dark gray (10YR 3/1) clay; moderate, medium, prismatic, breaking to moderate, medium, blocky structure; very firm, very sticky, very plastic; wavy boundary.

B22t 19 to 27 inches, very dark gray (10YR 3/1), heavy clay loam; moderate, medium, prismatic, breaking to moderate, medium, blocky structure; very firm, very sticky, very plastic; wavy boundary.

B3 27 to 34 inches, very dark gray (10YR 3/1) clay loam; moderate, medium, prismatic, breaking to moderate, medium, blocky structure; films on all vertical faces of peds, and patches on horizontal faces; calcareous.

C 34 to 45 inches, light olive-brown (2.5Y 5/4) and olive-brown (2.5Y 4/4) clay loam; moderate, medium, blocky structure; friable, sticky, plastic; many, white (2.5Y 8/2) lime segregations; smooth boundary.

C2ca 45 to 53 inches, light olive-brown (2.5Y 5/4) and olive-brown (2.5Y 5/4) and olive-brown (2.5Y 4/4) clay loam; moderate, medium, blocky structure; friable; sticky, plastic; many, white (2.5Y 8/2) lime segregations; calcareous; smooth boundary.

C3cag 53 to 60 inches, olive-gray (5Y 5/2) clay loam; dark-red (2.5YR 3/6) and reddish-brown (5YR 4/4) mottles; weak, angular blocky structure; friable, sticky, plastic; many, white (5Y 8/2) lime segregations; calcareous.

Climatic data (Forman, N. Dak.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1937-52 (deg. F.)	9	11	27	43	56	65	72	70	60	48	29	16	42
Mean precipitation, 1931-52 (inches)	0.5	0.6	0.9	1.9	2.4	4.0	3.1	2.2	1.4	1.2	0.7	0.5	19.5

Annual precipitation more than 12.0 and less than 27.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-6	Ap	0.7	2.3	2.9	7.0	7.1	50.2	29.8	30.0	31.7	---		3.25	12	--
6-11	A2	1.4	2.5	2.8	6.2	7.3	56.2	23.6	33.1	34.2	---		.95	9	--
11-19	B21t	3.5	3.4	4.7	11.4	6.8	29.6	40.6	26.2	16.8	3.3		.76	10	--
19-27	B22t	3.2	5.1	5.4	9.7	5.9	33.5	37.2	23.5	21.2	4.3		.74	10	--
27-34	B3	5.5	3.2	3.2	9.7	13.5	34.6	30.3	35.2	19.4	7.1		.33		6
34-45	C	5.2	6.3	5.4	9.8	8.7	36.8	27.8	27.7	23.4	9.7		.25		11
45-53	C2ca	6.3	6.2	5.4	9.7	8.4	35.6	28.4	26.4	23.2	12.1		.20		25
53-60	C3cag	6.7	6.3	5.7	10.4	8.8	35.9	26.2	27.2	23.3	8.0		.18		26

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	pH 1:10	Exch Na %	Sat. extract, soluble (meq./l.): Na	Ca	Mg	Moisture at saturation %	E. C. mmhos. per cm. 25° C.
28.7	20.8	7.4		0.1	0.7	6.6	7.0	--	0.4	3.4	2.2	54.0	0.6
18.0	10.7	5.1		.1	.4	6.0	6.5	1	.5	2.1	1.6	40.7	.4
29.1	15.8	11.0		.1	.5	5.7	6.4	--	.6	1.8	1.5	51.7	.4
28.2	16.8	10.9		.2	.5	6.2	6.9	1	.8	2.4	2.5	49.4	.6
19.0				.1	.3	7.7	8.6	1	.8	3.3	2.8	49.4	.7
15.2				.1	.2	7.8	8.6	1	.9	3.0	2.8	45.6	.7
14.5				.1	.3	8.0	8.8	1	.8	2.5	2.7	45.0	.6
13.3				.1	.2	8.1	8.7	1	1.0	2.5	3.3	42.0	.7

Profile No. 20

Area: King County, Washington.

Vegetation: Alder, some vine maple, a few western redcedar trees, hemlock, and second-growth Douglas-fir.

Parent material: Glacial alluvium or outwash and volcanic ash; gravel and rocks are mostly fine-grained basalt but are acid inside; many rocks and boulders as much as 2 feet in diameter.

Topography: Three percent slope; 800 feet elevation; terrace.

O1 — 2 to 0 inch, black (10YR 2/1), loose, fibrous mat of moss, fir needles, some alder leaves, and abundant roots, very dark grayish brown (10YR 3/2) when dry; pH 5.0; abrupt boundary.

A2 — 0 to 1½ inches, dark-gray (10YR 4/1), gravelly, light sandy loam, gray (10YR 6/1) when dry; single grain; loose, friable; abundant, coarse roots; pH 4.5; abrupt boundary.

B21irh — 1½ to 4½ inches, strong-brown (7.5YR 5/6) gravelly sandy loam, brown (10YR 5/3) when dry; structural units not distinctly water stable; firm, slightly compact, slightly plastic; abundant, coarse roots; very few or no shot; sand grains angular; many lumps of dark reddish-brown (5YR 3/4), weakly cemented ortstein; pH 5.8; gradual boundary.

B22irh — 4½ to 13 inches, strong-brown (7.5YR 5/6) gravelly sandy loam, brown (10YR 5/3) when dry; structural units not distinctly water stable; friable, slightly compact, slightly plastic; abundant, coarse roots; very few or no shot; sand grains angular; many lumps of dark reddish-brown (5YR 3/4), weakly cemented ortstein; pH 5.8; gradual boundary.

B23irh — 13 to 23 inches, dark yellowish-brown (10YR 3/4) very gravelly and stony sandy loam, light yellowish brown (10YR 6/4) when dry; single grain; loose, firm, nonplastic; abundant, coarse roots; porous; pH 5.8.

IIC1 — 23 to 36 inches, mixed olive (5Y 4/3) and pale-olive (5Y 6/3) gravelly sand, olive (5Y 5/3) and pale yellow (5Y 7/3) when dry; single grain; loose, nonplastic; pH 6.2.

IIC2 — 36 to 48 inches, olive (5Y 4/3) and (5Y 5/3) gravelly sand, olive (5Y 5/3) and pale-olive (5Y 6/3) when dry; single grain; loose, nonplastic; many, dark, mineral fragments; pH 6.2.

Climatic data (Cedar Lake, Wash.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	35	37	41	46	52	58	63	63	58	51	43	37	49
Mean precipitation, 1931-52 (inches)	12.4	10.7	11.4	7.2	6.1	5.3	2.1	2.4	5.4	10.3	13.3	15.4	102.1

Annual precipitation more than 69.7 and less than 134.5 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	C/N (k)	Free iron oxides Fe_2O_3 %
2-0	O1														
0-1½	A2	1.0	15.9	30.8	20.1	9.3	19.4	3.5					1.67	18	0.4
1½-4½	B21irh	3.5	27.2	31.1	13.3	6.4	14.4	4.1					2.71	27	1.2
4½-13	B22irh	9.5	15.5	14.2	17.8	13.2	24.7	5.1					2.31	20	1.6
13-23	B23irh	11.0	13.4	10.4	19.4	15.4	25.6	4.8					1.71	18	1.8
23-36	IIC1	29.3	21.2	13.4	18.7	7.3	7.5	2.6					.66	18	.6
36-48	IIC2	25.4	24.4	15.6	21.4	6.7	4.2	2.3					.38	13	.4

Cation exch. cap. (8)	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % (s)	pH 1:1
							4.9
16.2	0.6	0.1	15.0	0.1	0.4	7	4.3
26.4	.8	.1	25.1	.2	.2	5	5.2
25.3	.4	.1	24.5	.1	.2	3	5.4
23.9	.4	.1	23.1	.1	.2	3	5.6
9.0	.2	.1	8.5	.1	.1	6	5.5
5.7	.2	.1	5.3	.1	.1	7	5.6

*Exchange acidity.

Profile No. 21
Area: Brantley County, Georgia
Vegetation: Saw-palmetto, wiregrass, longleaf and slash pines, huckleberry, and runner oak.
Parent material: Coastal plains sand.
Topography: Approximately 2 percent slope; wide ridge; upland on coastal plain.

A1 0 to 3 inches, gray (10YR 5/1) sand; salt and pepper mixture of white sand and finely divided organic matter; clear boundary.

A2 3 to 16 inches, light-gray (10YR 7/1-7/2) sand; loose; a few gray (10YR 5/1) streaks up to 1/4 inch in diameter extend along root channels into this layer from the A1 horizon; clear, irregular boundary.

A3 16 to 17 inches, light brownish-gray (10YR 6/2) sand; loose; faint, coarse splotches approaching light brown (7.5YR 6/4) predominant near the lower boundary; abundant, medium roots.

B21h 17 to 18 inches, dark reddish-brown (5YR 2/2) to black (5YR 2/1) sand; hard, cemented; abrupt, irregular boundary.

B22h 18 to 20 inches, dominantly brown (7.5YR 4/4) sand, grading toward black at top and strong brown (7.5YR 5/6) toward bottom; fine to coarse, faint, dark-brown to strong-brown mottles; hard, cemented; a few, dark tongues, up to 1/4 inch in diameter, extend along root channels from B21h horizon; clear, irregular boundary.

B3 20 to 27 inches, pale-yellow (2.5Y 7/4) sand; loose; a few brown (7.5YR 4/4) or strong-brown (7.5YR 5/6) streaks extend along root channels; gradual, irregular boundary.

C1 27 to 39 inches, pale-yellow (2.5Y 8/4) to white (2.5Y 8/2) sand; few to common, medium, prominent mottles of brownish yellow to strong brown in 4-foot horizontal exposure; loose; abrupt, wavy boundary.

IIC2 39 to 44 inches, light yellowish-brown (10YR 6/4) sandy loam; common, coarse, faint mottles of brownish yellow (10YR 6/6); few, isolated mottles of brown; weak, medium, subangular blocky structure; very friable.

Climatic data (Waycross, Ga.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	56	56	61	68	75	81	82	82	78	70	60	55	69
Mean precipitation, 1931-52 (inches)	2.6	3.3	4.3	3.1	3.4	5.1	7.0	6.0	4.9	2.9	2.2	3.0	47.7

Annual precipitation more than 30.2 and less than 65.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-3	A1	0.4	21.2	36.2	31.4	5.3	5.0	0.5	20.4	3.1	0		1.12	29	<0.1
3-16	A2	.6	23.1	34.3	31.7	4.6	5.3	.4	20.4	3.3	0		.03	5	<.1
16-17	A3	.6	21.9	32.9	28.8	4.2	8.9	2.7	18.3	7.0	0		1.05	30	.1
17-18	B21h	.5	20.7	33.2	29.8	4.5	6.7	4.6	19.4	4.4	0		2.54	69	.1
18-20	B22h	.6	21.9	33.9	29.1	4.4	5.9	4.2	18.2	3.9	0		1.10	38	<.1
20-27	B3	.6	20.8	35.5	31.6	4.5	5.3	1.7	19.5	3.4	0		.10	12	<.1
27-39	C1	.6	23.3	34.0	31.5	5.2	4.7	.7	20.7	2.4	0		.02	4	<.1
39-44	IIC2	.5	18.6	29.6	26.7	3.9	16.0	4.7	18.8	12.3	0		.07	8	.2

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
5.8	1.5	0	4.3	<0.1	<0.1	26	4.8
1.0	.4	0	.6	<.1	<.1	40	5.6
6.6	.4	0	6.2	<.1	<.1	6	4.5
27.5	.2	.2	27.1	<.1	<.1	1	4.7
13.9	.2	.1	13.5	<.1	<.1	3	5.1
2.6	.4	0	2.2	<.1	<.1	15	5.3
1.4	.4	.1	.9	<.1	<.1	36	5.7
1.8	0	0	1.8	<.1	<.1	0	5.2

*Exchange acidity

Profile No. 22

Area: Otter Tail County, Minnesota

Vegetation: Mixed deciduous forest, main tree species are mainly red oak, other oaks, poplar (aspen, balm-of-Gilead), a few boxelders, and basswood, with an undercover of hazel brush.

Parent material: Calcareous till.

Topography: Slopes between 2 and 10 percent; till plain.

O2 2 to 0 inches, very dark brown (10YR 2/2) mat of leaves and roots.

A2 0 to 5 inches, light-gray (10YR 7/2) silt loam, white (10YR 8/2) when dry; moderate, thin, platy structure; slightly vesicular; very friable; abundant stones; clear boundary.

B21t 5 to 10 inches, dark grayish-brown (10YR 4/2) silty clay loam; light yellowish brown (10YR 6/4) when crushed; moderate, medium, subangular, blocky structure; hard, firm, plastic; peds coated with light gray (10YR 7/2) silt; abundant roots.

B22t 10 to 15 inches, dark grayish-brown (10YR 4/2) and very dark grayish-brown (10YR 3/2) clay loam, light yellowish brown (10YR 6/4) when crushed; strong, very coarse, subangular, blocky structure; hard, firm, plastic; peds partly coated in places with light gray; discontinuous, thick clay films; plentiful roots.

B3 15 to 23 inches, light yellowish-brown (10YR 6/4) sandy loam, pale yellow (2.5Y 7/4) when crushed; weak, very coarse, subangular blocky structure.

C1 23 to 29 inches, pale-yellow (2.5Y 7/4) sandy loam streaked with white carbonates; few reddish-brown mottles; single grain; few roots; few pebbles, largely dolomitic; calcareous.

C2 29 to 45 inches, pale-yellow (2.5Y 7/4) sandy loam streaked with white carbonates; few strong-brown (7.5YR 5/6) mottles; single grain; few roots; many pebbles, largely dolomitic; few reddish-brown stains; common lime segregations; calcareous.

C3 45 to 55 inches, pale-yellow (2.5Y 7/4) sandy loam; single grain; compact, friable; lime segregations in streaks; calcareous.

Climatic data (Detroit Lakes, Minn.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	5	8	22	40	54	64	70	68	58	45	26	12	39
Mean precipitation, 1931-52 (inches)	0.7	0.7	1.1	2.0	2.9	3.7	3.5	3.6	2.0	1.4	1.0	0.8	23.3

Annual precipitation more than 13.9 and less than 32.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxide Fe_2O_3 %
2-0	O2	---	---	---	---	---	----	----	----	----	---		----	---	---
0-5	A2	1.3	5.4	6.5	12.9	12.1	52.8	9.0	----	27.8	---		0.47	12	0.5
5-10	B21t	.5	1.8	2.1	4.8	7.6	54.0	29.2	----	30.1	---		.38	8	1.0
10-15	B22t	2.0	6.2	6.7	12.2	7.9	35.5	29.5	----	20.1	---		.30	6	1.0
15-23	B3	7.3	14.8	13.4	23.7	11.0	16.4	13.4	----	7.8	---		.23	10	.8
23-29	C1	6.5	14.5	14.1	25.5	12.5	18.1	8.8	----	8.0	---		.10	8	.5
29-45	C2	5.1	13.7	13.9	25.1	12.6	20.2	9.4	----	9.2	---		.14	13	.5
45-55	C3	5.1	13.1	13.5	24.5	12.1	20.4	11.3	----	10.1	---		.08	10	.4

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	Base sat. % s
----	----	---	---	---	---	6.6	---
8.9	6.2	1.4	1.1	0.0	0.2	7.4	88
20.5	13.8	3.6	2.6	< .1	.5	7.1	87
20.7	13.5	4.2	2.6	< .1	.4	7.0	87
----	----	---	---	---	---	7.0	---
----	----	---	---	---	---	7.8	---
19.4	17.4	2.0	0	< .1	< .1	8.2	100
----	----	---	---	---	---	8.1	---

*Exchange acidity

Profile No. 23

Area: Hall County, Nebraska.
Vegetation: Corn; (natural) mid grasses.
Parent material: Loess.
Topography: One percent slope; small depression about 500 feet wide; terrace.

Ap 0 to 5 inches, very dark gray (10YR 3/1) silt loam, gray (10YR 5/1) when dry; granular structure; friable.

A21 5 to 10 inches, mixed dark-gray (10YR 4/1) and very dark gray (10YR 3/1) silt loam, light gray (10YR 6/1) and gray (10YR 5/1) when dry; light and dark colors are mainly in alternating, horizontal bands; platy, breaking to granular structure; soft, friable.

A22 10 to 17 inches, mixed dark-gray (10YR 4/1) and very dark gray (10YR 3/1) silt loam, light gray (10YR 6/1) and gray (10YR 5/1) when dry; light and dark colors are mainly in alternating, horizontal bands; platy, breaking to blocky structure; very friable; common, fine, slightly hard, very dark pellets.

A23 17 to 22 inches, dark-gray (10YR 4/1) silt loam, light gray (10YR 6/1) when dry; medium, blocky structure; slightly vesicular.

B21t 22 to 31 inches, very dark grayish-brown (2.5Y 3/2) clay loam, grayish brown (2.5Y 5/2) when dry; strong, blocky structure; very hard, plastic; thick clay films continuous on ped faces.

B22t 31 to 45 inches, dark grayish-brown (2.5Y 4/2) silty clay loam, grayish brown (2.5Y 5/2) when dry; blocky structure; very hard, plastic; thick clay films continuous on ped faces.

B23 45 to 55 inches, very dark grayish-brown (2.5Y 3/2) silty clay loam, light brownish gray (2.5Y 6/2) when dry; blocky structure; hard, plastic; thin clay films on ped faces.

B24 55 to 62 inches, very dark grayish-brown (2.5Y 3/2) clay loam, grayish brown (2.5Y 5/2) when dry; blocky structure; hard, plastic; thin clay films on ped faces.

Climatic Data (Grand Island, Neb.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Temperatures, 1921-50 (deg. F.)	23	28	38	51	61	72	79	76	67	54	38	27	51
Mean precipitation, 1921-50 (inches)	0.6	0.7	1.3	2.2	3.9	3.7	2.6	2.4	2.6	1.3	1.0	0.6	22.7

Annual precipitation more than 14.1 and less than 31.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-5	Ap	0.2	0.3	0.5	1.2	13.7	55.3	28.8	48.2	21.5	--		2.1	14	0.6
5-10	A21	.1	.4	.6	1.2	19.0	53.4	25.3	55.4	17.7	--		.7	12	.5
10-17	A22	.2	.5	.5	1.4	18.7	59.0	19.7	58.0	20.6	--		.5	11	.4
17-22	A23	.7	1.0	.9	2.1	21.5	57.0	16.8	60.5	19.4	--		.3	10	.4
22-31	B21t	.2	.6	.7	1.6	23.8	42.0	31.1	57.3	9.5	--		.3	5	.4
31-45	B22t	.1	.3	.4	1.1	15.9	47.7	34.5	51.7	12.5	--		.3	7	.4
45-55	B23	.3	.4	.5	1.0	25.2	45.1	27.5	60.3	10.5	--		.2	7	.4
55-62	B24	.2	.4	.5	1.5	19.8	50.5	27.1	54.8	16.2			.3	8	.4

Cation exch. cap.[b]	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	pH 1:10	Moisture tensions 1/3 atmos. %	15 atmos. %	E. C. mmhos. per cm. 25° C.
23.2	12.0	3.9		0.3	1.9	5.1	5.6	38.6	13.4	1.0
18.4	10.9	3.7		.3	1.5	5.7	6.5	31.4	11.6	.4
13.2	8.2	2.4		.3	1.1	5.9	6.6	29.2	8.5	.5
10.8	6.7	2.1		.1	.9	6.0	6.6	26.2	7.6	.4
20.9	13.0	4.6		.1	1.5	6.1	6.9	32.0	15.0	.3
24.5	16.1	5.5		.1	1.8	6.4	7.1	36.4	18.0	.3
20.3	13.2	4.4		.4	1.6	6.5	7.4	32.0	14.2	.4
21.4	14.3	4.4		.3	1.6	6.4	7.4	33.1	14.0	.4

Profile No. 24

Area: Tompkins County, New York.
Vegetation: Deciduous forest consisting of beech, red oak, sugar and red maple, and ash.
Parent material: Olive-colored, medium-textured till.
Topography: Slightly less than 3 percent slope; elevation between 1,750 and 1,800 feet; till plain.

O1 1 to 0 inch, loose leaves of beech, red oak, sugar and red maple, and ash.

A11 0 to ½ inch, very dark brown (10YR 2/2) silt loam; weak and moderate, medium, granular structure; very friable; abundant, horizontal, fine roots occupy about half of the volume; earthworms common, their mounds numerous; abrupt, smooth boundary.

A12 1/2 to 3/4 inch, dark-brown (10YR 3/3) silt loam, gray (10YR 5/1) when dry; weak, fine, granular structure; very friable; matted with fine roots.

A21 3/4 to 1 inch, dark-brown (10YR 4/3) silt loam; very weak, thin, platy structure; weakly matted with mycelium.

A22 1 to 2 inches, brown (10YR 5/3) channery silt loam; weak, very thin, platy structure; friable; abundant, fine roots; discontinuous silt coats on some peds; abrupt, smooth boundary.

B 2 to 16 inches, dark yellowish-brown (10YR 4/4) channery silt loam; moderate, coarse, subangular blocky, breaking readily to moderate, fine, subangular blocky structure that crushes to weak, fine, granular peds; firm; roots plentiful; pores evident.

A'2x 16 to 24 inches, olive (5Y 5/3) and light olive-brown (2.5Y 5/4) channery silt loam; common, fine, faint mottles of olive brown (2.5Y 4/4); weak, thick, platy structure; very firm, weakly brittle; abrupt, wavy boundary.

B'21x 24 to 34 inches, olive-brown (2.5Y 4/4) channery loam; common, coarse, prominent and faint mottles of dark yellowish brown (10YR 4/4), strong brown (7.5YR 5/6), and olive (5Y 5/3); moderate, very coarse, prismatic structure; extremely firm, brittle; few roots; prominent mottles border the prisms, faint mottles are inside the domed prisms; abrupt, smooth boundary.

B'22x 34 to 42 inches, olive-brown (2.5Y 4/4) channery loam; weak, very coarse, prismatic structure; prisms about 12 inches in diameter; extremely firm; roots only between prisms; few, medium (1 mm.), clay-lined pores; outsides of prisms are olive colored (5Y 5/3), but under the surface is a thin layer of strong brown, which gives broken prisms the appearance of being streaked vertically and horizontally; clear, smooth boundary.

C 42 to 52 inches, olive (5Y 4/3) channery loam; massive; very firm, dense; very few pores; clay films evident in pores.

Climatic data (Ithaca, N. Y.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	26	24	23	45	57	66	71	69	62	51	40	29	48
Mean precipitation, 1931-52 (inches)	1.9	1.9	2.9	2.7	3.7	3.3	4.1	3.5	3.3	2.9	2.6	2.4	35.1

Annual precipitation more than 26.5 and less than 43.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N m	Free iron oxides Fe_2O_3 %
1/2-3/4	A12	9.3	5.8	3.4	7.3	8.3	56.1	9.8	35.5	33.3	6		7.6	27	1.52
3/4-1	A21	4.2	3.4	2.3	5.7	8.0	62.2	14.2	32.9	40.9	9		3.01	20	1.56
1-2	A22	3.4	2.4	1.8	4.4	6.8	65.6	15.6	32.9	42.2	23		1.30	14	1.52
2-16	B	3.8	2.8	1.7	3.7	5.3	59.0	23.7	26.9	39.7	30		.92	10	2.36
16-24	A'2x	9.1	7.2	3.8	7.8	6.6	52.2	13.3	32.1	31.5	34		.26	5	1.28
24-34	B'21x	7.5	6.1	3.4	6.6	7.8	49.0	19.6	28.9	32.0	33		.24	4	1.60
34-42	B'22x	7.4	6.6	3.7	6.8	7.6	47.7	20.2	27.4	31.9	46		.14	2	1.80
42-52	C	6.2	5.9	3.0	5.6	6.5	48.7	24.1	24.8	33.7	36		.19	3	1.80

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
24.4	1.8	0.6	21.7	0.1	0.2	11	4.0
18.6	.6	.4	17.4	.1	.1	6	4.0
14.8	.2	.3	14.1	.1	.1	5	4.2
16.0	.6	.2	15.0	.1	.1	6	4.4
6.4	.6	<.1	5.6	.1	.1	12	4.7
9.9	1.5	.1	8.1	.1	.1	18	4.8
14.3	6.6	1.9	5.6	.1	.1	61	5.1
18.5	3.3	10.7	4.3	.1	.1	77	5.8

*Exchange acidity.

Profile No. 25

Area: Clark County, Nevada.
Vegetation: Very sparse (about 2 percent) cover of shrubs, mainly creosotebush, shadscale and white bur-sage.
Parent material: Water-deposited material.
Topography: Slope is about 1 percent; slightly convex; facing east; elevation about 2,200 feet; terrace.

A — 0 to 1/2 inch, brown (7.5YR 5/4) fine sandy loam, pink (7.5YR 8/4) when dry; weak, medium, platy structure; very weakly vesicular; soft, very friable; few roots; abrupt, smooth boundary.

C1cs — 1/2 to 14 inches, pink (7.5YR 8/4) fine sandy loam, pinkish white (7.5YR 8/2) when dry; single grain; soft, very friable; numerous roots; large amount of gypsum; calcareous; abrupt, wavy boundary.

C2cs — 14 to 27 inches, pink (7.5YR 8/4) loam, white (N 8/) when dry; single grain; hard, firm; large amount of gypsum; calcareous; clear, wavy boundary.

C3 — 27 to 36 inches, pink (7.5YR 8/4), light clay loam; single grain; hard, firm; few, faint, white, calcareous segregations; medium-sized gypsum crystals; calcareous; clear, wavy boundary.

C4 — 36 to 47 inches, pink (7.5YR 8/4) loam; single grain; hard, firm; few, fine, faint, pinkish-white calcareous segregations; many, medium to large gypsum crystals; calcareous; clear, wavy boundary.

C5 — 47 to 57 inches, pinkish-white (7.5YR 8/2) loam; single grain; slightly hard, firm, slightly sticky; calcareous.

Climatic Data (Las Vegas, Nev.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Temperature, 1921-50 (deg. F.)	44	50	57	66	74	84	91	88	81	67	54	47	67
Mean Precipitation, 1921-50 (in.)	0.4	0.6	0.4	0.2	0.2	0.1	0.5	0.5	0.3	0.3	0.2	0.6	4.4

Annual precipitation more than 0.1 and less than 8.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
0-½	A	Particle size distribution not reported. Samples stirred twice with 1000 ml. of water, but most samples gave indication of flocculation from gypsum after this treatment.									3		0.52	9
½-14	C1cs										5		.10	4
14-27	C2cs										1		.17	
27-36	C3										16		.18	
36-47	C4										6		.28	
47-57	C5										33		.23	

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	$CaCO_3$ % v	E. C. mmhos. per cm. 25°C.	Percent gypsum by weight
9.4				0.5	0.4	7.9	19	3.3	5.0
10.0				.1	.1	8.0	<0.5	2.9	36.5
10.5				1.1	.3	8.1	5	11.3	34.8
20.9				3.6	.9	8.3	26	20.6	6.4
17.6				3.4	1.2	8.3	38	28.4	6.4
10.4				2.1	.7	8.4	68	24.0	2.7

Profile No. 26

Area: San Bernardino County, California.
Vegetation: 99 percent of surface barren; occasional clumps of shadscale about 24 inches high.
Parent material: Water-deposited material.
Topography: Nearly level; elevation about 3,000 feet; playa.

C1 0 to 2 inches, yellowish-brown (10YR 5/4) clay, pale brown (10YR 6/3) when dry; compound, weak, coarse, prismatic and strong, very fine, subangular blocky structure; very hard, firm; calcareous; abrupt, smooth boundary.

C2sa 2 to 6 inches, yellowish-brown (10YR 5/4) clay, light yellowish brown (10YR 6/4) when dry; strong, very fine, granular structure; soft, very friable; very few plant roots; 5 to 10 percent of volume is salt crystals as much as 1/8 inch in diameter; calcareous; abrupt, wavy boundary.

C3sa 6 to 10 inches, dark yellowish-brown (10YR 4/4) silty clay, yellowish brown (10YR 5/4) when dry; compound, weak, very coarse, prismatic and moderate, very fine to medium, granular structure; slightly hard, friable; few roots; calcareous; abrupt, smooth boundary.

C4sa 10 to 23 inches, brown (10YR 5/3) clay; compound, very weak, medium to coarse, prismatic and weak, fine, subangular blocky structure; very hard, firm; few roots; calcareous; clear, smooth boundary.

C5sa 23 to 34 inches, brown (10YR 5/3) clay; very weak, medium, subangular blocky structure; hard, firm; very few, fine roots; calcareous; abrupt, smooth boundary.

C6sa 34 to 41 inches, brown (10YR 5/3) clay; massive; very hard, firm; very few roots; common, fine to medium, white, calcareous segregations; calcareous; abrupt, smooth boundary.

C7 41 to 53 inches, pale-brown (10YR 6/3) clay; massive; very hard, firm; many, medium, white, calcareous segregations; calcareous; abrupt, smooth boundary.

C8 53 to 62 inches, light yellowish-brown (10YR 6/4) clay; massive; very hard, firm; few, medium, white, calcareous segregations; calcareous; abrupt, smooth boundary.

Climatic Data (Lucerne Valley, Cal.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Temperatures, 1939-58 (deg. F.)	42	45	50	58	65	72	79	78	72	60	49	43	60
Mean Precipitation, 1939-58 (in.)	1.1	0.9	0.9	0.4	0.0	0.0	0.1	0.2	0.2	0.3	0.5	1.0	5.5

Annual precipitation more than 0.4 and less than 10.6 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate												
0-2	C1	0.2	0.5	0.5	3.9	7.3	25.4	62.2	11.9	24.1	1		0.10	8
2-6	C2sa	.1	.4	.6	3.3	5.8	24.7	65.1	10.2	22.9	0		.17	14
6-10	C3sa	.3	.5	.5	2.9	4.7	45.4	45.7	20.1	32.2	0		.20	15
10-23	C4sa	.1	.2	.3	1.8	4.4	29.5	63.7	8.0	27.3	0		.16	12
23-34	C5sa	.1	.3	.2	1.1	2.7	30.5	65.1	5.6	28.4	0		.18	
34-41	C6sa	.2	.4	.4	1.5	2.9	24.0	70.6	6.5	21.6	0		.19	
41-53	C7	.0	.1	.0	.5	1.3	34.1	64.0	4.3	31.5	0		.13	
53-62	C8	.0	.2	.1	.6	.7	15.1	83.3	2.6	13.6	0		.15	

Cation exch cap b	Ca	Mg	H	Na	K	pH sat. paste	Exch. Na %	E. C. mmhos. per cm. 25° C.	$CaCO_3$ % v	Soluble salt %
	Extractable cations, meq./100 gm.									
33.0				20.2	6.2	8.6	61	10.8	13.8	0.3
32.8				24.5	6.2	8.5	75	92.6	13.6	3.9
31.3				28.6	5.3	8.4	91	99.0	13.9	4.1
33.7				24.5	6.2	8.4	73	63.8	16.7	2.5
35.4				22.6	4.3	8.5	64	36.4	21.9	1.6
36.2				26.1	4.0	8.6	72	30.2	24.0	1.1
33.3				25.8	3.1	8.6	77	22.0	28.5	0.8
41.1				26.9	4.1	8.5	66	21.6	31.4	0.9

Profile No. 27

Area: Puerto Rico.
Topography: Slightly less than 3 percent slope; upland.
Vegetation: Native grasses and trees.
Parent material: Serpentine.

A1 0 to 11 inches, dark reddish-brown (2.5YR 2/4) clay; strong, fine, granular structure; friable; abrupt, smooth boundary.

A3 11 to 18 inches, dark reddish-brown (2.5YR 3/4) clay (has feel of clay loam); weak, fine, blocky structure; very friable, nonsticky, nonplastic; clear, smooth boundary.

B21 18 to 28 inches, dark-red (7.5R 3/8) clay; weak, fine, blocky structure; very friable, nonsticky, nonplastic; diffuse boundary.

B22 28 to 38 inches, dusky-red (7.5R 3/4) to dark-red (7.5R 3/6) clay; massive; firm, nonsticky, nonplastic; few, small, iron-coated pebbles (probably serpentine); diffuse boundary.

B23 38 to 48 inches, dusky-red (7.5R 3/4) to dark-red (7.5R 3/6) clay; massive; friable, nonsticky, nonplastic; streaks of strong brown (7.5YR 5/6); few, iron-coated pebbles; clear boundary.

B3 48 to 62 inches, dark-red (7.5R 3/6) clay; massive; friable, nonsticky, nonplastic; streaks of strong brown (7.5YR 5/6); diffuse boundary.

C1 62 to 70 inches +, dusky-red (7.5R 3/4) clay; massive; very firm, nonsticky, nonplastic.

Climatic Data (Mayaguez, P. R.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Temperatures, 1931-52 (deg. F.)	71	71	72	74	75	77	77	77	77	79	77	76	75
Mean Precipitation, 1931-52 (in.)	2.0	1.7	3.8	4.1	8.5	8.6	9.9	10.4	11.1	8.1	5.4	2.5	75.9

Annual precipitation more than 57.1 and less than 94.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N % k	Free iron oxides Fe_2O_3 %
0-11	A1	1.5	2.0	0.9	2.3	2.5	36.3	54.5	10.6	29.6	Tr.		6.34	17	15.3
11-18	A3	2.9	1.5	.6	1.1	1.3	34.9	57.7	9.0	27.8	Tr.		2.04	18	14.3
18-28	B21	2.3	.9	.4	1.4	4.8	30.6	59.6	19.2	17.2	Tr.		1.33	17	17.5
28-38	B22	2.5	1.8	1.1	6.0	11.9	21.0	55.7	25.9	11.6	Tr.		.86		20.4
38-48	B23	1.7	1.8	1.1	4.3	8.1	23.3	59.7	20.3	14.1	Tr.		.72		21.5
48-62	B3	4.0	3.3	1.4	3.5	7.0	27.2	53.6	19.5	17.0	17.4		.56		22.8
62-70 +	C1	8.8	4.0	1.0	1.4	1.9	45.3	37.6	12.8	35.2	Tr.		.19		28.4

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH in H_2O 1:1	pH in KCl 1:1	Moisture tensions: 1/3 atmos. %	15 atmos. %	Cation exch. cap. s	Base sat. % s
26.7	1.4	1.5	33.5	0.1	0.1	12	5.1	4.3	37.0	26.5	36.6	8
12.1	.1	---	21.4	---	---	1	5.0	4.4	29.3	22.8	21.5	<1
8.2	---	---	15.7	---	---	--	5.0	4.7	30.3	24.8	15.7	0
6.4	---	---	12.8	---	---	--	5.4	5.7	31.6	25.9	12.8	0
5.3	---	.1	12.0	---	---	2	5.7	6.1	32.8	26.4	12.1	<1
3.8	---	---	12.8	---	---	--	5.9	6.4	30.3	24.5	12.8	0
1.4	---	---	9.4	---	---	--	6.1	6.7	22.4	18.0	9.4	0

*Exchange acidity

Profile No. 28

Area: Puerto Rico.
Vegetation: Tropical rain forest.
Parent material: Residuum from tuffaceous rock.
Topography: 60 percent slope, on mountain side; midway between top and bottom.

O1 2 1/2 to 2 inches, partly decomposed leaves.

O2 2 to 0 inch, very dark brown (10YR 2/2), highly decomposed plant litter; abundant roots.

A11 0 to 4 inches, brown (10YR 4/3) clay common, dark brown (10YR 3/3) mottles; weak, fine, subangular blocky structure; nonsticky, nonplastic; abundant roots make up about 50 percent of the total mass; clear, smooth boundary.

A12 4 to 7 inches, brown (10YR 4/3) to dark yellowish-brown (10YR 4/4) clay; moderate, fine, subangular blocky structure; nonsticky, nonplastic; abundant roots make up about 25 percent of the total mass; abrupt, wavy boundary.

B21 7 to 14 inches, yellowish-brown (10YR 5/6) to strong-brown (7.5YR 5/6) silty clay loam; many, medium, distinct, yellowish-red (5YR 5/6) mottles and a few, fine, and medium, very pale brown (10YR 7/4) mottles; moderate, medium, subangular blocky structure; nonsticky, nonplastic; abrupt, wavy boundary.

B22 14 to 19 inches, yellowish-brown (10YR 5/6) to strong-brown (7.5YR 5/6) clay loam; many, medium, distinct, yellowish-red (5YR 5/6) mottles and a few, fine and medium, very pale brown (10YR 7/4) mottles; weak, medium, subangular blocky structure; nonsticky, nonplastic; few subangular fragments of highly weathered, gray and brown, easily broken, tuffaceous rock up to 2 inches in diameter; clear, smooth boundary.

B3 19 to 28 inches, yellowish-brown (10YR 5/6) to strong-brown (7.5YR 5/6) silty clay loam; few, fine, very pale brown (10YR 7/4) mottles; very weak, medium, subangular blocky structure; nonsticky, nonplastic; yellowish-brown (10YR 5/4) plugs common in old root channels; few, soft, subangular fragments of highly weathered, gray and brown, tuffaceous rock up to 2 inches in diameter; abrupt, wavy boundary.

Ab 28 to 34 inches, brown (10YR 4/3) silty clay loam mingled with yellowish-brown (10YR 5/4) silt loam in the ratio of about 2 parts silty clay loam to 1 part of silt loam; few, fine, very pale brown (10YR 7/4) mottles; massive; nonsticky, nonplastic; few, soft, subangular fragments of highly weathered, gray and brown tuffaceous rock up to 2 inches in diameter; abrupt, irregular boundary.

Cb 34 to 44 inches, yellowish-brown (10YR 5/6) loam mingled with brown (10YR 4/3) silty clay loam in the ratio of 2 parts of loam to 1 part of silty clay loam; few, fine, very pale brown (10YR 7/4) mottles; massive; nonsticky, nonplastic; few, soft, subangular fragments of highly weathered, gray and brown tuffaceous rock up to 2 inches in diameter.

Climatic data (Rio Blanco Upper, P. R.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1935-44 (deg. F.)	68	67	68	69	70	72	72	73	73	72	71	69	70
Mean precipitation, 1931-52 (inches)	10.8	8.5	6.9	9.8	16.6	14.5	14.0	15.0	16.3	15.6	15.0	13.1	155.9

Annual precipitation more than 128.0 and less than 183.8 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-4	A11	7.4	2.3	0.9	1.4	2.0	35.7	50.3	7.1	31.4	Tr.		5.16	16	6.8
4-7	A12	4.4	2.1	1.0	2.1	2.9	38.0	49.5	9.9	32.3	--		3.05	11	9.4
7-14	B21	.9	2.0	1.7	5.4	5.3	45.9	38.8	15.8	38.7	--		.59	14	10.7
14-19	B22	2.9	5.9	4.1	9.3	7.3	36.7	33.8	20.6	28.6	--		.53	12	11.0
19-28	B3	.4	1.1	1.6	5.5	5.1	57.3	29.0	15.4	50.4	--		.25	12	10.6
28-34	Ab	.7	1.5	2.2	7.1	6.6	54.8	27.1	18.1	47.6	--		.13		7.9
34-44	Cb	3.4	5.6	4.8	10.2	7.3	46.6	22.1	20.5	39.1	--		.16		8.0

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH H_2O 1:1	pH in KCl 1:1	Base exch. % b	Base sat. % s	Cation exch. cap. s	Moisture tensions 1/3 atmos. %	15 atmos. %
17.4	0.5	0.8	28.8	0.2	0.1	4.8	4.1	9	5	30.4	37.9	24.6
13.9	.3	.8	21.3	.2	.1	4.8	4.1	10	6	22.7	36.1	24.1
11.1	.3	.5	15.5	.3	<.1	5.1	3.9	10	7	16.6	39.6	26.3
9.0	.1	.1	17.2	.3	<.1	5.0	4.0	6	3	17.7	42.0	27.1
8.1	<.1	.1	14.7	.2	<.1	5.2	4.0	4	2	15.0	45.9	22.7
8.8	<.1	.1	13.8	.2	<.1	5.2	3.9	3	2	14.1	45.7	21.4
9.9	<.1	<.1	17.2	.2	<.1	5.1	3.9	2	1	17.4	47.6	22.0

*Exchange acidity

Profile No. 29 Area: Strafford County, New Hampshire.
Vegetation: Hay; (natural) northern hardwoods.
Parent material: Till.
Topography: 2 percent slope; top of broad drumlin.

Ap 0 to 9 inches, very dark brown (10YR 3/3) sandy loam; weak, medium, granular structure; friable; abundant roots; 5 to 10 percent coarse fragments; clear, wavy boundary.

B21 9 to 13 inches, strong-brown (7.5YR 5/8) sandy loam, weak, coarse, subangular blocky structure; friable; plentiful roots; 5 to 10 percent coarse fragments; clear, wavy boundary.

B22 13 to 16 inches, yellowish-brown (10YR 5/4) sandy loam; weak, coarse, subangular blocky structure; friable; few, fine mottles of yellowish red (5YR 5/6); few roots; 15 to 25 percent coarse fragments; abrupt, wavy boundary.

C1x 16 to 24 inches, olive (5Y 5/3) sandy loam; weak, thick, platy structure, very firm; common, medium mottles of yellowish red (5YR 5/6); 20 to 30 percent coarse fragments; grayish-brown (2.5Y 5/2) vertical streaks, light brownish gray (2.5Y 6/2) when dry; the streaks occur at intervals of a few inches to several feet, are from less than 1 inch to several inches thick, and are bordered by yellowish-red (5YR 4/8) strips 1/4 inch thick. The platy structure in the pan does not extend into the bleached fracture planes or cracks; the structure in the bleached fracture planes is massive or weak subangular blocky. The bleached fracture planes extend downward through the pan and terminate at about 64 inches.

C2x 24 to 36 inches, olive (5Y 5/3) sandy loam; strong, medium, platy structure; firm; irregular layers of yellowish red (5YR 4/8) between layers of light brownish gray (2.5Y 6/2); diffuse boundary.

C3x 36 to 48 inches, similar to horizon above except that consistence is very firm.

C4x 48 to 64 inches, olive (5Y 5/3) fine sandy loam; moderate, medium, platy structure; very firm; clay films evident on ped faces and on pore walls; alternating layers of yellowish brown (10YR 5/4) and light brownish gray (2.5Y 6/2) 1/4 to 1/8 inch thick; 20 to 30 percent coarse fragments; diffuse boundary.

C5 64 to 83 inches, similar to horizon above except bleached fracture planes fade, clay films are absent, and structure is weak medium platy.

Climatic data (Durham, N. H.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	24	25	34	45	56	65	70	68	61	51	39	27	47
Mean precipitation, 1931-52 (inches)	3.6	2.8	3.9	3.7	3.1	3.5	3.5	3.2	3.5	2.8	4.1	3.6	41.1

Annual precipitation more than 28.3 and less than 53.9 inches during 9 years out of 10

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3
0-9	Ap	4.4	15.3	15.1	20.6	11.1	27.4	6.1	34.5	14.0	9		2.61	11	1.4
9-13	B21	5.2	16.2	15.0	20.8	11.6	28.2	3.0	34.4	15.6	11		.80	13	1.3
13-16	B22	5.2	18.2	16.9	21.8	11.6	23.9	2.4	33.8	12.4	8		.51	12	1.1
16-24	C1x	4.5	12.7	13.0	20.0	13.4	31.2	5.2	38.3	16.6	10		.10		1.0
24-36	C2x	6.1	13.6	10.6	18.5	15.9	29.8	5.5	40.7	15.2	10		.08		1.0
36-48	C3x	5.2	16.0	11.6	20.6	16.4	25.0	5.2	42.1	10.8	9		.03		.7
48-64	C4x	3.6	10.2	10.4	22.6	19.5	29.1	4.6	49.9	12.0	5		.03		.6
64-83	C5	3.7	10.3	10.6	21.8	16.8	26.9	9.9	43.2	13.0	6		.01		.6

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
17.2	3.7	0.3	12.9	0.1	0.2	25	5.4
7.9	.7	.2	6.7	.1	.2	15	5.7
5.6	.4	.2	4.8	.1	.1	14	5.7
3.9	.6	.1	3.0	.1	.1	23	5.8
3.9	.4	.2	3.0	.1	.2	23	5.4
4.6	1.3	.2	2.8	.1	.2	39	5.5
3.6	1.1	.2	3.0	.1	.2	44	5.6
3.7	1.5	.2	1.6	.2	.2	57	6.0

*Exchange acidity.

Profile No. 30

Area: Strafford County, New Hampshire
Vegetation: Northern hardwoods with some white pine.
Parent material: Till.
Topography: 4 percent slope, facing west; 900 feet downslope from top of broad drumlin.

O1 — 2 to $1\frac{1}{2}$ inches, recently fallen leaves.

O2 — $1\frac{1}{2}$ to 0 inches, partly decomposed litter.

A1 — 0 to 1 inch, grayish-brown (10YR 5/2) fine sandy loam; weak, medium, granular structure; very friable; fragments of subangular rock from 3 to 10 inches across occur on the surface at intervals of 6 to 8 feet; high in organic matter; very strongly acid; clear, wavy boundary.

A2 — 1 to 10 inches, light brownish-gray (10YR 6/2) loamy sand; weak, medium, subangular blocky structure; very friable; 5 to 10 percent coarse fragments 3 to 10 inches across; few, fine, faint mottles of yellowish brown (10YR 5/8); plentiful roots; clear, wavy boundary.

B1 — 10 to 18 inches, grayish-brown (2.5Y 5/2) loamy sand; few, fine, faint mottles of yellowish brown (10YR 5/8); weak, medium, subangular blocky structure; friable; plentiful roots; about 10 percent coarse fragments 3 to 10 inches across; clear, wavy boundary.

B2g — 18 to 20 inches, olive (5Y 5/3) loamy sand; many, coarse, distinct mottles of very dark brown (10YR 2/2); weak, thick, platy structure; friable; some peds coated with dark brown (10YR 3/3) and others with very dark brown (10YR 2/2); layers of dark reddish-brown (5YR 3/2) organic matter, 1/4 to 1/32 inch thick, between plates; many fine roots; abrupt, wavy boundary.

C1x — 20 to 23 inches, grayish-brown (2.5Y 5/2) and light brownish-gray (2.5Y 6/2) loamy sand; upper part of horizon has many coarse, distinct mottles of light olive brown (2.5Y 5/4); moderate, medium, platy structure; firm; lower part has many, coarse, prominent mottles of dark reddish brown to yellowish red; the red colors occur as blotches extending more or less continuously in both horizontal and vertical directions; massive; very firm, brittle; few roots throughout; about 10 percent coarse fragments 3 to 10 inches across; clear, wavy boundary.

C2x — 23 to 31 inches, yellowish-brown (10YR 5/4) to light olive-brown (2.5Y 5/4) sandy loam; massive; extremely firm in place, firm when removed; few roots; about 10 percent coarse fragments 3 to 10 inches across; occasional grayish vertical streaks, 2 to 3 inches long and 1/2 inch thick, enclosed by yellowish-red edge approximately 1/32 inch thick; a few horizontal streaks of similar color and thickness; gradual boundary.

C3 — 31 to 43 inches, yellowish-brown (10YR 5/8) loamy sand; common, medium, prominent mottles of light olive brown (2.5Y 5/4); weak, medium, platy structure; firm in place, friable when removed; 10 to 20 percent coarse fragments 3 to 10 inches across; gradual boundary.

C4 — 43 to 59 inches, olive (5Y 5/3) sandy loam; many, coarse, prominent mottles of yellowish brown (10YR 5/4) and dusky red (2.5YR 3/2); weak, medium, platy structure; friable; 10 to 20 percent coarse fragments.

Climatic data (Durham, N. H.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	24	25	34	45	56	65	70	68	61	51	39	27	47
Mean precipitation, 1931-52 (inches)	3.6	2.8	3.9	3.7	3.1	3.5	3.5	3.2	3.5	2.8	4.1	3.6	41.1

Annual precipitation more than 28.3 and less than 53.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	C/N (k)	Free iron oxides Fe_2O_3 %
0-1	A1	(Not determined-highly organic)													
1-10	A2	6.4	14.1	14.5	26.8	17.0	19.9	1.3	43.8	7.8	13		13.0	44	0.2
10-18	B1	5.6	14.7	15.1	26.9	17.1	17.9	2.7	42.2	7.0	13		.15	8	.2
18-20	B2g	5.5	15.8	15.3	25.9	17.0	18.5	2.0	41.7	7.5	10		.49	10	.2
20-23	C1x	5.1	17.4	17.2	28.1	14.0	15.4	1.7	37.1	6.5	12		.69	17	.6
23-31	C2x	5.8	12.3	11.7	23.6	17.8	26.1	2.7	46.1	11.1	9		.03	37	1.3
31-43	C3	6.2	14.7	13.0	25.1	19.2	20.0	1.8	45.7	7.7	19		.03		.6
43-59	C4	4.5	14.1	12.2	22.7	18.5	25.4	2.6	45.1	11.7	15		.01		.6

Cation exch. cap. (s)	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % (s)	pH 1:1
41.7	0.7	1.6	38.8	0.1	0.5	7	4.5
1.8	<.1	.1	1.6	<.1	.1	11	4.6
5.1	<.1	.2	4.8	<.1	.1	6	4.7
8.1	.1	.1	7.8	<.1	.1	4	4.8
4.4	.0	.1	4.0	<.1	.1	7	5.1
2.1	<.1	.1	1.8	.1	.1	14	5.4
1.7	<.1	.1	1.4	.1	.1	18	5.6
2.3	.6	.3	1.2	.1	.1	48	5.8

*Exchange acidity.

Profile No. 31

Area: Tehama County, California

Vegetation: Sparse; annual grasses and associated herbaceous plants; alfileria (Erodium cicutarium) predominates and is only about 2 inches high.

Parent material: Alluvium or valley-fill materials.

Topography: One percent slope; about halfway between mound and intermound areas, which are 5 to 20 feet in diameter; 315 feet elevation; terrace.

Ap 0 to 8 inches, dark reddish-brown (2.5YR 3/4), light gravelly loam, yellowish red (5YR 5/6) when dry; weak, granular structure; slightly hard, very friable, slightly plastic; plentiful, fine roots; gradual boundary.

A21 8 to 14½ inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; weak, blocky structure; slightly hard, friable, slightly plastic; plentiful, fine roots, but somewhat fewer than in layer above; gradual boundary.

A22 14½ to 19½ inches, yellowish-red (5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; weak, blocky structure; slightly hard, friable, slightly plastic; plentiful, fine roots; abrupt, wavy boundary.

B2t 19½ to 22 inches, yellowish-red (5YR 4/6) clay containing a small amount of gravel; strong, blocky to prismatic structure; very compact; extremely hard, extremely firm, very plastic; surfaces of peds glazed dark red (2.5YR 3/6); very few roots; coatings of manganese oxide evident; wavy boundary.

C1m 22 to 24½ inches, yellowish-red (5YR 4/6), very gravelly, indurated hardpan; massive; glazed surface is dark red (2.5YR 3/6); coatings of manganese oxide evident; gradual boundary.

C2m 24½ to 35 inches, yellowish-red (5YR 5/6), gravelly, strongly cemented hardpan; massive; coatings of manganese oxide evident, and, in general, material is harder where manganese oxide occurs.

Climatic data (Red Bluff, Calif.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-48 (deg. F.)	46	50	55	60	68	75	82	79	74	65	54	47	63
Mean precipitation, 1931-48 (inches)	4.1	3.6	2.8	2.2	1.2	0.5	0.0	0.0	0.3	1.6	2.2	4.8	23.2

Annual precipitation more than 11.4 and less than 35.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
0-8	Ap	9.1	8.6	4.3	10.0	18.2	40.2	9.6		19.8	25		0.36	
8-14½	A21	8.2	7.9	4.5	10.3	19.1	39.1	10.9		19.9	21		.18	
14½-19½	A22	10.1	7.5	4.3	9.7	17.5	38.7	12.2		19.5	19		.14	
19½-22	B2t	6.1	4.9	2.2	4.4	7.4	19.5	55.5		11.1	14		.35	
22-24½	C1m	28.5	15.5	4.6	6.5	5.0	13.9	26.0		10.0	51		.18	
24½-35	C2m	25.1	13.9	4.4	5.3	5.7	19.6	26.0		14.9	44		.05	

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH sat. paste
7.5	3.2	1.3	2.6	Tr.	0.38	65	5.7
8.0	3.2	1.9	2.6	<0.01	.25	67	5.6
8.6	3.2	2.6	2.6	.03	.17	70	5.5
32.8	12.6	13.4	6.2	.29	.29	81	5.3
33.0	13.5	13.5	5.4	.37	.28	84	5.5
28.1	12.6	12.2	2.9	.20	.21	90	6.8

*Exchange acidity.

Profile No. 32

Area: Aroostook County, Maine

Vegetation: Fallow strip between potatoes and timothy; (natural) sugar maple, beech, white and yellow birch, some spruce and fir.

Parent material: Till from calcareous shale with some limestone.

Topography: Long slopes of 3 to 8 percent, irregularly convex and concave; upland.

Ap 0 to 8 inches, brown (10YR 4/3) gravelly silt loam, light brownish gray (2.5Y 6/2) to light yellowish brown (2.5Y 6/4) when dry; weak, coarse and fine granular structure; very friable; 20 to 30 percent by volume of subrounded and angular fragments of dark-gray shale siltstone and fine-grained quartzite, $\frac{1}{4}$ to 3 inches in diameter, some of which are brown inside; abrupt, smooth boundary.

A2 8 to 12 inches, pale-brown (10YR 6/3) loam that appears light gray in places; weak, thin, platy or very weak, fine, granular structure; very friable; discontinuous, occurring as spots 8 to 12 inches wide and 1 to 2 inches thick at horizontal distances of 6 to 8 feet; abrupt, smooth boundary. (This horizon not sampled.)

B2ir 8 to 14 inches, brown (7.5YR 4/4) gravelly loam; compound, very weak, subangular and weak, very fine, granular structure; very friable discontinuous in the sample pit but, in general, occurs over 80 to 90 percent of the area; abundant roots; broken, wavy boundary.

A'2 14 to 25 inches, yellowish-brown (10YR 5/4) gravelly loam that crushes to a slightly browner hue; compound weak, thick, platy and weak, fine, subangular structure; horizontal faces of peds have a few clay films in pore channels and around openings; friable; slightly brittle; many, fine, vertical, cylindrical pores in plates, many of which extend continuously from top to bottom and with upper openings glazed with clay; abrupt, smooth boundary.

B'21t 25 to 32 inches, olive-brown (2.5Y 4/4), very gravelly, heavy loam; moderate, medium, subangular blocky structure; friable; clay films on ped faces; pore channels are evident on ped faces; many, fine, pores glazed with clay in interiors of peds; 60 to 80 percent by volume of angular and subangular pebbles 2 to 4 inches in diameter so conspicuous as to resemble a "stone line" or solifluction unconformity; about 20 percent of the fragments are very friable, leached, and brown; fine, faint, gray mottling occurs in a few places; pH 5.0 to 5.2; gradual, smooth boundary.

B'22t 32 to 40 inches, olive-brown (2.5Y 4/4), gravelly loam; very weak, very coarse, blocky structure; ped faces have a surface network of pore channels glazed with light olive- brown (2.5Y 5/4) clay; pores are mostly between peds and appear as channels when peds are separated; gradual, smooth boundary.

B'23t 40 to 49 inches, olive-brown (2.5Y 4/4) gravelly loam; very weak, very coarse, subangular blocky and moderate, medium, platy structure; clay films on blocky peds; friable; ped faces have a surface network of pore channels glazed with light olive brown (2.5Y 5/4) clay; pores are mostly between peds and appear as channels when peds are separated; gradual, smooth boundary.

C 49 to 58 inches, olive-brown (2.5Y 4/4) gravelly loam; with moderate, thick, platy structure; peds are $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, are 2 to 3 inches across, and are feathered at the edges; firm to very firm, nonplastic; a few, friable, leached fragments, $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter; calcareous.

Remarks: Shale fragments $\frac{1}{4}$ to 4 inches in diameter occur below a depth of 8 inches. They make up 60 to 80 percent by volume of the B'21 horizon and 10 to 40 percent of other horizons.

Climatic data (Presque Isle, Maine)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-59 (deg. F.)	12	14	25	38	52	61	66	65	56	44	32	17	40
Mean precipitation, 1931-50 (inches)	1.9	1.9	2.1	2.5	3.0	3.9	4.0	3.1	3.4	3.5	3.0	2.2	34.5

Annual precipitation more than 26.9 and less than 42.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N	Free iron oxides Fe_2O_3 %
0-8	Ap	8.8	6.2	4.0	7.6	8.6	49.6	15.2	32.6	30.0	26		2.56	10	2.1
8-14	B2ir	6.3	7.3	4.8	9.2	9.7	47.9	14.8	41.2	21.6	24		1.55	12	2.1
14-25	A'2	8.9	9.3	6.0	11.0	11.0	41.3	12.5	33.8	24.8	28		.16		1.5
25-32	B'21t	6.7	6.5	4.0	7.6	8.5	42.0	24.7	26.8	28.1	32		.14		2.1
32-40	B'22t	7.0	6.8	4.7	8.9	9.1	42.3	21.2	29.7	27.1	19		.08		1.8
40-49	B'23t	6.4	7.4	4.7	9.2	9.2	42.5	20.6	29.2	28.0	22		.10		1.9
49-58+	C	9.4	7.7	4.2	7.1	7.8	41.6	22.2	25.8	27.6	25		.08		2.0

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	CaCO3 equiv. % n	Moisture tensions 1/3 atmos. %	15 atmos. %
22.7	3.0	0.7	18.2	0.1	0.7	20	4.8		27.8	8.2
23.8	1.0	.1	22.3	<.1	.4	6	4.6		28.3	8.5
7.1	2.0	.3	4.6	<.1	.2	35	4.8		16.8	5.1
10.8	5.1	.8	4.6	.1	.2	57	5.1		21.0	9.2
9.7	6.1	.8	2.7	<.1	.1	72	6.0		20.0	8.2
9.7	6.1	.9	2.5	.1	.1	74	6.2		19.3	7.5
		Calcareous.					7.7	10	20.1	9.0

*Exchange acidity.

Profile No. 33

Area: Faribault County, Minnesota

Vegetation: Big and little bluestem (Andropogon gerardi and A. scoparius), wild sweetpea (Lathyrus), goldenrod (Solidago), wild rose (Rosa), milkweed (Asclepias), and Kentucky bluegrass (Poa pratensis).

Parent material: Calcareous glacial till.

Topography: 4 percent slope; morainic uplands.

A11 0 to 2½ inches, very dark brown (10YR 2/2) sandy clay loam; medium, granular structure; abundant, fibrous roots.

A12 2½ to 9 inches, very dark brown (10YR 2/2) sandy clay loam; moderate, medium, granular structure; the peds are 1/8 to 1/4 inch in diameter; friable; fine and medium roots; numerous worm casts; wormholes present; few small pebbles of mixed origin.

A13 9 to 15 inches, very dark brown (10YR 2/2), heavy loam streaked with dark brown (10YR 3/3); moderate, medium, granular structure; friable, slightly plastic, slightly sticky; peds coated with very dark brown, but, when crushed, the material is dark yellowish brown; abundant roots; many small pebbles; numerous worm casts.

B21 15 to 23 inches, dark yellowish-brown (10YR 4/4), heavy loam; moderate, fine, subangular blocky structure; friable, slightly plastic, slightly sticky; very dark brown material in a few channels and voids; very few pebbles; plentiful roots; few worm casts.

B22 23 to 28 inches, yellowish-brown (10YR 5/4) loam; weak, fine and medium, subangular blocky structure; peds ¼ to ½ inch in diameter; friable, slightly plastic; plentiful roots; few shale fragments and small pebbles of granitic origin; few worm casts and root channels.

B23 28 to 34 inches, yellowish-brown (10YR 5/4) sandy loam; weak, medium, subangular blocky structure; peds about ½ inch in diameter; friable; few roots; very few root channels; many shale fragments and granitic pebbles.

C1 34 to 37 inches, light yellowish-brown (2.5Y 6/3) sandy loam; friable; few fine roots; many shale fragments and small granitic pebbles; few dolomitic pebbles; calcareous material confined to coatings on pebbles rather than being in soil mass.

C2 37 to 46 inches, light yellowish-brown (2.5Y 6/3) loam; weak subangular blocky structure; friable; few very fine roots; many shale fragments and pebbles of granitic origin; few dolomitic pebbles; slight segregation of lime and iron; pebbles have coatings of limy material; few root channels partly filled with segregations of lime; calcareous.

C3 46 to 58 inches, light yellowish-brown (2.5Y 6/3) sandy loam; friable; few segregations of iron and lime, the latter occurring as streaks; numerous pebbles of mixed origin including fragments of shale; calcareous.

Climatic data (Winnebago, Minn.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	15	18	30	45	58	68	74	71	62	50	32	20	45
Mean precipitation, 1931-52 (inches)	0.8	0.8	1.6	2.0	3.8	4.8	3.2	3.8	3.2	1.5	1.5	1.0	27.9

Annual precipitation more than 18.8 and less than 37.0 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-2½	A11	2.2	5.0	6.9	22.4	12.8	27.8	22.9					4.58	15	1.0
2½-9	A12	2.9	5.4	6.5	21.2	13.7	27.2	23.1					2.38	12	1.0
9-15	A13	2.3	5.1	6.5	20.4	13.1	28.3	24.3					1.29	11	1.1
15-23	B21	2.8	5.0	6.1	19.3	13.9	29.5	23.4					.59	9	1.4
23-28	B22	2.6	4.7	6.6	21.3	14.6	30.8	19.4					.35	8	1.3
28-34	B23	3.4	6.0	7.1	21.9	14.6	30.1	16.9					.27		1.2
34-37	C1	5.9	5.9	7.0	22.2	14.5	29.9	14.6					.23		1.0
37-46	C2	4.5	6.0	6.9	19.3	15.2	34.1	14.0					.15		1.0
46-58	C3	4.8	6.0	6.6	19.3	15.7	33.4	14.2					.08		1.0

Cation exch. cap. s	Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	$CaCO_3$ equivalent % n
	Extractable cations, meq./100 gm.							
31.5	20.9	6.2	3.6	0.1	0.7	89	7.0	
24.6	15.5	4.9	3.9	.1	.2	84	6.8	
21.5	11.4	4.0	5.8	.1	.2	73	5.8	
19.9	11.1	4.0	4.4	.2	.2	78	5.9	
17.5	10.2	3.6	3.3	.2	.2	81	6.0	
15.5	9.4	3.0	2.8	.2	.1	82	6.2	
23.9	19.9	3.5	0	.3	.2	100	7.7	4.9
26.6	22.9	3.3	0	.3	.1	100	8.1	15.4
26.4	22.7	3.3	0	.3	.1	100	8.2	17.5

*Exchange acidity.

Profile No. 34

Area: Greenbrier County, West Virginia
Vegetation: Mixed stand of oak, hickory, yellow poplar, and cucumbertrees.
Parent material: Residuum from red siltstone, shale, and sandstone.
Topography: 25 percent slope; 2,400 feet elevation; dissected uplands.

- O1 — 3 to ½ inch, deciduous leaf litter.
- O2 — ½ to 0 inch, mixed, partly decomposed organic matter and mineral material.
- A1 — 0 to 2 inches, dark reddish-brown (5YR 3/3) silt loam; moderate, fine, granular structure; very friable; clear, wavy boundary.
- A2 — 2 to 7 inches, reddish-brown (5YR 5/3) silt loam; weak, fine, subangular and very weak, thin, platy structure; very friable; clear, wavy boundary.
- B2 — 7 to 13 inches, dark reddish-brown (5YR 3/4), heavy silt loam; moderate, fine and medium, subangular blocky structure; friable; discontinuous clay films on some peds, clear, wavy boundary.
- C — 13 to 23 inches, dark reddish-brown (5YR 3/4), heavy silt loam; massive to very weak, medium, subangular blocky structure; 75 percent by volume of channer-sized siltstone; clear, wavy boundary.
- R — 23 inches +, red siltstone.

Climatic data (Rainelle, W. Va.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	33	33	40	50	59	67	70	69	63	52	41	33	51
Mean precipitation, 1931-52 (inches)	4.4	4.0	5.1	4.1	4.7	5.1	5.1	5.1	3.3	2.7	3.5	4.0	50.9

Annual precipitation more than 40.7 and less than 61.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-2	A1	0.6	1.5	1.1	6.0	14.4	60.4	16.0	41.7	37.5	Tr		5.48	22	2.3
2-7	A2	.2	1.0	.9	4.8	12.8	62.1	18.2	39.2	39.3	Tr	1.41	1.13	16	2.6
7-13	B2	.1	.8	.7	3.2	7.6	64.4	23.2	30.7	43.5	Tr	1.72	.33	7	3.2
13-23	C	<.1	.5	.8	2.6	6.4	69.5	20.2	35.7	41.9	Tr	1.85	.14	4	4.0

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1	Base sat. % s	Cation exch. cap. s	Moisture tensions: 1/3 atmos. %	15 atmos. %
16.2	6.5	1.6	14.7	0.1	0.6	54	5.1	37	23.4	34.5	9.8
8.4	1.0	.6	9.5	<.1	.3	23	4.9	17	11.4	27.9	6.5
8.7	.7	1.0	9.7	<.1	.2	22	4.7	16	11.6	25.7	8.5
9.7	.7	1.4	10.0	<.1	.2	24	4.7	19	12.3	23.1	8.4

*Exchange acidity.

Chapter 6. Criteria of Classification in the Lower Categories

FAMILY AND SERIES

The criteria of classification proposed for use in the higher categories have been tested through a series of approximations. Those proposed here for the families have not been tested so thoroughly and are presented tentatively so that they may be tested. Genetic considerations have guided the classification in the higher categories, but plant growth and, to a lesser extent, soil mechanics have guided the classification in the lower categories. Soil genesis is not ignored in these lower categories but has a subordinate position.

Criteria for Families

The criteria proposed for differentiation of families within a subgroup are of two kinds. One applies to the solum below normal plow layer depth, or to arbitrary depths of 15 to 75 cm. (6 to 30 inches) if the sola are very thin or absent. Texture, mineralogy, and reaction are of this character. The other kind is applied to specific horizons or depths. An example is the defined characteristics associated with minor variations in wetness.

The criteria that can be proposed at this time are:

Texture: If texture is relevant, six broad classes according to particle-size distribution are proposed for use. In some orders or suborders, only one of these classes occurs; in other suborders all may occur. And in soils formed in recent volcanic ejecta, texture may have little or no relevance. These are the texture classes:

1. Fragmental soils: Stones, cobbles, gravel, and coarse sand.
2. Sandy soils: Sands other than coarse sand, and loamy sands.
3. Light loamy soils: Light sandy loams (less than 15 percent clay) other than light very fine sandy loam; and light loams (less than 15 percent clay).
4. Light silty soils: Silt; light silt loam (less than 15 percent clay); and light very fine sandy loam (less than 15 percent clay).
5. Heavy loamy soils: Heavy sandy loams, loams, and silt loams (all with more than 15 percent clay); sandy clay loam; clay loam and silty clay loam.
6. Fine-textured soils: Clay, silty clay, and sandy clay.

In classes 2 to 5 above, very gravelly subclasses may need recognition.

Mineralogy: Classes according to mineralogy are proposed for use where relevant. The mineralogy classes apply to the same depth limits as do the texture classes. The mineralogy classes are:

1. Quartzose: More than 65 percent quartz, chert, or other forms of SiO_2.
2. Carbonates and sulfates; more than 40 percent carbonates and sulfates. Carbonates alone to the extent of 40 percent may need to be distinguished from sulfates alone and from mixtures.
3. Layer lattice: More than 35 percent micas, silicate clays, and free oxides of iron and aluminum of clay size; less than 40 percent carbonates and sulfates. Subclasses according to kind of clay may be used as needed. Normally texture classes make the layer-lattice grouping unnecessary, but in some few cases the distinction is needed if carbonates are present in clay-size particles.
4. Mixed: Less than 65 percent quarts, 40 percent carbonates and sulfates, and 35 percent micas, silicate clays, and free oxides of clay size.

Some subclasses are sometimes needed in addition to the above. Among these two can be listed tentatively:

a. Phosphatic for phosphate-rich materials. In sands with more than 0.1 percent P, and in loamy and clayey soils with more than about 1 percent P.
b. Iron sulfates, commonly Jarosite (straw colored) if associated with a pH of 3.5 or less, or polysulfides with 0.75 percent sulfur or more in the absence of carbonates equivalent to the sulfur (for cat clays).

Reaction classes according to pH of the soil in water at 1:1: For precise measurements of pH, the soils of humid regions should be preleached to remove water soluble salts. pH classes are not used in jarositic soils (item b under mineralogy).

1. Acid, pH less than about 6.1.
2. Nearly neutral, pH between about 6.1 and 8.0.
3. Alkaline, pH higher than about 8.0.

The limits for reaction are approximate only, and apply to the average over the range of depths used for determining texture and mineralogy. A variation of one-half unit above or below the limits will undoubtedly have to be tolerated between adjacent pedons that are otherwise indistinguishable. Reaction classes are proposed for use only in Entisols.

Other criteria will be needed on occasions in particular classes. Among these are:

1. Bulk density and permeability need to be used singly or in combination in aquic soils, particularly Aquents, to distinguish the sea clays from river clays.

2. Characteristics associated with wetness, such as minor differences in depths to mottles of low chroma (2 or less) in Alfisols and Ultisols, chromas of more than 2 in the upper 50 centimeters of Aquents, or the presence or absence of an umbric epipedon in Humaquods.

3. Moisture equivalent, more or less than 2 percent in Quarzopsamments.

4. Consistence, both moist and dry, of Spodosols, to distinguish ortsteins and fragipans.

To this list we shall need to add others, for the criteria here will not provide reasonable families of Oxisols or Histosols.

Criteria for Soil Series

All differentiae used in higher categories are also differentiae between series. We may say that soil properties that can be seen, felt, measured, or inferred with reasonable accuracy may be used to define soil series. However, to be used, the properties should have relevance to soil genesis, to plant growth, or to engineering uses, or should be very obvious.

Satisfactory families are being approached but have not been generally developed for the soils of the United States. We therefore cannot make many specific statements at this time about the differentiae between series that are in the same family.

Chapter 7. Key to Orders and Suborders

A. Clayey mineral soils (more than 35 percent clay) having more than 30 milliequivalents exchange capacity per 100 grams of soil in all horizons below the surface 5 cm. (2 inches); having at some season, if not irrigated, cracks 1 to 25 cm. wide reaching at least to the middle of any solum present; and having one or more of the following: (1) Gilgai; (2) slickensides close enough to intersect; or (3) at some depth between 25 and 100 cm. (10 and 40 inches), wedge-shaped or parallelepiped natural structural aggregates with their long axis tilted 10 to 60 degrees from horizontal.

Order 2--Vertisol, p. 124

a. Vertisols having one or both of the following characteristics associated with periodic wetness, namely:

(1) Chromas less than 1.5 throughout the upper 30 cm. (12 inches).

(2) Distinct or prominent mottling within the surface 75 cm. (30 inches).

Suborder 2.1--Aquert, p. 124

b. Other Vertisols.

Suborder 2.2--Ustert, p. 128

B. Other mineral soils with a plaggen epipedon, or with no diagnostic horizon other than an ochric or anthropic epipedon, albic horizon, or agric horizon. May have a histic epipedon if the N value exceeds 0.5 in all layers between 20 and 50 cm. (8 and 12 inches). May have hardened plinthite. May have buried diagnostic horizons if the surface of the buried soil is buried to a depth of more than 50 cm. (20 inches), or to a depth between 30 and 50 cm. (12 and 20 inches) if the buried solum is less than twice the thickness of the overlying deposit.

Order 1--Entisol, p. 105

a. Entisols either saturated with water at some period of the year or artificially drained that have, at depths of less than 50 cm. (20 inches), characteristics associated with wetness, namely, one or more of the following:

(1) A histic epipedon if the N value exceed 0.5 in all horizons between 20 and 50 cm. (8 and 20 inches).

(2) Sodium saturation of more than 15 percent in the surface material and decreasing saturation with depth below 50 cm. (20 inches).

(3) Colors as follows:

(a) if hues are as red or redder than 10YR and there is mottling, chromas of 2 or less; or if there is no mottling, chromas of less than 1.

(b) If hues are between 10YR and 10Y and if there is distinct or prominent mottling, chromas of 3 or less; or if there is no mottling, chromas of 1 or less.

(c) Hues bluer than 10Y.

(d) Any color if due to uncoated grains of sand.

Suborder 1.1--Aquent, p. 105

b. Other Entisols that are usually moist and have coarse texture to a depth of 50 cm. (20 inches) or more. ("Coarse texture" includes all sands and all loamy sands except loamy very fine sand.)

Suborder 1.2--Psamment, p. 108

c. Other Entisols that, unless irrigated, are usually dry when not frozen.

Suborder 1.3--Ustent, p. 111

d. Other Entisols.

Suborder 1.4--Udent, p. 113

C. Other mineral soils, usually moist, that do not have spodic, argillic, and oxic horizons or mollic epipedons but do have conductivity of the saturation extract less than 1 millimho per cm. at 25°C. and one or more of the following diagnostic horizons:

Histic epipedon
Umbric epipedon
Cambic horizon
Fragipan
Duripan

Or, having a mollic epipedon if the clay fraction is dominated by allophane, or the silt and sand fraction is dominantly volcanic ash or pumice.

Order 3 - Inceptisol, p. 136

a. Inceptisols either saturated with water at some period of the year or artificially drained that have, at depths of less than 50 cm. (20 inches), characteristics associated with wetness, namely, one or more of the following:

(1) A histic epipedon.

(2) Sodium saturation of more than 15 percent in the surface material, and decreasing saturation with increasing depth below 50 cm. (20 inches).

(3) Colors, as follows, on ped faces if peds are present, or dominant in matrix:

(a) If hues are as red or redder than 10YR and there is mottling, chromas of 2 or less; and if there is no mottling, chromas less than 1.

(b) If hues are between 10YR and 10Y and there is distinct or prominent mottling, chromas of 3 or less; and if there is no mottling, chromas of 1 or less.

(c) Hues bluer than 10Y.

(d) Any color if due to uncoated grains of sand.

Suborder 3.1--Aquept, p. 136

b. Other Inceptisols in which more than 60 percent of the clay fraction of any ochric, umbric, or mollic epipedon or any cambic horizon consists of allophane, or in which the silt and sand fraction have more than 60 percent of volcanic ash or pumice.

Suborder 3.2--Andept, p. 139

c. Other Inceptisols with an anthropic epipedon, or with an umbric epipedon that is either 25 cm. or more thick or that has a mean annual temperature less than 8.3°C. (47°F.) and mean summer temperature less than 10°C. (50°F.) if underlying an O horizon.

Suborder 3.3--Umbrept, p. 141

d. Other Inceptisols.

Suborder 3.4--Ochrept, p. 143

D. Other mineral soils having an ochric epipedon and one of the following combinations of properties:

a. Unless irrigated, usually dry in and below the zone of rooting when not frozen, and with one or more of the following: cambic, argillic, calcic, gypsic, or salic horizons or duripans that are softened by a single treatment with acid followed by a single treatment with concentrated alkali; and, unless either an argillic horizon or a calcic horizon immediately underlies a calcareous epipedon, having, at some depth, a conductivity of the saturation extract greater than 1 millimho per cm. at 25 C.

b. Usually moist and lacking an argillic or spodic horizon, but having, a calcic, gypsic, or salic horizon or a duripan and having at some depth, a conductivity of the saturation extract greater than 1 millimho per cm. at 25 C.

Order 4--Aridisol, p. 156

c. Aridisols without argillic or natric horizon.

Suborder 4.1--Orthid, p. 156

d. Other Aridisols.

Suborder 4.2--Argid, p. 158

E. Other mineral soils having a spodic horizon.

Order 6--Spodosol, p. 192

a. Spodosols either saturated with water at some season or artificially drained that have characteristics associated with wetness, namely, one or more of the following:

(1) A histic epipedon.

(2) Mottling in an albic horizon or in the top of the spodic horizon, or a duripan in the albic horizon.

(3) If free iron and manganese are lacking in the upper part of the spodic horizon, no coatings of iron oxides on the individual grains of silt and sand in the materials immediately below the spodic horizon, or there are mottles in materials immediately below the spodic horizon.

Suborder 6.1--Aquod, p. 192

b. Other Spodosols having a spodic horizon enriched chiefly with humus or aluminum in at least the upper part (7.5 cm. or more) of the spodic horizon; and this part containing humus mainly in dispersed forms--coatings and pore fillings rather than rounded or subangular silt-sized pellets of humus or humus and iron.

Suborder 6.2--Humod, p. 196

c. Other Spodosols with spodic horizons having rounded to subangular silt-sized pellets of humus or of humus and iron.

Suborder 6.3--Orthod, p. 196

d. Other Spodosols.

Suborder 6.4--Ferrod, p. 199

F. Other mineral soils having an oxic horizon or having, within 30 cm. of the surface, plinthite that forms a continuous phase and that has not hardened.

Order 9--Oxisol, p. 238

(The suborders of the Oxisol order are discussed on pp. 238.)

G. Other mineral soils having an argillic horizon in which the base saturation is less than 35 percent (capacity determined by sum of bases plus exchange acidity); or, within the argillic horizon or the C, a base saturation that decreases with depth; or, if base saturation increases with depth within or immediately below the argillic horizon, no tonguing of an albic horizon into the argillic horizon.

Order 8--Ultisol, p. 226

a. Ultisols either saturated with water at some season or artificially drained that have characteristics associated with wetness, namely: mottles, iron-manganese concretions, or moist chromas of 2 or less immediately below any Ap or A1 horizon that has moist values of less than 3.5 when rubbed, and one of the following:

(1) If hues are as red or redder than 10YR and there is mottling, a dominant chroma of 1 or 2 on surfaces of the peds or in the matrix of the argillic horizon.

(2) If hues are yellower than 10YR and there is mottling, a dominant chroma of 1 to 3 on the surfaces of peds or in the matrix of the argillic horizon.

(3) Chromas of 1 or less on surfaces of peds or in the matrix of the argillic horizon.

Suborder 8.1--Aquult, p. 226

b. Other Ultisols with an ochric epipedon, and soils with an argillic horizon that has chroma of 6 or less, a moist value of less than 4 throughout, and a dry value that is no more than 1 unit higher than the moist value.

Suborder 8.2--Ochrult, p. 227

c. Other Ultisols.

Suborder 8.3--Umbrult, p. 230

H. Other mineral soils having a mollic epipedon.

Order 5--Mollisol, p. 168

a. Mollisols without argillic or calcic horizons but having material that contains more than 40 percent calcium carbonate immediately below the mollic epipedon; having a mollic epipedon not more than

30 cm. (12 inches) thick if the gravel content is less than 20 percent; and having a mollic epipedon not more than 50 cm. (20 inches) thick if gravel content exceeds 40 percent. Intermediate gravel content permits intermediate thickness.

Suborder 5.1—Rendoll, p. 168

b. Other Mollisols having an albic horizon immediately underlying the mollic epipedon; having an argillic horizon; and having characteristics associated with wetness in the albic and argillic horizons, namely: mottles, iron-manganese concretions, or both.

Suborder 5.2--Alboll, p. 168

c. Other Mollisols, either saturated with water at some period during the year or artificially drained, that have one or more of the following characteristics associated with wetness:

(1) A histic epipedon.

(2) Sodium saturation of more than 15 percent in the upper part of the mollic epipedon, and below 50 cm. (20 inches), decreasing saturation with increasing depth.

(3) Colors, as follows, immediately below the mollic epipedon:

(a) If hues are as red or redder than 10YR and there is mottling, chromas of 2 or less on surfaces of peds, or in the matrix if peds are absent; and if there is no mottling, chromas of less than 1.

(b) If hues are between 10YR and 10Y and there is distinct or prominent mottling, chromas of 3 or less on surfaces of peds, if peds are present, or in matrix if peds are absent; and if there is no mottling, chromas of 1 or less.

Suborder 5.3--Aquoll, p. 169

d. Other Mollisols having in the solum a mean annual temperature of 8.3° C. (47° F.) or less and having in the mollic epipedon, to depths of 15 cm. (6 inches) or more, a moist chroma of 1.5 or less.

Suborder 5.4--Altoll, p. 172

e. Other Mollisols having one of the following combinations of characteristics:

(1) An argillic or cambic horizon and either--

(a) In cambic or argillic horizon, a base saturation of less than 80 percent as determined by NH_4OAc; or:

(b) In cambic or argillic horizon, a base saturation of more than 80 percent, provided the conductivity of the saturation extract at 25° C. is less than 1 millimho per cm. down to whichever of these depths is least—to bedrock or down to the depth where the total water-holding capacity at 1/3 bar tension equals 12 inches of water; and with increase in depth below the cambic or argillic horizon, either no increase in saturation with Na+ and K+, or exchange acidity in excess of Na+ and K+.

(2) Without cambic or argillic horizons, but with either:

(a) Base saturation of less than 80 percent in mollic epipedon and in at least a part of next underlying horizon; or

(b) Base saturation of more than 80 percent in the mollic epipedon or in all parts of the next underlying horizon; and the conductivity of the saturation extract at 25° C. is less than 1 millimho per cm. down to whichever of these depths is least--down to bedrock or down to the depth where the total water-holding capacity measured at 1/3 atmosphere tension equals 12 inches; and with increase in depth in the C, either there is no increase of saturation with Na+ and K+, or there is exchange acidity in excess of Na+ and K+.

Suborder 5.5--Udoll, p. 174

f. Other Mollisols.

Suborder 5.6--Ustoll, p. 177

I. Other mineral soils with argillic horizons having (1) a base saturation (capacity determined by sum of bases plus exchange acidity) that is more than 35 percent in the argillic horizon and increases or remains constant with depth below the argillic horizon, or (2) that have a base saturation either more or less than 35 percent if an albic horizon tongues into the argillic horizon from the top and if, in or below the argillic horizon, base saturation increases with depth.

Order 7--Alfisol, p. 202

a. Alfisols either saturated with water at some season or artificially drained and having characteristics associated with wetness, namely: mottles, iron-manganese concretions, or chromas of 2 or less immediately below any Ap, or below any dark A1 that has moist values of less than 3.5 when rubbed, and one of these:

(1) If hues are as red or redder than 10YR and there is mottling, dominant chromas of 1 to 2 on surfaces of peds or in matrix of the argillic horizon.

(2) If hues are yellower than 10YR and there is mottling, dominant chromas of 1 to 3 in the matrix or on the surfaces of peds in the argillic horizon; or

(3) Chromas of 1 or less on surfaces of peds or in the matrix of the argillic horizon.

Suborder 7.1--Aqualf, p. 202

b. Other Alfisols with a mean annual temperature in the solum of 8.3° C. (47° F.) or less.

Suborder 7.2—Altalf, p. 204

c. Other Alfisols, usually or always moist in some part of the solum, but in parts of their solum seasonally dry for a period not to exceed 3 months, and in any horizon or layer, lacking a saturation-extract conductivity of as much as 1 millimho per cm. at 25° C.

Suborder 7.3--Udalf, p. 206

d. Other Alfisols.

Suborder 7.4--Ustalf, p. 209

J. Organic soils.

Order 10--Histosol, p. 247

Chapter 8. Entisols

The Entisols are those soils, exclusive of Vertisols, that have a plaggen horizon or that have no diagnostic horizon other than an ochric or anthropic epipedon, an albic horizon, an agric horizon, or, if the N value exceeds 0.5 in all horizons between 20 and 50 cm. (8 and 20 inches), a histic epipedon. Entisols may have hardened plinthite or buried diagnostic horizons if the surface of the buried soil is buried to a depth of more than 50 cm. (20 inches) or, if the buried solum is less than twice the thickness of the overlying deposit, to a depth between 30 and 50 cm. (12 and 20 inches).

Thus, the Entisols are soils either without natural genetic horizons or with only the beginnings of horizons. The horizons present are so weakly expressed that they fail to meet the requirements of any of the diagnostic horizons, except the albic horizon and those that are produced through cultivation by man. Hardened plinthite is permitted on the assumption that, with the hardening, a new cycle of soil formation is started with the plinthite as parent material.

At one extreme in age, an Entisol might consist of very recent alluvium, in place for only a few days or months. Such a soil might have an Ap horizon. It might also be mottled with gray and brown colors, for some mottles can develop in alluvium before the floodwaters that laid down the deposit have receded.

At the other extreme in age, the Entisols may include quartz sands that have been in place for many thousands of years. Unless conditions are favorable for the formation of Humaquods or Humods (Humus Podzols), no diagnostic horizons are apt to develop in quartz sand.

The Entisols thus include many but not all of the soils previously called Alluvial soils, Regosols, Lithosols, Tundra soils, and Low-Humic-Gley soils in the United States. They also include many of the plaggenboden and "man-made" soils of western Europe. The plaggen horizon is considered comparable to a deposit of fresh alluvium for classification at the Order level.

The central concept of Entisols includes soils in deep regolith or earth with no horizons except perhaps a plow layer. The soil may be of any color common to soil, from the bluish-gray colors of tidal marshes through the blacks and grays, and the yellows, browns, and reds. Color is not of significance.

There are many deviations possible from this central concept. Hard rock may be present at shallow depths. An ochric epipedon may be present with colors and thicknesses just short of the limits of the mollic or umbric epipedons. Soils of any Order may be buried 50 cm. (20 inches) below the surface, or even as little as 30 cm. (12 inches) if the buried solum is very thin.

Man may have formed a plaggen horizon or an anthropic epipedon. Even an agric horizon may be present.

Some Entisols, particularly the sandy ones (sands and loamy sands) may have thick albic horizons (bleached A2 horizons) lying on B horizons that contrast strongly in color but that show little contrast in any other respect.

In arid lands, the Entisols may show small secondary accumulations of carbonates, sulfates, or more soluble salts, but not enough to constitute calcic, gypsic, or salic horizons. In the strongly alkaline soils, there may even be cementation of portions of horizons into hard nodules, but not into a massive or platy duripan. Other Entisols may be found in the Arctic, with permafrost, or in the humid Tropics.

In marshes and swamps that have soils with N values above 0.5, with very low bearing capacities, a histic epipedon (a thin layer of peat or muck) may be present.

Clayey soils that lack distinct horizons are excluded from Entisols if they develop wide cracks at some season and have gilgai microrelief, slickensides close enough together to intersect within each pedon, or parallelepiped or wedge-shaped peds that have their long axes tilted from the horizontal by 10 to 60 degrees.

Other soils that to some soil scientists lack horizons are excluded if they have a horizon meeting the requirements of an oxic horizon. It perhaps needs emphasis that the weathering that has destroyed the weatherable minerals in an oxic horizon need not have occurred in the place where the soil is now found. It may have occurred in another place prior to the movement of the weathered materials to their present position. Chemically and mineralogically, the materials in an oxic horizon may be indistinguishable from materials at comparable depths in Entisols. When first deposited, strongly weathered earth could be classified with the Entisols. Only when the soil has been in place long enough to have lost the original fine stratification of the sediment, and to develop visible pores and possibly weak structure, can it be classified with the Oxisols.

Four suborders of Entisols are recognized: the Aquents, Psamments, Ustents, and Udents. The keys, definitions, and descriptions of these suborders, their great groups, and their subgroups follow.

AQUENTS (1.1)

The Aquents are Entisols that are saturated with water at some season, or that have been artificially drained. They have, in addition, one or more of the following properties at depths of less than 50 cm. (20 inches):

1. A histic epipedon if the N value exceeds 0.5 in all horizons between 20 and 50 cm. (8 and 20 inches).
2. Sodium saturation of more than 15 percent in the surface, and decreasing saturation with depth below 50 cm. (20 inches).
3. Colors as follows:
   a. In hues as red or redder than 10YR, chromas of 2 or less if mottled, and less than 1 if not mottled.
   b. In hues between 10YR and 10Y, chromas of 3 or less if with distinct or prominent mottles, and 1 or less if lacking mottles.
   c. Hues bluer than 10Y.
   d. Any color that may be due to uncoated sand grains.

Aquents are Entisols found in naturally wet places such as permanent or temporary swamps and marshes.

Man may have produced some by flooding other Entisols to grow rice. The Aquents include some of the wettest Alluvial soils, some Low-Humic Gley soils, and some, if not most, Tundra soils.

The common characteristics are the lack of horizons that define the Entisols, and the superimposed effects of wetness. These include gleying, the accumulations of replaceable sodium near the surface, and a histic epipedon if associated with high N values. Absence of iron-oxide coatings or concentration of free oxides into mottles are the normal, common features.

The Aquents may be found in almost any climate from the tundra to the desert or to the humid tropics. Outside of the tundra region, where the Aquents may occupy much of the landscape, they are largely restricted to tidal marshes and swamps, low lying portions of flood plains, and a few desert playas that receive seasonal runoff low in salt. Naturally wet soils that do not receive regular deposits of new sediments will rarely be Aquents.

Key to Aquents

1.11 Aquents with mean annual temperature less than 8.3° C. (47° F.) and with mean summer temperature less than 15.5° C. (60° F.) if with an Ap, and less than 10° C. (50° F.) if with an O horizon. (Note that these temperature limits are tentative.

Cryaquent, p. 107

1.110 Aquents with permafrost at depths of less than 75 cm. (30 inches); and either with an Al thinner than 2.5 cm. (1 inch) if its moist value is less than 3.5 and the chroma below the Al is 1 or less, or with an Al or surface layer having a color value of 3.5 or more and a color-value contrast of less than 2 with the underlying layer or horizon when chromas of the underlying layers are 1 to 3 in hues yellower than 10YR, and 1 to 2 in hues of 10YR or redder; and lacking organic soil within any pedon.

Orthic Cyraquent, p. 107

1.11-1.14 Other Cryaquents with colors as above but lacking permafrost within 75 cm. (30 inches).

Haplic Cryaquent, p. 107

1.11-3.14 Other Cryaquents with permafrost within 75 cm. (30 inches) but having an Al that is thicker or an Al or Ap that is thicker and darker than 1.110.

Cryaqueptic Cryaquent, p. 107

1.11-3.12 Other Cryaquents lacking permafrost within 75 cm. (30 inches) and having an Al that is thicker, or an Al or Ap that is thicker and darker than 1.110.

Umbraqueptic Cryaquent, p. 107

1.12 Other Aquents with sandy textures to a depth of at least 50 cm. (20 inches). (Sandy textures include all sands and all loamy sands except loamy very fine sand.)

Psammaquent, p. 107

1.120 Psammaquents with sandy textures to a depth of at least 75 cm. (30 inches); and with chromas of 2 or less in 80 percent of the mass below any Al to a depth of 75 cm. (30 inches) or more. (Reddish quartz is an exception. It may have the chroma of the quartz, but less than 20 percent of the matrix should be mottled with chromas stronger than those of the quartz.)

Orthic Psammaquent, p. 107

1.12-1.14 Other Psammaquents with textures finer than loamy fine sand within a depth of 75 cm. (30 inches) and colors as in 1.120.

Haplic Psammaquent, p. 107

1.12-1.2 Other Psammaquents with colors other than those of 1.120 and with sandy textures to a depth of 75 cm. (30 inches) or more.

Psammic Psammaquent, p. 107

1.12-1.4 Other Psammaquents with textures finer than loamy fine sand within a depth of 75 cm. (30 inches) and colors other than those of 1.120.

Udic Psammaquent, p. 108

1.13 Other Aquents with N value of more than 0.5 in layers between 20 and 50 cm. (8 and 20 inches) and with at least 8 percent clay and at least 3 percent organic matter.

Hydraquent, p. 108

1.130 Undefined at present.

1.14 Other Aquents.

Haplaquent, p. 108

1.140 Haplaquents having the following properties:
(1) Colors below any Al to a depth of 75 cm. (30 inches) as follows; chromas of less than 1, or hues bluer than 5Y, or chroma of 2 or less in 80 percent of the mass if mottles are present.
(2) No horizon as much as 30 cm. (12 inches) thick that lies immediately below an Al or Ap and that has a chroma of 1 or more, or hues redder than 5Y, but that lacks mottles.
(3) An N value less than 0.9 between 50 and 80 cm. (20 and 32 inches) and less than 0.5 in all layers between 20 and 50 cm. (12 and 20 inches).

Orthic Haplaquent, p. 108

1.14-1.13 Other Haplaquents with N values higher than those of 1.110.

Hydric Haplaquent, p. 108

1.14-1.4 Other Haplaquents with more than 20 percent of volume in mottles with high chromas, or with matrix chromas higher than 2 at depths of less than 75 cm. (30 inches).

Udic Haplaquent, p. 108

1.14-6 Other Haplaquents with a horizon that has chromas of 1 or more in hues redder than 5Y, that has no mottles, that is 30 cm. (12 inches) or more thick, and that lies immediately below an A1 or an Ap.

Spodic Haplaquent, p. 108

Cryaquents (1.11)

Cryaquents are the cold Aquents. They have mean annual temperatures less than 8.3° C. (47° F.) and mean summer temperatures below 15.5° C. (60° F.) if they lack an O horizon, or below 10° C. (50° F.) if an O horizon is present. The summer temperature limits are very tentative. They differ according to the presence or absence of an O horizon, because this horizon affects the mean summer temperature. Cultivated soils will lack an O horizon, and their temperatures will follow air temperatures more closely than will soils that are insulated with an O horizon. Since it is a principle of this classification to keep arable soils in the same classes with their virgin counterparts when first plowed, it became essential to have different temperature limits.

Cryaquents are rarely cultivated. Generally they are found under tundra, though some have boreal forests. In the tundra particularly, there commonly are polygons formed by frost, and profiles vary with the position in the polygon. Churning of the materials by the frost is common, and streaks of A1 or 0 may be seen at any depth above the permafrost. The Cryaquents have previously been called Tundra soils for the most part.

The central concept of the Cryaquents is that of the Orthic Cryaquent. The other subgroups represent permissible variations within the Cryaquents.

Orthic Cryaquents (1.110)

The Orthic Cryaquents are Cryaquents with permafrost at depths of less than 75 cm. (30 inches) and with only thin, dark A1 horizons and dominantly gray colors. If the moist color value of the A1 is less than 3.5, and the chroma of the underlying horizon is 1 or less, the A1 must be thinner than 2.5 cm. (1 inch). If the moist color value of the A1 or the surface horizon is 3.5 or more, the color value of the next underlying horizon or layer should be less than 2 units lighter. The dominant chroma below the A1 must be 3 or less in hues yellower than 10YR, and 2 or less in hues as red or redder than 10YR. The base saturation, texture, and mineralogy are not significant to the classification at the subgroup level. Profile 35, page 117, illustrates an Orthic Cryaquent.

These soils normally have polygonal forms, and bits of raw humus may be found at any depth down to the permafrost. Where polygons are small, less than 25 feet, and where organic soils are present as a part of each polygon, ruptic intergrades to Histosols replace the Orthic Cryaquents.

Haplic Cryaquents (1.11-1.14)

The Haplic Cryaquents are comparable to the Orthic Cryaquents in all respects save the depth to permafrost. The Haplic Cryaquents either have no permafrost, or have the permafrost at depths greater than 75 cm. (30 inches). Profile 36, page 118, is an example of a Haplic Cryaquent.

Cryaqueptic Cryaquent (1.11-3.14)

The Cryaqueptic Cryaquents are comparable to the Orthic Cryaquents in chromas, and in having permafrost at depths of 75 cm. (30 inches) or less. They differ in having a thicker dark A1 that approaches an umbric epipedon, or an A1 or surface horizon that meets the thickness requirements of an umbric epipedon though it is not quite dark enough to be an umbric epipedon, and that is 2 or more units darker than the next underlying horizon.

Umbraqueptic Cryaquents (1.11-3.12)

The Umbraqueptic Cryaquents are comparable to the Cryaqueptic Cryaquents in color values, and to the Orthic Cyraquents in chromas. They differ from both however in having no permafrost or in having it at depths greater than 75 cm. (30 inches).

Psammaquents (1.12)

The Psammaquents, as the name implies, are the sandy Aquents. They include the Aquents that have sandy textures, including the loamy fine sands and coarser textures, to depths of 50 cm. (20 inches) or more. Most commonly, the soil colors are white, with faint or distinct mottles that appear to be largely organic. A1 horizons may be present that have colors and thicknesses up to the limits of the mollic or umbric epipedons. Faint B horizons are permitted if they are so weakly developed that they do not meet the requirements of spodic, argillic, or oxic horizons. And, buried soils may occur at depths greater than 50 cm. (20 inches), or between 30 and 50 cm. (12 and 20 inches) if the solum of the buried soil is less than twice the thickness of the sandy overburden.

The central concept of the Psammaquents is reflected by the Orthic Psammaquents. Variations from this concept are reflected by the other subgroups.

Orthic Psammaquents (1.120)

These are the Psammaquents that have chromas of 2 or less in 80 percent of the mass throughout the subsurface horizons to a depth of 75 cm. (30 inches) or more. Also included are a few soils with colored quartz, usually red. These soils may have the chromas of the quartz but have less than 20 percent of the matrix mottled with chromas higher than the chromas of the quartz.

Sandy textures extend to depths of 75 cm. (30 inches) or more in these soils, and only an ochric epipedon may be present.

Haplic Psammaquents (1.12-1.14)

These soils have the same colors as the Orthic Psammaquents but have textures finer than loamy fine sand at some depth less than 75 cm. (30 inches).

Psammic Psammaquents (1.12-1.2)

These soils have the same textures as the Orthic Psammaquents, but differ in color. Either the chromas of 2 or less cover less than 80 percent of the mass to a depth of 75 cm. (30 inches), or there are higher chromas than 2 in most of the matrix in some of the horizons or layers that lie within the upper 50 cm. (20 inches). From a genetic viewpoint, the ground water is deeper in these soils, or persists for shorter effective periods. The name of this class follows the rules suggested for nomenclature, but seems to need revision.

Udic Psammaquents (1.12-1.4)

These soils include those Psammaquents that have textures finer than loamy fine sand within a depth of 75 cm. (30 inches) and that have colors other than those of the Orthic Psammaquents. Either chromas of more than 2 occupy more than 20 percent of the mass to a depth of 75 cm. (30 inches) or chromas of more than 2 cover most of the matrix in some of the horizons or layers that lie within the upper 50 cm. (20 inches).

Hydraquents (1.13)

The Hydraquents are those Aquents that have very high water content and low bearing capacities. They are most commonly found in tidal marshes and swamps, or under shallow water--fresh, brackish, or salty. Typically, colors are either neutral or the hues are bluer than 10Y. Ferrous iron is nearly always present, and on exposure these soils change color. Sulfides are common in areas with brackish water. It is in this class that many of the undrained cat clays belong.

The Hydraquents are those Aquents with N values above 0.5 in all layers between 20 and 50 cm. (8 and 20 inches) and that contain at least 8 percent clay and at least 1.74 percent organic carbon (3 percent organic matter). The subgroups are as yet undefined.

Profile 37, page 119, is an example of a soil that should be considered an Orthic Hydraquent. The N values are well in excess of 0.5 in all horizons. This soil contains some salt and considerable sulfur as sulfides, for the pH drops appreciably on drying. The salt and sulfides are not essential to the definition of the orthic subgroup.

Haplaquents (1.14)

The Haplaquents are those Aquents that have textures finer than loamy very fine sand within some part or all of the upper 50 cm. (20 inches); that have mean annual temperatures greater than 8.3° C. (47° F.), or if with an Ap, that have mean summer temperatures greater than 15.5° C. (60° F.), and if with an 0 horizon, have a mean summer temperature greater than 10° C. (50° F.); and that have N values of 0.5 or less in some or all layers between 20 and 50 cm. (8 and 20 inches).

The Haplaquents are normally restricted to areas subject to occasional or frequent flooding with muddy water. Typically they are found in the low parts of large or fairly large flood plains, or in closed depressions in till plains or karst areas.

The central concept of the Haplaquents is reflected in the orthic subgroup. Other subgroups reflect permissible variations from the central concept.

Orthic Haplaquents (1.140)

The Orthic Haplaquents are those Haplaquents that (1) have in all horizons to a depth of 75 cm. (30 inches), chromas of 1 or less or hues bluer than 5Y, if unmottled; if mottled, they have chromas of 2 or less in 80 percent or more of the matrix; (2) have in the first 30 cm. (12 inches) below any A1-Ap mottles, or chromas of less than 1, or hues bluer than 5Y; and (3) have an N factor of less than 0.5 in all horizons between 20 and 50 cm. (8 and 20 inches) and an N factor less than 0.9 between 50 and 80 cm. (20 and 32 inches).

Profile 38, page 120, illustrates the Orthic Haplaquent. Data on the N factor for this profile are not available, but the consistence is such that the N factors must be less than 0.5 throughout.

Hydric Haplaquents (1.14-1.13)

These soils differ from the Orthic Haplaquents in having either an N factor of less than 0.5 in some horizon between 20 and 50 cm. (8 and 20 inches) or an N factor of more than 0.9 at some depth between 50 and 80 cm. (20 and 32 inches).

Commonly these soils represent Hydraquents that have been partially drained, either naturally or by man. Like the Hydraquents, they are found largely in tidal marshes or swamps, or in areas that have been diked.

Udic Haplaquents (1.14-1.4)

These soils differ in color from the Orthic Haplaquents. They either have more than 20 percent of the matrix mottled with high chromas (3 or more) or have some horizon shallower than 75 cm. (30 inches) that has chromas higher than 2 throughout the matrix. This subgroup therefore shows either less pronounced or deeper gleying than the Orthic subgroup.

Spodic Haplaquents (1.14-6)

These soils differ from the Orthic subgroup in having a horizon immediately below the A1 or Ap that has a chroma of 1 to 2 but that has no mottles. They have, therefore, an albic horizon, and may have a weak B horizon, too thin or too weakly developed to constitute a spodic horizon.

PSAMMENTS (1.2)

The Psamments are those Entisols that are usually moist in some horizon or layer and that have textures coarser than loamy very fine sand to depths of 50 cm. (20 inches) or more; that either are not saturated with water at any season and lack artificial drainage, or that, because of coatings of clay and iron oxides on the sand grains, have chromas, to depths of at least 50 cm., of more than 2 in hues of 10YR or redder, or of more than 3 in hues yellower than 10YR.

The Psamments include many of the soils formerly called Dry sands, that were later combined with Regosols, and the very sandy Alluvial soils. Psamments may therefore be found in subhumid to humid climates. They include the sands that have been in place too short a time to develop diagnostic horizons other than an albic horizon, as well as the sands so rich in quartz and other unweatherable minerals that no diagnostic horizons other than an albic horizon can be developed. They range in properties from the calcareous sands on natural levees or recent dunes to the quartz sands commonly found on perhumid coastal plains. The common characteristics are the normal presence in some horizon or layer of moisture held at tensions of less than 1/10 bar, coarse textures, lack of diagnostic horizons other than an albic horizon, and the presence of coatings on the sand that produce chromas of more than 2 or 3, depending on the hue.

Thin lamellae--too thin, too few, or with too little humus, iron or clay to constitute spodic or argillic horizons--are often present.

Key to Psamments

1.21 Psamments with more than 95 percent quartz, zircon, tourmaline, rutile or other normally insoluble minerals that do not weather to liberate iron or aluminum.

Quarzopsamment, p. 109

1.210 Quarzopsamments with no mottles that have chromas of 2 or less to a depth of 1 meter (40 inches); without colors definitive for Orthic Psammaquents between 50 and 100 cm. (20 and 40 inches); with coarse textures to 75 cm. (30 inches) or more; and with no albic or other horizon that is at the surface or immediately underlying an A1 or Ap and that is underlain by another horizon having values more than 1 unit darker or having chromas of 6 or more.

Orthic Quarzopsamment, p. 110

1.21-1.1 Other Quarzopsamments with colors of the upper 50 cm. (20 inches) as in orthic subgroup, and with coarse textures to 75 cm. (30 inches) or more, but with mottles that have chromas of 2 or less within 1 meter (40 inches) of the soil surface or with colors of Orthic Psammaquents between depths of 50 and 100 cm. (20 and 40 inches).

Aquic Quarzopsamment, p. 110

1.21-1.14 Other Quarzopsamments that have textures finer than loamy fine sand within 30 inches (75 cm.); that have mottles with chromas of 2 or less within 1 meter (40 inches); and that have no albic or other horizon that is at the surface or immediately underlying an A1 or Ap, and that is underlain by a horizon having values more than 1 unit darker or having chromas of 6 or more.

Haplaquentic Quarzopsamment, p. 110

1.21-6 Other Quarzopsamments having an albic horizon underlain by a horizon that is more than 1 unit darker in value when moist.

Spodic Quarzopsamment, p. 110

1.21-8 Other Quarzopsamments with chromas and values increasing with depth and with moist chromas reaching 6 or more, and moist values reaching 5 or more within 1 meter (40 inches), with base saturation of less than 35 percent or base saturation that decreases with depth below 1 meter (40 inches); with some 2:1 lattice clays.

Ultic Quarzopsamment, p. 110

1.21-9 Other Quarzopsamments with a horizon having all properties of an oxic horizon except the percentage of clay.

Oxic Quarzopsamment, p. 111

1.22 Other Psamments

Orthopsamment, p. 111

1.220 Orthopsamments having no mottles that have chromas of 2 or less to a depth of 1 meter (40 inches); with coarse textures (loamy fine sand or coarser) to a depth of 75 cm. (30 inches); with no albic horizon that is underlain by a horizon having color values 1 unit or more darker; with no lamellae that have more clay and free iron than the overlying horizon.

Orthic Orthopsamment, p. 111

1.22-1.1 Other Orthopsamments that have chromas of 2 or less within 1 meter (40 inches); with no albic horizon that is underlain by a horizon having color values 1 unit or more darker; and with coarse textures to a depth of 75 cm. (30 inches) or more.

Aquic Orthopsamment, p. 111

1.22-1.4 Other Orthopsamments with textures finer than loamy fine sand within 75 cm. (30 inches); with no mottles having chromas of 2 or less within 1 meter (40 inches), and with no albic or other horizon underlain by a horizon that has color values 1 unit or more darker.

Udic Orthopsamment, p. 111

1.22-6 Other Orthopsamments with an albic horizon underlain by a horizon that has color values more than 1 unit darker.

Spodic Orthopsamment, p. 111

1.22-7 Other Orthopsamments with lamellae that have redder hues or stronger chromas, with more clay and free iron than the overlying horizon, and with base saturation of more than 35 percent in the horizons containing the lamellae.

Alfic Orthopsamment, p. 111

Quarzopsamments (1.21)

The Quarzopsamments are those Psamments so rich in quartz and other essentially unweatherable minerals that few of the diagnostic subsurface horizons can be formed. If primary minerals cannot be altered to silicate clays, formation of argillic and cambic horizons may be impossible. Spodic horizons, particularly of illuvial humus, are possible in such materials, but climate and vegetation may be unfavorable. In humid climates the quartz-rich soils may therefore remain in place for long periods without developing the horizons that would be expected in materials of more mixed mineralogy. The influence of time in horizon development is apt to be very different in soils from quartz-rich parent material than it is in soils from most other parent materials.

The Quarzopsamments are intended to include those soils that lack horizons largely because of an extreme kind of parent material. They include the soils that have coarse textures--loamy fine sand or coarser--to a depth of 50 cm. (20 inches) or more; that lack diagnostic horizons other than an ochric epipedon, an albic horizon, or both; that have 95 percent or more of quartz, zircon, tourmaline, rutile, or other minerals that do not normally weather to liberate iron or aluminum; and that are usually moist, that is, have moisture held in some horizon at tensions of less than 15 bars for more than half of the time that they are not frozen. The orthic subgroup represents the central concept, and the other subgroups represent the permissible variations within the Quarzopsamments.

Orthic Quarzopsamments (1.210)

The orthic subgroup includes those Quarzopsamments that have textures coarser than loamy very fine sand to depths of more than 75 cm. (30 inches); that to a depth of 1 meter (40 inches) or more, are free of mottles having chromas of 2 or less; that have chromas of more than 1 between 50 and 100 cm. (20 and 40 inches), or that lack groundwater within this depth and have no artificial drainage; that have no albic or other horizon at the surface or immediately underlying an A1 or Ap and underlain, in turn by, another horizon that has values more than 1 unit darker than the values of the albic horizon, or underlain by a horizon with chromas of 6 or more; that in some horizon within the soil or within 3 meters (10 feet), contain at all times moisture held at tensions of less than 15 bars. The limits on moisture are presented here only tentatively, as they have not been discussed or tested.

The profile of the Orthic Quarzopsamment is a very simple one. It may have an A1 horizon that is thick and slightly darkened by humus, with moist color value of 4 or more, or that has less than 1 percent organic matter; it may have an A1 horizon that is only an inch or two thick, but that has moist color values of 1 to 3; or it may have an Ap that has color values of 4 or more, or that has less than 1 percent organic matter. Below the A1 or the Ap there are normally only faint color differences between horizons. Textures are normally coarse to depths of several meters, though finer layers (IIC) or buried finer textured horizons (Btb) may be present below 75 cm. (30 inches). Chromas of the subsurface horizons are less than 6, but more than 2 if mottled. Mottles with chromas of 2 or less are absent, or deeper than 1 meter. If no mottles are present, chromas may be less than 2, provided there is no artificial drainage, and no ground water at any season within 1 meter of the surface.

Recognizable illuvial horizons too weakly expressed to meet the requirements of angillic or spodic horizons are also absent. These often are seen as bands in roadcuts (see figure 12) but the individual lamellae may be too thin or too few to constitute argillic or spodic horizons. Their presence, however, is a basis for excluding soils from the orthic subgroup.

Aquic Quarzopsamments (1.21-1.1)

The Aquic Quarzopsamments include Quarzopsamments that have the textures and mineralogy of the orthic subgroup. They have, in addition, mottles that have chromas of 2 or less within depths of 1 meter (40 inches), or they may be soils that have either seasonal ground water within 1 meter, or artificial drainage, and that have, in addition, at some depth between 50 cm. and 1 meter (20 and 40 inches), chromas of less than 1 throughout the matrix.

From a genetic viewpoint, these soils show the effect of ground water at some depth between 50 cm. and 1 meter, a depth too great for an Aquent, and too shallow for the Orthic Quarzopsamment.

Haplaquentic Quarzopsamments (1.21-1.14)

This subgroup includes those Quarzopsamments that have textures as fine or finer than loamy very fine sand within 75 cm. (30 inches), and that in addition, have within depths between 50 cm. and 1 meter (20 and 40 inches) mottles with chromas of 2 or less. They have the faint horizonations of the Orthic Quarzopsamments but have at or near the surface no albic or other horizon that is underlain by a horizon that is more than 1 unit darker or that has chromas of 6 or more. Thus, the materials below the A1 or Ap, to a depth of 50 cm. (20 inches), have chromas of less than 6 when moist, and more than 2 if mottled. Between 50 cm. and 1 meter, there must be some mottles with chromas of 2 or less.

Spodic Quarzopsamments (1.21-6)

This subgroup includes the Quarzopsamments that have an albic horizon underlain by a horizon that is more than 1 unit darker in moist value. Because of the high quartz content, the albic horizon is usually nearly white, and is often very striking in appearance. The B horizon is too weakly developed to qualify as a spodic horizon, though it may contain detectable amounts of humus and iron.

Soils of this subgroup have generally been called Podzols because the A2 horizon is so strikingly developed. Yet the B is so weakly expressed that it may not be possible to determine whether the soil intergrades toward Humods, Orthods, or Ferrods. Intergrades toward the various suborders of Spodosols are not defined here, though intergrades toward Humods, and possibly all suborders of Spodosols, exist and are possible to define.

A soil with a few thin lamellae that are almost free of iron but that are darkened by humus could appropriately be called a Humodic Quarzopsamment (1.21-6.2).

Profile 39, page 121, illustrates the concept of the Spodic Quarzopsamment. In this soil, the sand fraction is nearly pure quartz. The albic horizon, at depths between 1 and 12 inches, is a very striking horizon when seen in the field. The horizons from 12 to 25 inches constitute a B horizon, but development is too weak for an argillic or a spodic horizon.

Ultic Quarzopsamments (1.21-8)

This subgroup includes the Quarzopsamments that are free of mottles and that have chromas of 2 or less within 1 meter (40 inches). The soils have no albic horizon underlain by a horizon more than 1 unit darker when moist. They do have, within a depth of 1 meter, moist chromas of 6 or more and values of 5 or more, and base saturation of less than 35 percent from 15 to 75 cm. (6 to 30 inches), or base saturation that decreases with depth below 75 cm. They also have some 2.1 lattice clay, usually vermiculite, in the clay fraction.

Profile 40, page 122, illustrates the concept of the Ultic Quarzopsamment. The soil has an ochric epipedon resting at 18 inches on loamy sand with a chroma of 6. Coarse textures extend to more than 70 inches. Clay mineralogy data for this profile show the clay fraction has approximately 10 percent free iron, and that vermiculite and kaolin are present in moderate amounts, and gibbsite in traces. The sand is nearly pure quartz.

Oxic Quarzopsamments (1.21-9)

This subgroup includes the Quarzopsamments with horizons that have too little clay to constitute oxic horizons, but that meet all other requirements for an oxic horizon. So far as is known, this subgroup does not occur in the United States but may be widespread in Africa and Australia. It is possible that intergrades to the various suborders of Oxisols will be wanted, but until there has been agreement on the definitions of the suborders, no definitions of such subgroups are possible.

Orthopsamment[1] (1.22)

The Orthopsamments are those Psamments that have more than 5 percent feldspars, micas, glass, ferromagnesium minerals, calcite or other minerals that are soluble or can weather to liberate iron or aluminum. Like the Psamments, they have textures coarser than loamy very fine sand to depths of 50 cm. (20 inches) or more, and in some horizons they have moisture held at tensions of less than 15 bars most of the time that they are not frozen. They may have ochric epipedons, and albic horizons, but do not have spodic or argillic horizons or mollic or umbric epipedons. Chromas down to 50 cm. (20 inches) generally are more than 2.

The Orthopsamments are found chiefly in climates that are humid, but the climates may be cold or hot. Since they contain weatherable minerals but lack most diagnostic horizons, the Orthopsamments generally are on recent land surfaces. They may be found on natural levees along rivers, recent beaches, or areas with recent dunes.

The orthic subgroup reflects the central concept of this Great Group. The other subgroups reflect the permissible variations.

Orthic Orthopsamments (1.220)

Orthic Orthopsamments are those Orthopsamments that lack mottles with chromas of 2 or less to a depth of 1 meter (40 inches) or more; have textures coarser than loamy very fine sand to depths of 75 cm. (30 inches) or more; have no albic or other horizon underlain by a horizon with color values 1 unit or more darker; and have at all times some horizon within the soil or within 3 meters (10 feet) that contains moisture held at tensions of less than 15 bars. The limits on moisture presented here are very tentative, as they have not been discussed or tested. The profile shows no lamellae, or bands, in cuts (see figure 12) that are too thin or too few to qualify as argillic or spodic horizons.

Soils of this subgroup are largely restricted to natural levees, beaches, or areas with very recent dunes. These soils have previously been considered to be Alluvial soils if on flood plains, or Regosols if the sand was deposited by wind.

Aquic Orthopsamments (1.22-1.1)

This subgroup includes the Orthopsamments that have at depths of less than 1 meter (40 inches) mottles with chromas of 2 or less. The chromas are too high in the upper 50 cm. (20 inches) for Aquents, though colors characteristic of Aquents may be present below 50 cm. They have, in addition, coarse textures--coarser than loamy very fine sand--to depths of 75 cm. (30 inches) or more. Lamellae normally are not present in soils mottled within these depths.

Udic Orthopsamments (1.22-1.4)

This subgroup includes the Orthopsamments that have textures as fine or finer than loamy very fine sand at some depth between 50 and 75 cm. (20 and 30 inches), but coarse textures to 50 cm; have no mottles within 1 meter that have chromas of 2 or less; have no albic or other horizon underlain by a horizon that has color values 1 unit or more darker; and have at all times, in some horizon or layer within the soil, moisture held at tensions of less than 15 bars.

Spodic Orthopsamments (1.22-6)

This subgroup includes the Orthopsamments that have an albic horizon underlain by a horizon with color values more than 1 unit darker. The soils of this subgroup have been called Podzols because the albic horizon is often thick and prominent in the profile. The B horizon may show considerable color contrast to the albic horizon, but it contains too little organic matter or too little sesquioxide to qualify as a spodic horizon. The B horizon should, however, have the other properties of a spodic horizon. It may occur as a single horizon several inches thick, or as a series of very thin lamellae, or as both.

Alfic Orthopsamments (1.22-7)

This subgroup includes the Orthopsamments that have lamellae containing more clay and free iron than the overlying horizon, but that are too thin or too few to constitute an argillic horizon. The soils also have, in the horizons containing the lamellae, base saturation that is more than 35 percent and that increases or remains constant with depth below the lamellae.

At this writing, it is not certain that subgroups for intergrades to the individual suborders of the Alfisols will be useful, though the definitions are possible.

USTENTS (1.3)

The Ustents include many of the soils of arid and semiarid regions that have been called Lithosols,

[1]This name is unsatisfactory, and will need to be changed. It combines improperly in subgroup names.

Regosols, and Alluvial soils. The Ustents have ochric epipedons. They lack other diagnostic horizons, although they may have discernible secondary carbonates or accumulations of salts. They may even show slight cementation in some horizons, enough to give few to many hard or very hard disconnected nodules. The regolith, or unconsolidated material, may be very thin or very thick, but the soils generally are thin unless stony or gravelly, because lack of moisture limits rooting to shallow depths. Unless the soil is irrigated, moisture is held at tensions of more than 15 bars throughout the soil for more than half of the time that the soil is not frozen. If the soil is being irrigated, moisture may be held at tensions of less than 15 bars at all times. If irrigation ceases, the soil soon becomes dry. It is believed that it will be possible in all instances to determine what the moisture regime would be if irrigation were stopped. The use of soil moisture for classifying soils creates a problem when dry soils are irrigated. For the present, it is the intent to disregard moisture added by irrigation.

Key to Ustents

1.31 Soils with coarse texture (coarse textures include sands and loamy sands coarser than loamy very fine sand) to depths of 50 cm. (20 inches) or more.

Psammustent, p. 112

1.310 Psammustents with textures coarser than loamy very fine sand to 75 cm. (30 inches) or more, and with less than 95 percent quartz in the sand fraction.

Orthic Psammustent, p. 112

1.31-1.32 Other Psammustents with textures as fine or finer than loamy very fine sand within 75 cm. (30 inches), and with less than 95 percent quartz in the sand fraction.

Orthustentic Psammustent, p. 112

1.31-9 Other Psammustents with 95 percent or more quartz in the sand fraction and with a horizon meeting all requirements of an oxic horizon except for the quantity of clay.

Oxic Psammustent, p. 112

1.32 Other Ustents.

Orthustent, p. 113

1.320 With continuous regolith in each pedon to depths of 30 cm. (12 inches) or more (that is, with hard rock (R) at depths of more than 30 cm., and without rock outcrops in the pedon), and having no evident cementation into small nodules that will not soften in acid, and having less than 40 percent of expanding lattice clay.

Orthic Orthustent, p. 113

1.32-2 Other Orthustents with 40 percent or more of expanding lattice clay.

Vertic Orthustent, p. 113

1.32-R Other Orthustents with hard rock at depths of less than 30 cm. (12 inches).

Lithic Orthustent, p. 113

1.32-4.12 Other Orthustents with cementation into hard nodules that will not soften in acid.

Durorthidic Orthustent, p. 113

Psammustents (1.31)

The Psammustents are the coarse-textured soils that lack water held at tensions of less than 15 bars most of the time that they are not frozen. Coarse textures must extend to depths of 50 cm. or more, and, as used here, include sands and loamy sands coarser than loamy very fine sand. Texture classes are based on the fractions finer than 2 mm. Consequently, very gravelly or stony sandy loams are not considered "coarse textured."

Mineral composition of the sands varies widely. Some are largely gypsum, and others quartz, but commonly the mineralogy is mixed. The Psammustents most often are found on at least partially stabilized dunes. Some of the sands have been deposited by water on fans or on flood plains. The vegetation is scattered and is xerophytic if perennial.

The Psammustents have been included with Alluvial soils and Regosols.

Orthic Psammustents (1.310)

This subgroup includes the soils with coarse textures (sands and loamy sands finer than loamy very fine sand) to depths of 75 cm. (30 inches) or more and with more than 5 percent of the sand fraction that is not quartz, tourmaline, zircon, rutile, or similar minerals.

The soils of this subgroup may vary widely in mineralogy but at least 5 percent of their sand fraction is soluble in water or contains iron or aluminum in the lattice. Some Orthic Psammustents are largely gypsum, but most are of highly mixed mineralogy. Carbonates are very common, and some redistribution in a ca horizon is permitted within this subgroup, but the soils may not have a calcic or gypsic horizon.

Orthustentic Psammustents (1.31-1.32)

This subgroup includes the Psammustents that have textures as fine or finer than very fine sand within 75 cm., and that have more than 5 percent of the sand fraction that is soluble in water or contains iron or aluminum in the lattice. Carbonates are normally present in these soils. As they are stratified, many of them are on fans or on flood plains.

Oxic Psammustents (1.31-9)

This subgroup includes soils that have been highly weathered chemically during some previous period. The sand fraction is dominantly quartz, 95 percent or more. The clay fraction is mostly 1.1 lattice clay and free oxides, but the clay content is too low for an oxic horizon. These soils are not known to occur in the United States but are thought to occur in parts of Africa and Australia.

Orthustents (1.32)

The Orthustents include soils that have textures finer than loamy fine sand within 50 cm. (20 inches) and that do not have a horizon in which water is held at tensions of less than 15 bars during most of the period that the soil is not frozen. They have an ochric epipedon that may or may not be slightly darker than the underlying horizons or layers. Weak cementation that is not destroyed by soaking in acid is permitted in the lower horizons if only cemented nodules are present. Accumulations of secondary lime, gypsum, or salts may be seen as efflorescences or mycelia. Distinct cs and sa horizons may be present, but not gypsic or salic horizons. Redistribution of carbonates sufficient to give a ca horizon underlying a horizon that has lost its carbonates is not permitted, for the leached horizon comes within the definition of a cambic horizon. Data are inadequate at this writing to permit a precise definition of the amount of carbonate movement that is permissible in the Orthustents.

The regolith may vary from a few inches to many meters in thickness within the Orthustents. Consequently, they may be found on flood plains, fans, or on uplands throughout the arid and semiarid regions.

Vegetation, if undisturbed, consists of annuals and zerophytic perennials. The orthic subgroup represents the central concept of the Orthustents, and the other subgroups reflect the permissible variations.

It should be noted that the name Orthustent combines improperly and is unsatisfactory. It probably will be changed. The name is used here for lack of a better one at the time of this writing.

The soils have been called Alluvial soils, Regosols, and Lithosols.

Orthic Orthustents (1.320)

This subgroup includes Orthustents having a regolith thicker than 30 cm. (12 inches), having less than 40 percent expanding lattice clay, and in lower horizons lacking cementation into small nodules that will not soften in acid.

Secondary accumulations of gypsum and salts that do not constitute gypsic or salic horizons are permitted but not required. Visible secondary lime is also permitted, but leached surface horizons lying on ca horizons are excluded.

Profile 41, page 123, illustrates the Orthic Orthustent. Some visible secondary lime is present between 15 and 19 inches, but in the stratified parent material it is impossible to determine the amount of movement of lime that has occurred. If the horizon above, at depths between 6 and 15 inches, had shown a blocky or prismatic structure, or were noncalcareous, this soil would be excluded from the subgroup. It will be noted that there has been a slight accumulation of organic matter, and slight redistribution of carbonates, but little other evidence of horizon development.

These soils have been previously called Alluvial soils and Regosols.

Vertic Orthustents (1.32-2)

This subgroup includes the Orthustents that have more than 40 percent expanding lattice clay but that lack the cracks, slickensides, gilgai, or structure diagnostic for Vertisols. These soils are generally shallow to a basic rock.

Lithic Orthustents (1.32-R)

This subgroup includes Orthustents that have hard rock (R) at shallow depths, less than 30 cm. (12 inches). Rock outcrops in each pedon are common but are not required in the subgroup. Textures are variable but do not include clays that have 40 percent or more expanding lattice clay. The soils in this subgroup have previously been called Lithosols for the most part.

Durorthidic Orthustents (1.32-4.12)

The soils of this subgroup include the Orthustents that have less than 40 percent expanding lattice clay, a regolith thicker than 30 cm. (12 inches), and in some horizon partial cementation by acid insoluble materials into small or large nodular aggregates. The cementation makes boring or digging difficult and imparts a very gritty feeling to loamy materials. The cementation, however, is too weak to form a duripan.

Soils of this subgroup have previously been called Alluvial soils for the most part.

UDENTS (1.4)

The Udents include the Entisols that, when not frozen, are usually moist in some horizon or layer within the soil, have textures of loamy very fine sand or finer somewhere within a depth of 50 cm. (20 inches), and, within depths of 50 cm. (20 inches), lack the characteristics associated with wetness defined for Aquents. In general, if mottles are present within 50 cm., the dominant chromas are more than 2 in hues as red or redder than 10YR.

The Udents may have an ochric, anthropic, or plaggen epipedon and an albic horizon. They are not permitted to not have mollic or umbric epipedons or an argillic, spodic, cambic, or oxic horizon, nor may they have a fragipan or duripan.

The textures must be finer than loamy very fine sand somewhere within 50 cm. (20 inches) but may not be clayey (more than 40 percent clay) if there are slickensides, gilgai, or cracks and structures diagnostic for Vertisols. (Order 2)

The Udents include some of the soils that have been called Regosols, Lithosols, and Alluvial soils. They may have consolidated rock at depths of a very few inches, or they may be found in alluvium many meters thick. The Udents therefore are found chiefly in humid climates, ranging from the tropics to the tundra. A few are found in arid and semiarid climates where there is natural irrigation.

Many of these soils have no natural vegetation, as they have accumulated during cultivation of the area in which they occur. They may have received slow deposition under a forest vegetation, or they may have undergone recent severe erosion. Some Udents were formerly Mollisols, Chernozems, or Brunizems, for example, but under cultivation have lost all diagnostic horizons. The sediments that came from this erosion may have buried other Mollisols on flood plains, and converted them to Udents. The Udents, then, are found chiefly on flood plains or on slopes that have undergone recent geologic or accelerated erosion. Their lack of horizons is due chiefly to the lack of time for horizons to develop.

Key to Udents

1.41 Udents with mean annual temperatures less than 8.3° C. (47° F.) and mean summer temperatures less than 15.5° C. (60° F.) if with an Ap horizon, or less than 10° C. (50° F.) if with an O horizon. (Note that these temperature limits are tentative.)

Cryudent, p. 114

1.410 Cryudents with permafrost within 75 cm. (30 inches), or if hard rock is at depths of less than 75 cm., with frost above the rock more than 7 months of the year.

Orthic Cryudent, p. 114

1.41-1.43 Other Cryudents.

Haplic Cryudent, p. 115

1.42 Other Udents having an anthropic epipedon or an agric horizon, but lacking a plaggen epipedon.

Agrudent, p. 115

1.43 Other Udents, lacking a plaggen epipedon.

Hapludent, p. 115

1.430 Hapludents, with no mottles within 50 cm. (20 inches), that have chromas of 2 or less; that have less than 40 percent of expanding lattice clays; that have no part of a buried mollic epipedon 20 cm. (8 inches) or more thick within the upper 60 cm. (24 inches), and no part of a buried argillic horizon between 50 and 80 cm. (20 and 32 inches); that have less than 60 percent either of allophane in the clay fraction or of volcanic ash; and that do not have R, hard bedrock, within 50 cm. (20 inches) of the surface.

Orthic Hapludent, p. 115

1.43-1.14 Hapludents that have less than 40 percent expanding lattice clay and that have mottles with chromas of 2 or less within 50 cm. (20 inches) of the surface, or that have between 50 cm. and 1 meter (20 and 40 inches) horizons that are saturated with water at some season or have artificial drainage, and have chromas of less than 1 or hues bluer than 10Y.

Aquic Hapludent, p. 115

1.43-3.2 Other Hapludents that have 60 percent or more either of allophane in the clay fraction, or of volcanic ash.

Andeptic Hapludent, p. 116

1.43-R Hapludents with R, hard bedrock, within 50 cm. (20 inches) of the surface.

Lithic Hapludent, p. 116

1.43-2 Other Hapludents that have 40 percent or more expanding lattice clay.

Vertic Hapludent, p. 116

1.43-5 Other Hapludents that have a buried mollic epipedon that is 20 cm. (8 inches) or more thick and has its upper boundary within 60 cm. (24 inches) of the surface.

Thapto Mollic Hapludent, p. 116

1.43-7 Other Hapludents with a buried argillic horizon that has more than 35 percent base saturation and has its upper boundary between 30 and 75 cm. (20 and 30 inches) below the surface.

Thapto Alfic Hapludent, p. 116

1.44 Other Udents, having a plaggen epipedon.

Plaggudent, p. 116

Cryudents (1.41)

The Cryudents are the Udents that have low enough temperatures during most of the year to seriously interfere with root growth or moisture movement. They lack diagnostic horizons other than an ochric epipedon, or very thin spodic and albic horizons that would be obliterated by plowing. They have, however, either permafrost or low summer temperatures within the layers above 75 cm. (30 inches). If the soils are being cultivated or have no O horizon, the mean temperature must be less than 15.5° C. (60° F.), but if the soils have an O horizon the summer temperature must be less than 10° C. (50° F.). These temperature limits are presented here only tentatively and may require adjustment.

The regolith may be very thick or very thin. Textures may vary widely but must be as fine or finer than loamy very fine sand within some part of the upper 50 cm. (20 inches).

The soils occur in boreal, arctic, or alpine regions under tundra or boreal forests. Land surfaces on which Cryudents occur are generally young. They may be flood plains, or areas on upland that are currently receiving deposition. They may also be found on the steeper slopes on which erosion is or has recently been active. The central concept of the Cryudents is reflected in the orthic subgroup; the other subgroups represent permissible variations.

The Cryudents have been called Tundra soils, Alluvial soils, Regosols, and Lithosols.

Orthic Cryudents (1.410)

The Orthic Cryudents are those that have permafrost within 75 cm. (30 inches) if the regolith is that deep, or that have frost in the regolith more than 7 months of each year if the regolith is shallower than 75 cm. At this writing, no lower limit on thickness of regolith can be suggested for the subgroup, although it appears that it will be necessary to establish one. Certainly, soils only 10 to 15 cm. thick on hard rock should be placed in a lithic subgroup.

A typical profile of these soils may or may not show a thin O and a thin A1 horizon, slightly darkened by humus. If present, these rest on a brownish, massive C horizon that usually has chromas of 3 or 4 and values of 4 to 6. A few mottles are normally present, unless the C is very gravelly. Streaks of A1 or of O may be seen occasionally throughout the C. If the regolith is thick alluvium, buried wood may be found at any depth. Base saturation is quite variable, but carbon-nitrogen ratios are normally very wide, or from 20 to 30. Permafrost may be present at depths ranging from perhaps 15 cm. (6 inches), or a little more, to 75 cm. (30 inches).

Haplic Cryudents (1.41-1.43)

This suborder includes the Cryudents that have no permafrost within 75 cm. (30 inches) and that have no hard bedrock within a depth limit that cannot yet be specified. The typical profile shows an Ap horizon, or an O, and a thin A1 on C material. The C material is as fine or finer than loamy very fine sand within 50 cm. (20 inches), and chromas of 3 or 4 and values of 4 to 5 are usual. Mottling is permitted but is less common than in the orthic subgroup.

Lithic Cryudents (1.41-R)

This subgroup has not yet been defined.

Agrudents (1.42)

The Agrudents include soils with an anthropic epipedon or an agric horizon, or both, but with no other diagnostic horizons. In the United States these soils have been found only on kitchen middens and are not thought to be representative of the orthic subgroup. However, the subgroups have yet to be defined for the Agrudents. Generally, these soils have had no good place in other classifications.

Hapludents (1.43)

The Hapludents include many of the soils that have been called Regosols or Lithosols, and many of the Alluvial soils with moderately good or good drainage. They are soils with textures as fine or finer than loamy very fine sand within a depth of 50 cm. (20 inches); with chromas of the upper 50 cm. of usually 3 or 4, but higher than those permitted in the Aquents; with mean annual temperatures of 8.3° C. (47° F.) or higher, or with mean summer temperatures of 15.5° C. (60° F.) if being cultivated, or more than 10° C. (50° F.) if an O horizon is present (temperature limits above are tentative and subject to change); with moisture held at tensions of less than 15 bars in some horizon or layer within the soil most of the time that the soil is not frozen; with no plaggen or anthropic epipedon or agric horizon; and with no mollic or umbric epipedons or argillic, spodic, or cambic horizons or pans unless they are buried. Buried soils are permitted if they are buried to depths of more than 50 cm. (20 inches), or to depths of between 30 and 50 cm. (12 and 20 inches) if the buried solum is less than half the thickness of the overlying sediment. The regolith may be very thin, 1 cm. or less, or may be many meters thick.

The lack of diagnostic horizons in Hapludents is attributed to lack of time for formation. They are therefore found largely in places where there has been geologically recent deposition or erosion. Slow deposition or erosion may not preclude formation of a mollic epipedons, so the Hapludents rarely have had grass vegetation for periods longer than a few decades or possibly centuries. In the United States, the Hapludents are commonly found in deposits that have accumulated through accelerated erosion, or on slopes that have been subjected to such erosion. They may also be found on the steeper slopes where natural erosion has been recently active, or on forested flood plains.

The central concept of the Hapludents is reflected by the orthic subgroup. Other subgroups represent permissible variations.

Orthic Hapludents (1.430)

This subgroup includes the Hapludents that, within the upper 50 cm. (20 inches) have an ochric epipedon on C material that has chromas of 3 to 4 or more; have no mottles with chromas of 2 or less; have textures that are as fine or finer than loamy very fine sand; lack as much as 40 percent expanding lattice clay; have less than 60 percent allophane in the clay fraction and volcanic ash in the silt and sand; and have no R layers. Below 50 cm. (20 inches) there may be either R or C material. If the regolith is thick, there can be no part of a buried mollic epipedon as much as 20 cm. (8 inches) thick to a depth of 60 cm. (24 inches) and no part of a buried argillic horizon between 50 and 80 cm. (20 and 32 inches). Buried soils otherwise are permitted if they are buried to depths of more than 50 cm. (20 inches), or to depths of between 30 and 50 cm. (12 and 20 inches) if the buried solum is less than half the thickness of the overlying sediment. One horizon or another within the soil is usually moist, with moisture held at tensions of less than 15 bars in some horizon or layer most of the time that the soil is not frozen. There must be no plaggen or anthropic epipedon or agric horizon, and no mollic or umbric epipedons or argillic, spodic, or cambic horizons or pans unless they are buried.

The lack of diagnostic horizons in Hapludents is attributed to lack of time for formation. They are therefore found largely in places where there has been geologically recent deposition or erosion. Slow deposition or erosion usually does not preclude formation of a mollic epipedon, so the Hapludents rarely have had grass vegetation for periods longer than a few decades or possibly centuries. In the United States the Hapludents are commonly formed in deposits that have accumulated through accelerated erosion, or on slopes that have been subjected to such erosion. They may also be found on the steeper slopes where natural erosion has been recently active.

A representative profile of an Orthic Hapludent may show an Ap, or an A1 that is ochric. This rests on a loamy C layer that is massive and has chromas of 3 or 4 and values of 4 or 5 with no mottles. The C may be calcareous or strongly acid, for base saturation is not significant except at family and series levels. There should be some 2.1 lattice clays, carbonates, or silt- or sand-size minerals that contain bases, iron, or aluminum in the lattice, though the amounts of these minerals may be small.

Aquic Hapludents (1.43-1.14)

This subgroup includes Hapludents that are like the Orthic Hapludents except for the presence of some mottles within 50 cm. (20 inches) that have chromas of 2 or less, and the presence of either seasonal ground water within the depth or artificial drainage.

Below depths of 50 cm. these soils often show the low chromas and mottles that would be diagnostic for Aquents if they occurred at shallow depths.

Lithic Hapludents (1.43-R)

This subgroup includes Hapludents that have less than 40 percent expanding lattice clay, less than 60 percent allophane in the clay fraction, and less than 60 percent of volcanic ash in the silt and sand fraction; and have a hard rock (R) layer within 50 cm. (20 inches) of the surface. They have only an ochric epipedon, and a C with chromas of 3 or more and with variable thickness. They are apt to be confused with some of the Ochrepts (3.4). The distinction that is easiest to observe in the field is the presence of rock structure in the C of the Hapludents. Usually these are soils that have had horizons diagnostic of other orders and have been truncated either under cultivation or by recent geologic erosion. Occasionally, they may be formed by deposition of a thin mantle of loess, or alluvium, on hard rock.

Soils of this subgroup have been called Lithosols.

Vertic Hapludents (1.43-2)

This subgroup includes all Hapludents that have 40 percent or more expanding lattice clay. They may have an R horizon that is shallow or deep. They have an ochric epipedon, clayey textures, and chromas usually near 3 but too high for the Aquents. Mottles with high chromas may be present or absent in the upper 50 cm. (20 inches). These soils however lack the gilgai, the intersecting slickensides, and the wide, deep cracks or structure diagnostic for Vertisols.

Andeptic Hapludents (1.43-3.2)

This subgroup is provided for Hapludents that have more than 60 percent volcanic ash in the silt and sand fraction or more than 60 percent allophane in the clay fraction. Typically, these soils consist of fresh ash having a thin A1 horizon or no A1 horizon. Some may consist of weathered ash that has been recently moved and redeposited. The regolith is thicker than 50 cm. (20 inches). If an R is present within that depth, a Lithic Andeptic subgroup is required. These subgroups are not otherwise defined at this time.

Thapto Mollic Hapludents (1.43-5)

This subgroup includes Hapludents that have a buried mollic epipedon, 20 cm. (8 inches) or more thick, that has its upper boundary less than 60 cm. (24 inches) below the surface. This subgroup as named, could require that the buried soil have the properties of the Hapludoll; that is, have a mollic epipedon on a C layer that has chromas of 3 or more. Or the name could be used if the mollic epipedon were the only buried horizon of significance to the classification. The buried soil might have been a Haplaquoll or Argaquoll, but if the additional horizons or properties diagnostic for those great groups lay more than 1 meter below the surface, they would not be a basis for defining the present subgroup. Horizons lying more than 75 cm. (30 inches) below the surface of Hapludents are treated at the phase level.

Thapto Alfic Hapludents (1.43-7)

This subgroup includes the Hapludents that have no buried mollic epipedon, but that have, between depths of 50 and 75 cm. (20 and 30 inches), a buried argillic horizon having more than 35 percent base saturation. The A horizon of the buried soil may or may not be present, but generally it is found. The subgroup is intended to include only buried soils with properties diagnostic for Alfisols. Redefinition of the subgroup may become necessary to provide for buried soils belonging to the different suborders of Alfisols.

Plaggudents (1.44)

The Plaggudents include all Entisols having a plaggen epipedon. Since the soils do not occur in the United States, the definition of the Plaggudents and its subgroups can be best developed by others.

Profile Descriptions for Chapter 8

(Colors for moist soil unless otherwise stated)

Profile No. 35

Area: Near Fairbanks, Alaska.

Vegetation: Black spruce, birch, and alder with a ground cover of sphagnum moss, Labrador-tea, horsetail, and lowbush cranberry.

Parent material: Medium-textured alluvium.

Topography: Level; less than 1 percent slope; bottom land.

O1 5 to 0 inches, very dark brown (10YR 2/2) mat of moss, roots, and mycelia; abrupt, smooth boundary.

A1 0 to 3 inches, mixed very dark grayish-brown (10YR 3/2) and dark-gray (5Y 4/1) silt loam; weak, very thin, platy, breaking easily to weak, very fine, granular structure; friable; abundant roots; few, small particles of charcoal; clear, smooth boundary.

C1 3 to 11 inches, dark-gray (5Y 4/1) silt loam; many, medium, distinct mottles of dark brown (10YR 3/3); weak, very thin, platy structure, breaking to weak very fine subangular blocky; friable, nonsticky; plentiful roots; few, small particles of charcoal; clear, smooth boundary.

C2 11 to 21 inches, dark grayish-brown (2.5Y 4/2) silt loam; common, medium, faint mottles of olive brown (2.5Y 4/4); weak, very thin, platy structure; friable, nonsticky, few roots; gradual boundary.

C3 21 to 29 inches +, dark grayish-brown (2.5Y 4/2) silt loam; slightly coarser textured than horizon just above; weak, very thin, platy structure; very friable, nonsticky; few roots.

C4f 29 to 30 inches +, frozen soil material.

Remarks: This area has been burned over or cleared within the past 50 years. The soil was frozen, beginning at a depth of 29 inches, when the sample was taken on September 4, 1958.

Climatic data (Univ. Expt. Sta., Alaska)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1922-52 (deg. F.)	-6	2	12	30	47	58	59	55	45	28	7	-5	28
Mean precipitation, 1922-52 (inches)	0.9	0.5	0.5	0.3	0.9	1.4	2.0	2.4	1.5	1.4	1.0	0.7	13.4

Annual precipitation more than 9.1 and less than 17.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
5-0	O1	------	------	------	------	------	------	------	------	------	------		36.38	30	
0-3	A1	1.6	1.5	0.8	1.8	2.5	76.4	15.4	29.4	50.4	-		11.51	29	2.3
3-11	C1	.2	.5	.3	.7	2.1	79.6	16.6	30.5	51.6	-		1.62	20	2.2
11-21	C2	.1	.2	.2	.6	2.8	80.4	15.7	36.2	47.4	-		.70	13	2.0
21-29+	C3	<.1	2.1	.3	10.5	3.0	75.6	8.5	56.8	26.3	-		.36	10	1.3

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1	Base sat. % s	Cation exch. cap. s
------	------	------	------	------	------	------	5.4	------	------
40.5	24.3	11.8	27.2	0.3	0.5	91	5.7	58	64.1
22.3	14.7	7.6	6.4	.4	.1	102	6.9	78	29.2
18.4	13.6	5.6	2.8	.3	.1	106	7.7	88	22.4
11.9	9.8	3.4	1.6	.2	.1	113	7.8	89	15.1

*Exchange acidity.

Profile No. 36

Area: Kenai Peninsula, Alaska

Vegetation: Forest of white spruce and birch with a ground cover of moss, Labrador-tea, and lowbush cranberry.

Parent material: Silty material over alluvium consisting of sand and gravel.

Topography: 2 percent slope; nearly level land adjacent to a muskeg; alluvial plain.

O — 4 to 0 inches, dark reddish-brown (5YR 2/2) mat of roots, moss, decomposing parts of plants and mycelia; abrupt, smooth boundary.

A1 — 0 to 6 inches, dark yellowish-brown (10YR 4/4), heavy sandy loam; mottles of grayish brown (2.5Y 5/2) and very dark gray (N3/); massive, breaking to very fine, granular structure; friable; abundant roots; clear, wavy boundary.

C1 — 6 to 20 inches, mottled dark yellowish-brown (10YR 4/4), dark grayish-brown (2.5Y 4/2), and grayish-brown (2.5Y 5/2) gritty silt loam; weak, thick, platy structure; nonsticky; few roots; few mycelia; gradual boundary.

C2 — 20 to 25 inches, olive-brown (2.5Y 4/4) silt loam; mottles of grayish brown (2.5Y 5/2) and very dark grayish brown (2.5Y 3/2); massive; nonsticky; few roots; abrupt, wavy boundary.

IIC3 — 25 to 40 inches +, olive (5Y 4/3) gravelly coarse sand; structureless; loose; pebbles rounded; many feet thick.

Climatic data (Kasilof, Alaska)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1930-52 (deg. F.)	14	20	24	35	43	51	55	54	47	37	24	15	35
Mean precipitation, 1930-52 (inches)	1.1	1.0	0.7	0.5	0.6	1.2	2.0	2.3	3.2	1.7	1.5	1.2	17.1

Annual precipitation more than 7.9 and less than 26.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
4-0	O	---	---	---	---	---	---	---	---	---	Tr.		39.81	35	
0-6	A1	0.8	4.9	12.0	22.4	11.6	43.4	4.9	42.3	23.1	11.9		5.37	29	2.1
6-20	C1	1.6	4.7	9.8	13.3	12.8	53.2	4.6	46.5	26.9	7.8		2.16	20	2.0
20-25	C2	.6	1.3	3.4	8.3	12.8	69.2	4.4	51.7	34.4	4.7		1.69	15	2.2
25-40+	IIC3	19.5	20.9	22.2	27.8	3.1	5.4	1.1	13.5	3.6	59.6		.19		.4

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1	Base sat. % s	Cation exch. cap. s
18.9	1.2	0.6	30.3	0.1	0.1	10	4.1	6	32.3
9.9	.9	<.1	18.6	.1	.1	11	5.2	6	19.7
9.5	.7	.3	17.0	.1	.1	13	5.8	6	18.2
2.7	.3	.1	4.0	<.1	.2	22	5.9	13	4.6

*Exchange acidity.

Profile No. 37

Area: Colleton County, South Carolina.
Vegetation: Giant cordgrass.
Parent material: Marine clay.
Topography: Flat; about sea level.

C1g 0 to 6 inches, dark greenish-gray (5GY 4/1) clay; dark grayish-brown (10YR 4/2) mottles; massive, breaking to weak, angular blocky structure.
C2g 6 to 12 inches, dark greenish-gray (5GY 4/1) clay; massive; sticky under field moisture conditions, but offers no resistance, and, when gentle hand pressure is applied, the material escapes readily between the fingers.
C3g 12 to 22 inches, dark greenish-gray (5GY 4/1) clay; massive; sticky under field moisture conditions, but offers no resistance, and, when gentle hand pressure is applied, the material escapes readily between the fingers.
C4g 22 to 34 inches, dark bluish-gray (10B 4/1) clay; massive; sticky under field moisture conditions, but offers no resistance, and, when gentle hand pressure is applied, the material escapes readily between the fingers.

Climatic data (Beauford, S. C.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	52	53	58	66	73	80	81	81	77	68	58	52	67
Mean precipitation, 1931-52 (inches)	2.5	3.0	3.7	2.5	3.1	5.0	5.6	6.7	5.4	2.2	2.0	2.9	44.6

Annual precipitation more than 29.0 and less than 60.2 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-6	C1g	0.2	0.6	0.6	1.6	1.0	29.9	66.1	6.9	24.8			4.6	12	5.7
6-12	C2g	.4	.5	.2	.6	.3	27.8	70.2	5.5	23.0			3.9	10	1.7
12-22	C3g	.8	.5	.3	1.0	.8	29.0	67.6	6.6	23.8			4.6	13	4.5
22-34	C4g	.4	.6	.5	1.6	1.3	27.3	68.3	8.2	21.4			4.3	12	2.0

Cation exch. cap.	Extractable cations, meq./100 gm. Ca	Mg	H	Na	K	pH 1:1 Initial	pH 1:1 Dried 1 week	pH 1:1 Dried 1 month	N Value	Elec. resistance Initial	Dried 1 week	Dried 1 month	Field moisture % s
						5.4	5.2	5.2	2.0	53	48	37	196
						6.5	6.0	5.5	1.1	71	64	48	120
						6.7	6.2	5.1	2.1	64	53	35	215
						6.3	5.3	4.8	2.0	43	37	31	201

Profile No. 38

Area: Nottoway County, Virginia
Vegetation: (Natural) sweetgum, blackgum, water oak, ash, poplar, hickory, beech, elm, and alder.
Parent material: Alluvium from materials derived from granite, gneiss, and schist.
Topography: <1 percent slope; level; flood plain.

Ag 0 to 22 inches, light-gray (10YR 7/2) clay loam; common, medium, distinct mottles of yellowish brown (10YR 5/6); weak, fine, subangular blocky structure; friable; abundant roots.

Cg 22 to 36 inches +, light-gray (10YR 7/2), light silty clay loam; common, coarse, distinct, and prominent mottles of yellowish brown (10YR 5/6) and black, massive; friable; very few roots.

Climatic data (Blackstone, Va.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1945-59 (deg. F.)	40	41	47	58	66	74	78	76	70	60	49	40	58
Mean precipitation, 1945-59 (inches)	3.1	3.0	3.2	3.7	4.0	3.8	5.8	4.3	4.1	3.0	3.6	3.4	45.0

Annual precipitation more than 34.5 and less than 55.5 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate										B.D. (gm. per cc.)	Organic matter		Free iron oxides
		Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2		C % w	C/N k	Fe_2O_3 %
0-22	Ag	0.3	2.7	4.2	9.9	5.6	39.9	37.4	16.3	34.8	0		1.10	11	2.6
22-36+	Cg	.2	1.0	1.8	8.6	8.1	44.4	35.9	24.1	34.2	0		.22	7	1.3

Cation exch. cap. s	Extractable cations, meq./100 gm. Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
16.6	4.2	2.4	9.8	--	0.14	41	5.3
18.8	6.8	6.0	5.7	--	.26	69	5.9

*Exchange acidity.

Profile No. 39

Area: Sarasota County, Florida

Vegetation: (Natural) mainly dwarf live oak, rosemary, runner oak (Quercus pumila), pricklypear cactus, wiregrass, and scattered clusters of saw-palmetto.

Parent material: Loose, acid sand.

Topography: About 5 percent slope; nearly level to gently undulating.

A1 0 to 1 inch, gray (N 5/) to dark-gray (N 4/) fine sand mixed with some light gray, which gives the soil a salt-and-pepper color; loose; abundant, fine roots; clear, wavy boundary.

A2 1 to 12 inches, white (N 8/) fine sand; loose; abundant, fine roots; abrupt, irregular boundary.

A3 12 to 18 inches, pale-yellow (5Y 8/3) fine sand with some grains of white and yellow; loose; plentiful, coarse and fine roots; gradual, irregular boundary.

B2 18 to 25 inches, brownish-yellow (10YR 6/6) to light yellowish-brown (10YR 6/4) fine sand; nearly loose; few, coarse and fine roots; gradual, irregular boundary.

C1 25 to 64 inches, pale-yellow (2.5Y 7/4) fine sand containing a small amount of white and yellow; loose; few roots in upper part; diffuse, irregular boundary.

C2 64 to 70 inches, pale-yellow (2.5Y 7/4) fine sand; common, coarse, distinct, and prominent mottles of yellowish brown, gray, and very dark brown; loose.

Climatic data (Sarasota, Fla.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-50 (deg. F.)	62	63	66	70	75	79	80	80	79	74	67	63	71
Mean precipitation, 1931-50 (inches)	1.8	2.5	2.7	2.7	2.4	7.9	9.1	10.6	8.2	2.7	1.3	1.6	53.5

Annual precipitation more than 35.9 and less than 71.1 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
0-1	A1	0.6	15.7	25.0	56.4	0.9	0.2	1.2		0	0		1.04	
1-12	A2	.4	4.6	16.8	74.7	2.4	.3	.8		.3	0		.06	
12-18	A3	.4	4.1	16.0	74.8	2.7	0	2.0		0	0		.12	
18-25	B2	.5	3.6	15.2	75.4	3.2	.1	2.0		.1	0		.15	
25-64	C1	.5	4.4	14.8	75.2	3.4	0	1.7		0	0		.05	
64-70	C2	1.0	4.7	14.2	75.0	3.4	0	1.7		0	0		.06	

Cation exch. cap. s	Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
4.1	1.5	0.1	2.5	<0.1	<0.1	39	5.4
1.6	.3	.0	1.3	.0	<.1	19	6.4
1.9	.5	.1	1.3	.0	<.1	32	6.0
3.3	.4	.1	2.8	.0	<.1	15	5.8
1.4	.1	.0	1.3	.0	<.1	7	6.1
1.8	.5	.1	1.2	.0	<.1	33	6.0

*Exchange acidity.

Profile No. 40

Area: Richland County, South Carolina.
Vegetation: Forest: (natural) pine, mainly longleaf, and an undergrowth of blackjack, post oak, and other scrub oaks.
Parent material: Sand.
Topography: Less than 5 percent slope; upland on the Atlantic Coastal Plain.

A11 0 to 3 inches, gray (10YR 5/1) sand; very weak, fine, granular structure; very friable; abundant, fine roots; clear, smooth boundary.
A12 3 to 11 inches, light olive-brown (2.5Y 5/4) sand; very weak, fine, granular structure; very friable; plentiful, fine roots; gradual, smooth boundary.
A2 11 to 18 inches, very pale brown (10YR 7/4) sand; few, medium, faint, yellow (10YR 7/6) mottles; very weak, fine, granular structure; very friable; plentiful, fine roots and a few, coarse roots; gradual, smooth boundary.
B2 18 to 39 inches, brownish-yellow (10YR 6/6) sand; very weak, medium, subangular blocky structure; very friable; few, coarse roots; gradual, smooth boundary.
B3 39 to 62 inches, yellow (10YR 7/6) sand; few, fine, faint mottles of very pale brown (10YR 7/4); very weak, fine, granular structure; very friable; gradual, smooth boundary.
C 62 to 70 inches, very pale brown (10YR 7/4) sand; common, medium, faint, yellow (10YR 7/6) mottles; very weak, fine, granular structure; a few, large mottles of yellowish brown (10YR 5/4), which appear to be very soft accumulations of iron or clay.

Climatic data (Columbia, S. C.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	47	49	55	64	72	80	81	80	76	65	54	47	64
Mean precipitation, 1921-50 (inches)	3.1	3.6	3.8	3.5	3.2	4.1	6.6	5.5	4.4	2.4	2.3	3.6	46.2

Annual precipitation more than 33.2 and less than 59.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-3	A11	5.4	34.8	21.3	21.5	6.3	8.5	2.2	19.8	5.0	0		1.47	32	0.2
3-11	A12	5.9	30.4	19.9	23.9	8.3	8.6	3.0	23.1	5.6	0		.51	30	.2
11-18	A2	5.3	32.2	21.0	23.4	7.2	7.8	3.1	20.8	5.2	0		.17		.2
18-28	B21	5.8	30.9	20.0	23.3	7.1	7.9	5.0	20.6	5.5	0		.10		.3
28-39	B22	5.9	31.4	20.7	23.7	7.1	7.2	4.0	20.7	4.6	0		.05		.2
39-52	B3	5.2	29.4	21.5	27.6	7.9	5.2	3.2	23.2	2.9	0		.03		.2
52-62	B3	7.7	30.5	20.8	25.7	6.8	4.9	3.6	20.8	2.9	0		.09		.3
62-70	C	9.1	32.1	20.5	24.4	6.4	4.4	3.1	19.5	2.6	0		.03		.2

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Clay mineralogy: Gb %	K %	Vm
3.9	0.3	<0.1	3.6	<0.1	<0.1	8	4.9	3	10	xx
1.7	< .1	<.1	1.7	<.1	<.1	<1	5.3	5	20	xx
1.1	.1	<.1	1.0	<.1	<.1	9	5.4	5	15	xx
1.3	.3	<.1	1.0	<.1	<.1	23	5.6	10	20	xx
1.1	.2	.1	.8	<.1	<.1	27	5.9	5	15	xxx
.7	< .1	.1	.6	<.1	<.1	14	5.5	5	25	xxx
1.0	< .1	.2	.8	<.1	<.1	20	5.7	10	25	xxx
1.0	< .1	.2	.8	<.1	<.1	20	5.3	10	30	xxx

*Exchange acidity.

Profile No. 41

Area: Beryl-Enterprise, Utah.
Vegetation: Barren; (natural) sparse cover of sagebrush (Artemesia tridentata) and galleta grass (Hilaria jamesii).
Parent material: Alluvium originating mainly from rhyolite with some latite, andesite, and obsidian.
Topography: Gently sloping; alluvial fan; elevation between 5,000 and 5,500 feet.

A1 0 to 6 inches, dark reddish-brown (5YR 3/4) loam, reddish brown (5YR 5/4) when dry; weak, very fine, granular structure; the half-inch surface layer may be a very fine vesicular horizon, with weak, very thin, platy structure; soft, very friable; calcareous.

C1 6 to 15 inches, reddish-brown (5YR 4/4) loam, reddish brown (5YR 5/4) when dry; very weak, coarse, granular crushing to medium and fine, granular structure; slightly hard, friable; many tubular pores and root channels (some up to 3 millimeters in diameter); calcareous.

C2 15 to 19 inches, reddish-brown (5YR 4/4) loam, reddish brown (5YR 5/4) when dry; very weak, coarse, granular structure; slightly hard, friable; many tubular pores and root channels (some up to 3 millimeters in diameter; visible, thin lime seams and flecks.

C3 19 to 60 inches, yellowish-red (5YR 4/6) sandy loam, yellowish red (5YR 4/6) when dry; very weak, coarse, granular crushing to medium and fine, granular structure; slightly hard, friable; calcareous.

Climatic data (Modena, Utah)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1930-52 (deg. F.)	25	31	38	47	55	63	72	70	62	50	37	29	48
Mean precipitation, 1930-52 (inches)	0.8	0.8	1.0	0.8	0.7	0.5	0.9	1.3	0.7	1.1	0.6	1.0	10.1

Annual precipitation more than 4.9 and less than 15.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-6	A1	0.1	3.1	2.9	13.3	17.3	43.5	19.8		22.7	5		0.47	9
6-15	C1	.3	1.5	2.0	9.2	17.8	50.2	19.0		23.9	1		.37	9
15-19	C2	2.7	3.9	3.8	15.3	17.1	40.7	16.5		18.6	3		.27	--
19-60	C3	4.5	8.5	8.5	20.2	14.1	30.2	14.0		15.3	10		.22	--

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	pH 1:5	$CaCO_3$ equiv. % v
						7.9	9.0	10.3
						7.9	8.9	16.6
						7.9	9.0	11.2
						8.0	8.8	8.3

Chapter 9. Vertisols

The Vertisols include swelling clays that have gone by many names. Among them are Grumusol, at least a part of the Regur and Tirs, Black Cotton, Tropical Black Clays, Gray and Brown soils of heavy texture, and Smonitza. The Vertisols also include some soils that have been called Alluvial soils, particularly those with large amounts of expanding lattice clays in climates with pronounced hot dry seasons.

The common characteristics of the soils of the order are: high content of expanding lattice clay, more than 35 percent and usually more than 40 percent; more than 30 milliequivalents exchange capacity in all horizons below the surface 5 cm. (2 inches); cracks, unless irrigated, 1 to 25 cm. wide at some seasons that reach to the middle of any solum present; and with gilgai, or with slickensides close enough together to intersect in places, or at some depth between 25 and 100 cm., with wedge or parallelepiped structural aggregates having a long axis tilted 10° to 60° from the horizontal. Vertisols may have a mollic or umbric epipedon. If one of these is present, the lower boundary is often very irregular, but the irregularity is not diagnostic for it can be the result of frost action. There may also be a horizon meeting the requirements of an argillic horizon, if its upper boundary lies within 5 cm. (2 inches) of the surface. An albic horizon as much as 5 cm. thick may overlie the argillic horizon. Calcic horizons and ca horizons are common.

The Vertisols normally are developed in montmorilloritic parent materials derived from limestones or basic igneous rocks but they may be found in granitic areas too. Climates may be subhumid to arid, but normally there are seasonal sources of water adequate to saturate the soil, with consequent swelling and closing of cracks. The water may come as rain or in floods. At the extreme, it seems likely that some Vertisols are fully moistened only once every few years. However, all Vertisols that are not irrigated have, at some season, a moisture content low enough to produce wide cracking. Temperatures may range from tropical to temperate. Hot dry seasons are normal, and in most years air temperatures at some time exceed 38° C. (100° F.)

The vegetation on Vertisols not cultivated is normally grass or herbaceous annuals. On some of them, scattered, usually drought-tolerant, woody plants may be present. *Eucalyptus*, *Acacia*, *Juniperus*, and *Prosopis* (Mesquite) are common genera.

The Vertisols are found in a wide variety of positions, from the floodplains of rivers to steeply sloping uplands.

The central concept of Vertisols is one of soils that crack widely, and that often remoisten from water that runs into the cracks rather than from water that percolates through the soil. If the surface mulches during the dry season there may be a significant amount of A1 material that sloughs into the cracks. In these the lower boundary of the A1 is often very irregular and there is gilgai microrelief unless the area has been leveled by man. In other Vertisols, sloughing is probably minor in its influence. However, the moistening and swelling of a layer, with dry soil above and below, causes shearing within the soil and produces slickensides and wedge-shaped or parallelepiped structure.

The shrinking, cracking, and shearing in the Vertisols, and the mass movement, make them unstable and introduce severe problems in use. Fences, and telephone poles are thrown out of line; trees are tilted (fig. 29). Pavements may be broken and shifted laterally. Foundations of buildings may be destroyed, and pipelines broken. Terraces may crack and give rise to gullying when the rains come. These are some of the problems.

Figure 29.–Fenceposts thrown out of line by mass movement in Vertisols. Note tilted Eucalyptus tree in right background.

AQUERTS (2.1)

The Aquerts are those Vertisols that have chromas of 1.5 or less throughout the upper 30 cm. (12 inches), or that have distinct or prominent mottling within the surface 75 cm. (30 inches), or both.

The Aquerts are saturated with water at some season, and are gleyed, though they have so few noncapillary pores when wet that it is difficult to make specific statements about the presence of ground water. They do have low chromas and either concretions of iron and manganese, or mottles.

The Aquerts may have a mollic, umbric, or ochric epipedon, but darkness is a poor guide to the content of organic matter. Some have a very thin eluvial A horizon, up to 5 cm. (2 inches) thick, underlain by a thin argillic horizon. These horizons however are mixed if the soil is plowed. Some have a ca or cs horizon, or even a calcic horizon, but these horizons are only diagnostic at subgroup, family, and series levels.

The Aquerts are found on floodplains or level to hilly uplands in subhumid and humid climates. In semiarid and arid climates they are only in areas subject to flooding.

Key to Aquerts[1]

[1]Ruptic intergrades are very common in Aquerts. This key is intended only for application to the part of the pedon that comes within the definition of Aquerts. Other kinds of profiles must be traced independently in the key. In classification, the great group is based on the kind of profile having the greatest area. The kind of ruptic intergrade is determined by the profile with the lesser area.

2.11 Aquerts that, have, when dry and undisturbed since a rain sufficient to saturate the upper 15 cm. (6 inches), a loose, porous, surface mulch of discrete, very hard aggregates, dominantly less than 3 mm. in diameter; that do not have a platy or massive surface crust that has uncoated silt or sand grains and that persists after drying; and that do not have fragments of a platy or massive crust in an Ap.

Grumaquert, p.125

2.110 Grumaquerts that throughout each pedon to a depth of 30 cm. (12 inches), are as dark or darker than 3.5 when moist and 5 when dry, and that have no calcic horizon within 37.5 cm. (15 inches) of the surface.

Orthic Grumaquert, p. 126

2.11-1 Other Grumaquerts that have no calcic horizon within 37.5 cm. (15 inches).

Entic Grumaquert, p.126

2.11-5 Other Grumaquerts with a calcic horizon within 37.5 cm. (15 inches) and with moist color values of 3.5 or less and dry values of 5 or less to a depth of 30 cm. (12 inches).

Mollic Grumaquert, p. 126

2.12 Other Aquerts that have a platy or massive surface crust, the upper surface of which has a light-colored matrix of uncoated silt and sand thick enough to be visible in cross section without magnification, or that have fragments of such a crust mixed in an Ap.

Mazaquert, p. 126

2.120 Mazaquerts that have, throughout each pedon, to depths of 30 cm. (12 inches) or more below the surface crust, moist color values of 3.5 or less and dry values of 5 or less; and that have less than 15 percent extractable sodium within this depth.

Orthic Mazaquert, p. 128

2.12-1 Other Mazaquerts that have less than 15 percent extractable sodium and pH values (1:1 in water) of 5.5 or more in all parts of the upper cm.

Entic Mazaquert, p. 128

2.12-5.35 Other Mazaquerts that have moist color values of 3.5 or less and dry values of 5 or less below the surface crust to a depth of 30 cm. (12 inches) and that have 15 percent or more extractable sodium in some part of the upper 30 cm.

Natraquollic Mazaquert, p. 128

2.12-7.16 Other Mazaquerts that have moist color values of more than 3.5 and or dry values of more than 5 and that have 15 percent or more extractable sodium in some part of the upper 30 cm. (12 inches).

Natraqualfic Mazaquert, p. 128

2.12-8.1 Other Mazaquerts that have most color values of more than 3.5 or dry values of more than 5 below the surface crust but within 30 cm. (12 inches); and that have pH values (1:1 in water) of less than 5.5 in some part of the upper 30 cm. (12 inches).

Aquultic Mazaquert, p. 128

Grumaquerts (2.11)

The Grumaquerts are the self-mulching Aquerts. They have gray to black colors, with chromas of 1.5 or less throughout the upper 30 cm. (12 inches), or with distinct or prominent mottles within 75 cm. (30 inches), or both. On drying the surface cracks into a loose, porous mulch of discrete very hard aggregates, mostly 1 to 3 mm. in diameter. There is no platy or massive surface crust with an upper layer of uncoated sand or silt grains after drying. If cultivated, the Ap shows no fragments of such crusts.

The normal appearance of the dry surface mulch of the Grumaquerts is shown in figures 26 and 30. Fig. 30 shows the sloughing of the mulch into the wide cracks. The granular mulch, from which the term self-mulching is taken, contrasts sharply with the massive or platy crust of the Mazaquerts (fig. 31). Unfortunately, the self-mulching clays grade to the crusty clays, and easily determined limits are impossible to define at present.

The Grumaquerts are found chiefly in temperate or tropical climates ranging from arid to humid. So far as is known, there is always some season with a substantial excess of evapo-transpiration over precipitation. In humid climates there is a season with a surplus of precipitation, but in arid climates there may only be a season when the soil is flooded by runoff from other areas, sometimes very distant. The net effect on the soil is much the same--the soil is saturated at some seasons, and at other seasons its moisture content is reduced enough to produce cracks. Under irrigation, the cracking may be halted and the gilgai leveled. However, it is thought that under irrigation the diagnostic structure will persist in the lower horizons. The evidences of the earlier gilgai often persist, after leveling, as spots with thin or no A1 horizon, or as calcareous spots in a generally noncalcareous soil.

The central concept of the Grumaquerts is reflected in the orthic subgroup. Other subgroups reflect permissible variations.

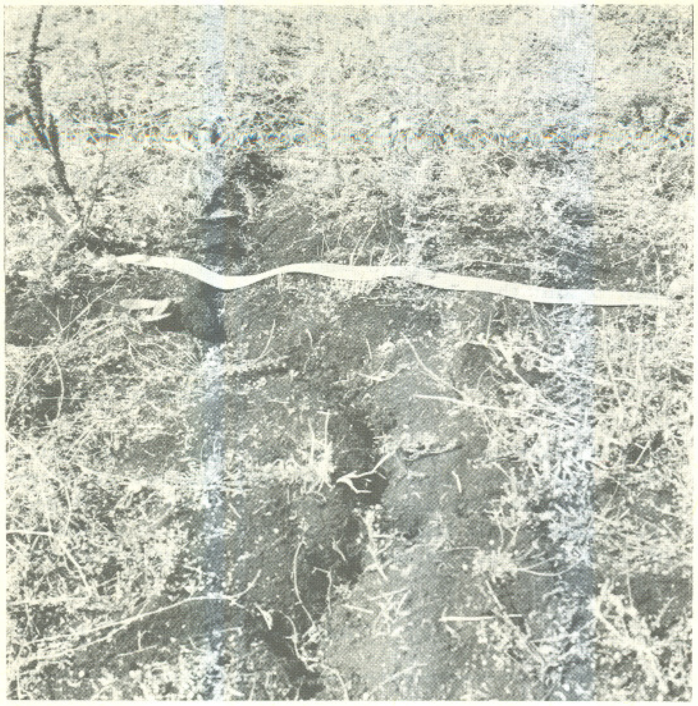


Figure 30.—Sloughing of surface mulch of a Grumaquert into wide cracks.

Figure 31.—Dry, massive surface of a Mazaquert. Compare this with the loose, granular mulch on dry surfaces of Grumaquerts shown in figures 26 and 30.

Orthic Grumaquerts (2.110)

The Orthic Grumaquert has a surface horizon that is as dark or darker than 3.5 when moist and 5 when dry and that is more than 30 cm. (12 inches) thick. The surface horizon may be acid or calcareous, but there must be no calcic horizon within 37.5 cm. (15 inches) of the surface. Extractable sodium is usually less than 15 percent to depths of 30 cm. or more.

Profile 42, page 131, is an example of the Orthic Grumaquert, the central concept of the Grumaquerts. The sodium saturation of this profile, though higher than normal for the subgroup, is not unusual. Carbonates are present throughout the profile, but many orthic profiles are noncalcareous. Repeated analyses of the clay fraction of these soils in the United States show montmorillonite to be the dominant clay.

In the Orthic Grumaquerts, the profiles such as 42 are continuous through each pedon, and though the thickness of the A1 horizon may vary greatly, it remains more than 30 cm. (12 inches).

If the profile comparable to 42 occurs in each pedon but does not occupy the full pedon, the soil is not an Orthic Grumaquert. The soil is considered a Grumaquert if the properties of the Grumaquerts occupy more than half the area of the pedons. If a portion of each pedon has the profile of another subgroup, Entic Grumaquert for example, the subgroup is a ruptic intergrade. If the major portion of the pedon has the profile of the Orthic Grumaquert, this name is retained as the final part of the subgroup name, e.g., Ruptic Entic Orthic Grumaquert. If the minor portion has this profile, the name would be Ruptic Orthic Entic Grumaquert.

Entic Grumaquerts (2.11-1)

In this subgroup are the Aquerts that have less than 30 cm. (12 inches) of a surface horizon as dark or darker than 3.5 when moist and 5 when dry, and that have no calcic horizon within 37.5 cm. (15 inches) of the surface. They have, like the other Grumaquerts, a self-mulching surface.

The Entic Grumaquerts are considered intergrades to Entisols because they lack distinctive horizons. These soils are found in the Gray Soils of Heavy Texture, in Australia, but are not important in the United States.

Mollic Grumaquerts (2.11-5)

In this subgroup are the Grumaquerts that have a calcic horizon within 37.5 cm. (15 inches) of the surface horizon comparable to that of the Orthic Grumaquerts—thicker than 30 cm. (12 inches) and as dark or darker than 3.5 when moist and 5 when dry.

Mazaquerts (2.12)

The Mazaquerts are the Aquerts that have crusty surface horizons, or that lack self-mulching surfaces. They have chromas of 1.5 or less throughout the upper 30 cm. (12 inches) or have distinct or prominent mottles within 75 cm. (30 inches); have a clay texture, with 2.1 expanding lattice clays dominant in the clay fraction; and have a crusty surface.

The self-mulching surface was discussed under Grumaquerts. The crusty surface is massive or platy and less than 5 cm. (2 inches) thick. The upper surface of the crust, and generally the entire crust, shows under the hand lens, clean silt and sand grains with no visible coatings. To be considered crusty, this surface crust must be thick enough to be seen in cross section without the use of a hand lens. The appearance of a surface crust in the field is illustrated by figure 31. The crust in a dry soil is generally cracked, but fine cracks usually are spaced at intervals of 7.5 to 12.5 cm. (3 to 5 inches), and wide cracks at irregular but much greater intervals.

Figure 32 shows a profile of a Mazaquert, in which the massive surface crust may be seen in cross section at its maximum thickness. Figure 33 shows another Mazaquert with a much thinner crust, but with well developed wedges and parallelepipeds bounded by slickensides.

Figure 34 is a photograph of the detail of a crusty surface. The scale is 1 cm. It will be noted that the bleached silt and sand grains make a layer here about 1 cm. thick. Below this, the clay has cracked into blocks and granules, mostly 1 to 3 cm. in diameter.

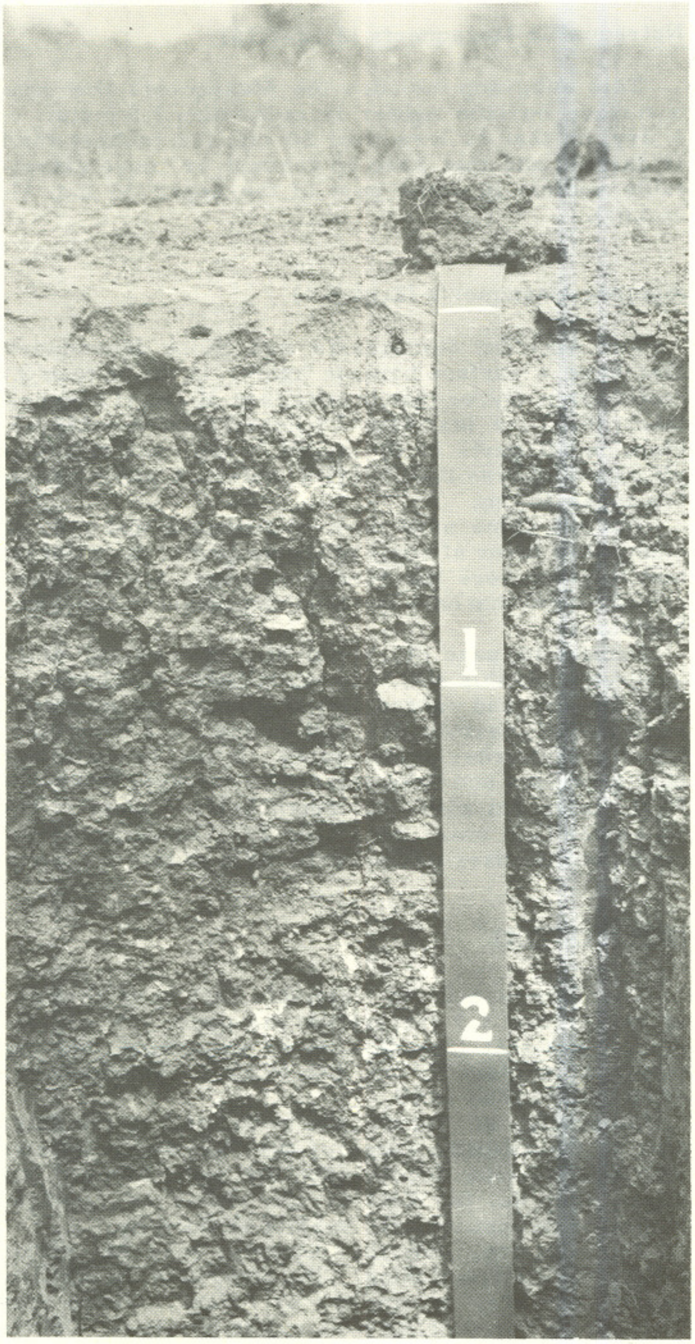


Figure 32.–Profile of a Mazaquert showing massive, light-colored crust at surface and, between 9 and 18 inches, wedges and parallelepipeds tilted from the horizontal.

Figure 33.–Profile of a Mazaquert showing tilted wedges and parallelepipeds.

Figure 34.–Details of a crust (scale is 1 cm.), showing bleached grains of sand and silt in light-colored crust about 1 cm. thick; and below, clay cracked into blocks and granules 1 to 3 cm. in diameter.

If the soil has been plowed and there has been no rain since the last cultivation, the surface may be granular or cloddy, but fragments of the crust may be seen in the plow layer. If a rain sufficient to saturate the soil to a depth of 6 inches has fallen since the last cultivation, the surface crust will be thin but visible. The crusting interferes with seedling emergence of most plants, and tillage of the crusty soils is difficult without power machinery.

The reasons why some Vertisols are crusty and others are self-mulching are as yet unknown. However, the Aquerts in the more humid range of the suborder are generally crusty, and the individuals, on their margins, often border Aquults (8.1). In the drier range of the climate, the individuals of the Mazaquerts most often border Natraqualfs, (7.16). In each case, the crust thickens into an albic horizon.

The crust is actually a very thin eluvial A2 (albic) horizon. It may be underlain by a very thin argillic horizon, or the eluvial clay may be disseminated through a thick clayey layer in which it cannot be recognized. If there is a thin argillic horizon, normal plowing will mix the albic and argillic horizons. Hence, they are disregarded in order not to have the classification changed by brief cultivations.

The central concept of the Mazaquerts is reflected by the orthic subgroup. Other subgroups reflect permissible variations. As with the Grumaquerts, ruptic intergrades are very common, and not all of them are defined here.

Orthic Mazaquerts (2.120)

The Orthic Mazaquerts have, throughout each pedon, a surface horizon 30 cm. (12 inches) or more thick that has a moist color value of 3.5 or less and a dry value of 5 or less. Chromas are 1.5 or less to a depth of 30 cm., or there is distinct or prominent mottling within 76 cm. (30 inches). Extractable sodium is less than 15 percent of the exchange capacity to a depth of 30 cm. (12 inches). These soils have a massive or platy surface crust, with clean sand or silt grains on the upper surface, or fragments of the crust in the plow layer. The crust is visible in cross section without a hand lens, but is less than 5 cm. (2 inches) thick.

Profile 43, page 132, is presented as the best available example of the Orthic Mazaquert. The clay in the profile is dominantly montmorillonite. Extractable sodium exceeds 15 percent at 30 inches, but it is low in the upper 18 inches. It is perhaps more common in the orthic subgroup that extractable magnesium is high, often the dominant cation, and that carbonates are absent in the upper horizons. Profile 43 is borderline as an Orthic Mazaquert, as the colors are on the margin of the class at depths between 6 and 18 inches.

Profiles of Orthic Mazaquerts commonly are found as parts of pedons. Nomenclature for such soils parallels that of the Grumaquerts and is discussed under the Orthic Grumaquert.

Entic Mazaquerts (2.12-1)

This subgroup includes Mazaquerts that have a thinner or lighter colored surface horizon than the orthic subgroup and that have less than 15 percent extractable sodium throughout the upper 30 cm. (12 inches). The surface horizon either has a moist value of more than 3.5 or a dry value of more than 5, or if darker, is less than 30 cm. (12 inches) thick. The pH values (1:1 water) of the Entic Mazaquerts are 5.5 or more in all parts of the upper 30 cm. (12 inches). The pH value is used here tentatively, and it is possible that some other characteristic will be substituted. The pH seems poorly correlated with any other property of these soils.

Natraquollic Mazaquert (2.12-5.35)

This subgroup consists of Mazaquerts that have a surface horizon 30 cm. (12 inches) or more thick with moist color values as dark or darker than 3.5, and dry values as dark or darker than 5; and that have more than 15 percent extractable sodium in some part of the upper 30 cm. (12 inches).

Natraqualfic Mazaquerts (2.12-7.16)

This subgroup includes the Mazaquerts that have a surface horizon lighter in color than 3.5 moist, or 5 dry, or that is less than 30 cm. (12 inches) thick if darker; and that have 15 percent or more extractable sodium in some part of the upper 30 cm. (12 inches).

Aquultic Mazaquerts (2.12-8.1)

The Aquultic Mazaquerts are those Mazaquerts that have a surface horizon lighter in color than 3.5 moist, or 5 dry, or that is less than 30 cm. (12 inches) thick; that have less than 15 percent extractable sodium in all parts of the upper 30 cm.; and that have pH values of less than 5.5 (1:1 water) in some part of the upper 30 cm.

The pH value used here is tentative and may be changed in favor of some other property. It is the intent to group here the Mazaquerts that are in humid climates and that have low base saturation in the upper horizons.

Profile 44, page 133, illustrates the concept of the subgroup. In this soil, montmorillonite dominates in both the fine and coarse clay fractions, but kaolinite, mica (illite), vermiculite, and quartz have been identified in that order of abundance. It will be noted that both pH values and base saturation are very low in the first meter but rise with depth below 1 meter. The pH values (1:1 water or 1:1 in KCl) however do not relate well to base saturation in soils of this subgroup.

USTERTS (2.2)

The Usterts are the Vertisols that have chromas of more than 1.5 throughout the upper 30 cm. (12 inches) and that lack distinct or prominent mottling within the surface 75 cm. (30 inches). The hues are often redder than 10YR.

Generally, the Usterts are restricted to the drier part of the climatic range of the Vertisols. Usterts and Aquerts may occur under the same climate, but where they do, the Usterts are either on stronger slopes or in positions not subject to flooding.

The Usterts, like the Aquerts, may be either crusty or self-mulching. The epipedon is usually ochric, but may be umbric or mollic. There may be ca or cs horizons, or even calcic horizons. Colors are normally brown or reddish brown. Textures are clayey, with a dominance of expanding lattice clay. Parent materials may be shales, limestones, or basic igenous rocks.

The Usterts are mostly on uplands and terraces in positions not subject to overflow. Usterts developed from basic igneous rock often have many boulders and rocks in the surface material. These appear to be brought to the surface by the churning, but once on the surface, they must remain.

Key to Usterts

2.21 Usterts that have, when dry and undisturbed since a rain sufficient to saturate the upper 15 cm. (6 inches), a loose, porous mulch of discrete very hard aggregates, dominantly less than 3 mm. in diameter; that do not have a platy or massive surface crust containing uncoated silt and sand grains that persists after drying.

Grumustert, p. 129

2.210 Grumusterts that have throughout each pedon moist values of 3.5 or less, and dry values of 5 or less to depths of 30 cm. (12 inches), or more; and have less than 15 percent extractable sodium in all parts of the upper 30 cm.

Orthic Grumustert, p. 129

2.21-1 Other Grumusterts with less than 15 percent extractable sodium throughout the upper 30 cm.

Entic Grumustert, p. 129

2.22 Other Usterts that have a platy or massive surface crust, the upper surface of which has a light-colored matrix of uncoated silt and sand thick enough to be visible in cross section without magnification, or that have fragments of such a crust in an Ap.

Mazustert, p. 129

2.220 Mazusterts having a surface horizon 30 cm. (12 inches) or more thick and colors throughout that are as dark or darker than 3.5 when moist and 5 when dry, and having less than 15 percent extractable sodium throughout the upper 30 cm (12 inches).

Orthic Mazustert, p. 130

2.22-7.42 Other Mazusterts with 15 percent or more extractable sodium in some part of the upper 30 cm. (12 inches) and usually moist in some horizon or layer within the soil.

Natrustalfic Mazustert, p. 130

2.22-4.23 Other Mazusterts with 15 percent or more extractable sodium in some part of the upper 30 cm. (12 inches) and usually dry throughout the soil.

Natrargidic Mazustert, p. 130

Grumusterts (2.21)

The Grumusterts are Vertisols that have brown or reddish-brown colors and a self-mulching surface. They have clay content of 35 percent or more (usually more than 40 percent) and a clay fraction dominated by expanding lattice clay. They have chromas of more than 1.5 to depths of 30 cm. (12 inches) or more, and lack distinct or prominent mottles to a depth of 75 cm. (30 inches). They have also a self-mulching surface, one that, when dry, consists of a loose granular mulch of fine aggregates, mostly less than 3 mm. in diameter. Grumusterts show gilgai, slickensides, or wedge or parallelepiped structure in some horizon between 25 and 100 cm. (10 and 40 inches). These are the diagnostic properties of the group. They may have, in addition, a mollic or an umbric epipedon, or the epipedon may be ochric. They may have ca or cs horizons, or even calcic horizons.

The Grumusterts may be developed in montmorillonitic clays or from residuum from weathering of limestone, basalt, or other basic rocks. If the parent material is a basic igneous rock, boulders and stones are often very common on the surface, but are much less common in the soil.

The natural vegetation is generally grass, sometimes with scattered xerophytic shrubs and trees.

The central concept of the group is reflected in the orthic subgroup. Other subgroups reflect permissible variations. It should be noted that ruptic subgroups are not uncommon, but are not defined here. The principles for nomenclature follow those discussed under Orthic Grumaquerts.

Orthic Grumusterts (2.20)

The Orthic Grumusterts are those Grumusterts having surface horizons that are thicker than 30 cm. (12 inches) and that are as dark or darker than 3.5 when moist, and 5 when dry; and that have less than 15 percent extractable sodium in all parts of the upper 30 cm.

Profile 45, page 134, is an example of the Orthic Grumustert. The clay in this soil is dominantly montmorillonite. Soils of this character have been called Brown Soils of Heavy Texture in Australia, and some but not all of the Tirs soils seem to be of this character.

Entic Grumustert (2.21-1)

The Entic Grumusterts resemble the Orthic Grumusterts in all respects but that of the darkness in the surface horizon. The surface horizon of the Entic subgroup may have a moist value of more than 3.5, or a dry value of more than 5; if it is darker than these limits, the surface horizon is less than 30 cm. (12 inches) thick.

Mazusterts (2.22)

The Mazusterts are the Usterts that are crusty. When dry, they have a platy or massive surface crust if sufficient rain has fallen since the last cultivation to saturate the soil to a depth of 15 cm. (6 inches). If the soils are being cultivated, fragments of the crust may be found in the plow layer. Chromas are more than 1.5 throughout the upper 30 cm. (12 inches), and there are no prominent or distinct mottles within the upper 75 cm. (30 inches). The Mazusterts are mostly in semiarid to arid climates, in positions not subject to overflow or to ponding of water. The native vegetation is mostly annual grasses and herbs, with scattered xerophytic shrubs and trees.

The orthic subgroup reflects the central concept of the Mazusterts. Other subgroups reflect permissible variations.

Orthic Mazusterts (2.220)

The Orthic Mazusterts have a surface horizon 30 cm. (12 inches) or more thick that has, throughout, a moist color value of 3.5 or less and a dry value of 5 or less. They also have less than 15 percent extractable sodium throughout the upper 30 cm. They have, in addition, the clayey texture, the crusty surface, and the chromas or lack of mottles definitive of the Mazusterts.

Profile 46, page 135, is an example of the orthic subgroup. It should be noted that the platy surface horizon has less clay than the underlying horizons and probably is an eluvial horizon. This horizon may be as thick as 5 cm. (2 inches), or may have been obliterated by plowing. The stoniness of the surface horizons is typical of many of the soils developed from basic igneous rocks, but is not an essential property.

In the orthic subgroup, the diagnostic properties are continuous through each pedon. Ruptic intergrades may exist, but they are not here defined or named. The principles given in the discussion of the Orthic Grumaquert apply to the Orthic Mazustert.

Natrustalfic Mazusterts (2.22-7.42)

This subgroup includes the Mazusterts that are usually moist, and that have 15 percent or more extractable sodium within some part of the upper 30 cm. (12 inches). The soils of this subgroup most often are in a Mediterranean climate. At this writing, they are not known to exist in the United States.

Natrargidic Mazusterts (222-4.23)

This subgroup includes the Mazusterts that are usually dry and that have 15 percent or more replaceable sodium within some part of the upper 30 cm. (12 inches). None have been identified in the United States at this writing.

Profile Descriptions for Chapter 9
(Colors for moist soil unless otherwise stated)

Profile No. 42

Area: Nueces County, Texas.
Vegetation: Plowed field following grain sorghum; (natural) tall and short grasses.
Parent material: Clay of Pleistocene age.
Topography: Flat; terrace on Gulf Coastal Plain.

Ap 0 to 5 inches, black (10YR 2/1) clay, very dark gray (10YR 3/1) when dry; moderate, fine, granular structure; very hard, friable, very sticky, plastic when wet; calcareous.

A12 5 to 12 inches, black (10YR 2/1) clay, very dark gray (10YR 3/1) when dry; weak, angular, irregularly shaped peds with two long axes in upper 2 inches and moderate to strong, fine and very fine, blocky structure in lower part; hard, extremely firm; few to common, fine and very fine pores; calcareous.

A13 12 to 19 inches, black (10YR 2/1) clay, very dark gray (10YR 3/1) when dry; weak, coarse, angular, irregularly shaped peds commonly with two long axes not parallel to the surface, breaking to strong, fine and very fine, blocky structure; extremely hard, firm; blocky peds have glossy surfaces when moist; slickensides in lower part; few to common fine and very fine pores; calcareous.

A14 19 to 29 inches, very dark gray (10YR 3/1) clay; moderate, coarse, and medium to fine, moderate structure consisting of angular, irregularly shaped peds, commonly with two long axes not parallel to the surface, breaking to coarse, medium to fine blocky structure; extremely hard, firm; distinct or pronounced slickensides; few, fine pores; calcareous.

A15 29 to 38 inches, very dark gray (10YR 3/1) clay; common, fine and medium, distinct mottles of gray (10YR 5/1) when dry; moderate, coarse, blocky structure; a few, fine, irregularly shaped peds with two long axes not parallel to the surface and a few, fine, blocky peds; extremely hard, firm; pronounced slickensides; few, fine pores; calcareous; gradual boundary.

AC 38 to 45 inches, finely mottled, very dark gray (10YR 3/1) and dark grayish-brown (10YR 4/2) clay, dark gray (10YR 4/1) and grayish brown (10YR 5/2) when dry; weak, blocky structure; extremely hard, firm; pronounced slickensides; few, fine pores; a few, soft segregations of calcium carbonate up to 6 millimeters in diameter; calcareous.

C1 45 to 53 inches, pale-brown (10YR 6/3) clay, very pale brown (10YR 7/3) when dry; splotches and streaks of gray; weak, blocky structure; firm; few, soft segregations of calcium carbonate; calcareous; diffuse boundary.

C2 53 to 65 inches, pale-brown (10YR 6/3) clay, very pale brown (10YR 7/3) when dry; splotches and streaks of gray; weak, blocky structure; firm; a few very dark gray worm casts; segregations of gypsum crystals make up 1 to 2 percent of soil volume; a few, soft segregations of calcium carbonate; calcareous.

Climatic data (Corpus Christi, Texas)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	56	59	64	71	77	81	83	83	80	74	64	58	71
Mean precipitation, 1921-50 (inches)	1.4	1.4	1.6	1.7	3.4	2.9	2.3	2.1	4.7	2.5	1.7	2.3	28.0

Annual precipitation more than 14.2 and less than 41.8 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-5	Ap	0.3	0.4	0.3	4.9	10.1	32.2	51.8	30.8	15.8	---		1.18	14	5
5-12	A12	.1	.2	.2	4.5	14.5	25.0	55.5	28.8	14.7	---		1.03	17	6
12-19	A13	.1	.2	.2	4.5	14.4	24.6	56.0	28.1	15.0	---		.98	16	6
19-29	A14	.2	.2	.2	4.0	13.0	24.6	57.8	25.8	15.4	---		.87	16	7
29-38	A15	.1	.2	.2	3.7	12.5	25.1	58.2	24.5	16.4	---		.64	---	8
38-45	AC	.2	.1	.2	3.4	12.2	25.6	58.3	24.9	15.9	---		.43	---	8
45-53	C1	---	.1	.1	3.1	12.1	25.9	58.7	24.6	16.1	---		.20	---	9
53-65	C2	.1	.1	.1	3.1	12.3	25.8	58.5	24.8	16.0	---		.12	---	9

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Est. salt %	pH 1:1	pH 1:10	Exch. Na %	E.C. mmhos. per cm. 25° C.	Saturation ext. soluble (meq./l.): Na	HCO_3	Cl	SO_4	H_2O at sat. %
37.1	43.6	4.9	---	1.2	1.8	<0.20	7.9	8.3	3	1.1	4.8	---	---	---	69.6
38.4	42.5	5.8	---	2.7	1.2	< .20	7.9	8.5	7	1.1	7.6	---	---	---	79.9
37.8	40.1	6.4	---	4.4	1.2	< .20	7.9	8.8	12	2.1	15.3	---	---	---	90.1
36.8	37.2	6.5	---	6.7	1.4	.34	7.9	8.7	18	4.0	29.6	4.0	25.3	5.2	99.3
36.4	35.0	6.8	---	7.9	1.6	.46	7.8	8.9	22	5.1	42.5	---	---	---	106.0
35.4	33.3	6.3	---	8.1	1.7	.55	7.9	8.8	23	7.0	52.9	3.3	49.6	18.0	105.3
34.2	33.5	6.0	---	8.0	1.8	.66	7.9	8.8	23	8.6	58.8	---	---	---	103.3
33.0	46.6	5.5	---	6.0	1.6	.98	7.6	8.3	18	12.0	85.5	2.1	65.3	65.2	96.2

*Exchange acidity.

Profile No. 43

Area: Denton County, Texas.
Vegetation: Plowed field; (natural) tall grass.
Parent material: Calcareous clay.
Topography: Less than ½ percent slope; outer edge of a wide, high terrace lying 50 feet below the upland.

Ap 0 to 6 inches, black (5Y 2/1) clay, very dark gray (5Y 3/1) when dry; thin, gray, surface crust when dry; moderate, fine, granular structure and a few, fine, blocky **peds**; extremely hard, very plastic; calcareous.

A12 6 to 18 inches, dark olive-gray (5Y 3/2) clay, very dark gray (5Y 3/1) when dry; moderate, medium structure with angular, irregularly shaped peds commonly with 2 long axes **not** parallel to the surface; few, fine, blocky peds; extremely hard, very firm; few, very fine pores; flat and rounded pebbles of chert, 3 to 15 mm. in diameter, make up 1 to 2 percent of soil volume; calcareous.

A13 18 to 29 inches, dark olive-gray (5Y 3/2) clay, very dark gray (5Y 3/1) when dry; moderate, medium structure with angular, irregularly shaped peds commonly with 2 long axes not parallel to the surface; a few, fine, blocky peds; extremely hard hard, very firm; distinct slickensides at 45 degree angle to ground surface; very few, very fine pores; flat and rounded pebbles of chert, 3 to 15 mm. in diameter, make up 1 to 2 percent of soil volume; few, small, soft segregations of calcium carbonate in lower part; calcareous.

A14 29 to 39 inches, dark olive-gray (5Y 3/2) clay; moderate, medium structure consisting of angular, irregularly shaped peds with 2 long axes commonly not parallel to the surface; extremely hard, very firm; slickensides at 45 degrees angle to ground surface; very few, fine pores; soft segregations of calcium carbonate make up 2 to 3 percent of soil volume; chert up to 10 mm. in diameter makes up 1 to 2 percent of volume; calcareous.

A15 39 to 46 inches, dark olive-gray (5Y 3/2) clay, olive gray (5Y 4/3) when dry; common, fine, distinct and weak, olive mottles; massive; very firm; slickensides evident; soft segregations of calcium carbonate make up 3 to 5 percent of the soil volume; few crystals of gypsum; calcareous.

C 46 to 59 inches, mottled very dark gray (5Y 3/1) and olive (5Y 4/3) clay, dark gray (5Y 4/1) and olive (5Y 5/3) when dry; massive; very firm; numerous soft segregations of salt crystals; calcareous.

Climatic data (McKinney, Texas)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	45	49	56	65	72	81	84	85	78	68	55	47	65
Mean precipitation, 1931-52 (inches)	3.1	2.9	2.5	3.4	5.0	3.0	1.8	2.4	2.6	3.1	2.5	2.6	34.7

Annual precipitation more than 22.0 and less than 47.4 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	E. C. mmhos. per cm. 25° C.
0-6	Ap	0.8	0.5	0.4	2.0	3.7	34.8	57.8	20.2	19.7	1.2		1.34	15	0.7
6-18	A12	.8	.6	.4	2.0	3.7	34.6	57.9	20.3	19.4	3.4		.98	16	.8
18-29	A13	.9	.6	.4	1.9	3.6	33.8	58.8	19.6	19.1	3.4		.90	15	1.2
29-39	A14	1.5	.6	.5	1.7	3.3	34.2	58.2	19.5	19.3	Tr.		.83	--	2.6
39-46	A15	1.8	.6	.4	1.3	2.6	33.1	60.2	17.6	19.1	3.6		.60	--	6.5
46-59	C	2.2	.5	.3	1.1	2.7	33.5	59.7	17.9	19.2	4.1		.40	--	6.6

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH 1:1	pH 1:10	Exch. Na %	$CaCO_3$ equiv. % v	Saturation extract soluble (meq./l.): Na	HCO_3	Cl	SO_4	H_2O sat. %
49.2	59.4	3.2		1.1	1.3	7.8	8.0	2	2	2.5	--	--	--	83.0
47.0	57.2	3.9		2.8	.9	7.9	8.5	6	3	4.9	--	--	--	78.6
46.3	50.9	4.0		6.7	.9	8.2	8.7	14	3	8.6	--	--	--	86.4
45.4	45.0	4.5		9.5	.8	8.1	8.7	21	3	18.8	--	--	--	98.7
43.6	57.4	4.8		7.3	.9	7.5	8.0	17	5	44.2	2.6	5.6	72.6	95.8
39.9	--	--		6.9	.8	7.5	7.9	17	4	45.8	--	--	--	87.8

Profile No. 44

Area: Monroe County, Mississippi
Vegetation: Cleared of post oak and mixed hardwoods within last 5 years but not cultivated.
Parent material: Acid clay over marl.
Topography: Nearly level; gilgai microrelief.

A11 0 to 1 inch, very dark gray (10YR 3/1) silty clay; weak, fine, granular structure; friable, slightly plastic; abundant, fine roots; abrupt, smooth boundary.

A12 1 to 5 inches, grayish-brown (2.5Y 5/2) silty clay; common, fine mottles of yellowish brown (10YR 5/8) and brownish yellow (10YR 6/6); weak, fine, subangular blocky structure; friable, slightly plastic, abundant, fine roots; many old root and worm channels filled with material from layer above; abrupt, smooth boundary.

A13 5 to 9 inches, mottled light yellowish-brown (2.5Y 6/4), olive-yellow (2.5Y 6/6), gray (5Y 6/1), and brownish-yellow (10YR 6/8) silty clay; moderate, very fine and fine, subangular and angular blocky structure; friable, very plastic, very sticky; abundant, fine and coarse roots; clear, wavy boundary.

C1g 9 to 21 inches, gray (5Y 6/1) clay; many, fine, prominent mottles of brownish yellow (10YR 6/8); moderate, very fine and fine, subangular and angular blocky structure; friable, very plastic, very sticky; plentiful, fine roots; gradual, wavy boundary.

C2g 21 to 41 inches, light-gray (5Y 7/1 - 7/2) clay; many, fine mottles of brownish-yellow (10YR 6/8); moderate, very fine to medium, subangular and angular blocky structure; friable, very plastic, very sticky; numerous slickensides up to 2 inches wide; plentiful, fine roots; gradual, wavy boundary.

C3g 41 to 58 inches, mottled light-yellowish-brown (2.5Y 6/4) and gray (5Y 6/1) clay; moderate, coarse, blocky structure; friable, very sticky, very plastic; numerous, large slickensides; fine roots along ped faces; few, coarse roots; root channels filled with bluish-gray (10BG 5/1) clay; gradual, irregular boundary.

C4 58 to 72 inches, brownish-yellow (10YR 6/8) clay; many, fine and medium, prominent, gray (5Y 6/1) mottles; moderate, very fine to medium, subangular and angular blocky structure; friable, very sticky, very plastic; numerous slickensides, 2 to 3 inches wide, gray on faces of slickensides; few, fine roots; few, manganese coatings on ped faces.

C5g 72 to 82 inches, mottled gray (5Y 6/1) and yellowish-brown (10YR 5/8) clay; very fine to medium, subangular and angular blocky structure; friable, very sticky, very plastic; numerous slickensides; few lime concretions; few, fine roots on ped faces.

Climatic data (Aberdeen, Miss.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	47	48	56	64	72	80	82	82	76	65	53	47	64
Mean precipitation, 1931-52 (inches)	5.6	5.6	6.5	4.2	3.5	4.0	5.3	3.2	3.0	2.5	4.0	5.1	52.5

Annual precipitation more than 33.4 and less than 71.6 inches during 9 years out of 10

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron Fe_2O_3 %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-1	A11	0.2	0.7	0.6	0.8	5.1	51.6	41.0	29.8	27.0	--		3.74	17	1.4
1-5	A12	.2	.6	.6	.7	5.2	46.5	46.2	26.8	25.0	--		1.18	16	1.4
5-9	A13	.1	.4	.4	.6	4.0	43.2	51.3	24.0	23.4	--		.51	13	1.4
9-21	C1g	.2	.2	.3	.4	2.8	36.6	59.5	18.6	20.8	--		.18	12	1.2
21-41	C2g	.1	.2	.2	.4	2.8	36.2	60.1	18.4	20.7	--		.13	18	1.0
41-58	C3g	<.1	.1	.2	.8	2.4	37.5	59.0	18.1	22.3	--		.10	--	1.2
58-72	C4	.1	.1	.2	.8	2.3	39.7	56.8	19.8	22.7	--		.10	--	2.0
72-82	C5g	<.1	.1	.2	1.0	2.7	40.0	56.0	20.4	22.9	--		.06	--	2.2

Cation exch. cap. b	Ca	Mg	H*	Na	K	pH 1:1	Base sat. % s	Cation exch. cap. s	Moisture tensions 1/3 atmos. %	Moisture tensions 15 atmos. %
	Extractable cations, meq./100 gm.									
28.9	14.7	4.3	19.3	0.1	0.5	4.8	50	38.9	35.6	16.9
28.6	6.1	2.2	28.9	.1	.3	4.4	23	37.6	33.7	17.5
31.5	4.3	2.1	34.3	.1	.3	4.3	16	41.1	35.3	18.9
35.8	7.5	1.9	35.6	.3	.3	4.3	22	45.6	40.1	21.7
37.9	13.8	2.5	28.4	.6	.3	4.4	38	45.6	39.5	22.0
38.0	21.8	3.2	20.2	1.1	.3	4.4	57	46.6	41.4	21.9
32.8	30.0	4.4	10.6	1.9	.3	4.6	78	47.2	36.3	20.1
32.7	34.1	4.6	6.2	2.0	.4	6.6	87	47.3	37.9	20.1

*Exchange acidity.

Profile No. 45

Area: Yavapai County, Arizona

Vegetation: Grass-juniper cover with many barren spots. Tobosa, ring muhly, and dropseed grasses, Utah cedar, Opuntia sp., and little smokeweed. Junipers seem to be 100-150 years old.

Parent material: Weathered basalt, probably mixed with some cinders and ash.

Topography: About 2 percent slopes toward the east, slightly convex; plateau; elevation about 4,700 feet.

A11 0 to 1 inch, dark-brown (7.5YR 3.5/2) very stony silty clay, dark brown (7.5YR 3.5/2) when dry; strong, very fine, granular structure; upper 1/4 inch is a soft crust of granules; hard, friable, very sticky, very plastic; few roots; stones are fragments of basalt, mostly sharp cornered; abrupt, smooth boundary.

A12 1 to 4 inches, dark-brown (7.5YR 3/2) stony silty clay, dark brown (7.5YR 3.5/2) when dry; strong, medium and fine, subangular blocky, breaking to moderate, very fine, granular structure; extremely hard, very firm, very sticky, very plastic; abundant roots; calcareous; clear, wavy boundary.

A13 4 to 9 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 3.4/2) when dry; numerous slickensides forming coarse (about 1 inch by 4 inches), angular, irregularly shaped peds with 2 long axes not parallel to the surface; peds break to moderate, medium and fine, subangular blocky structure; extremely hard, very firm, very plastic, very sticky; abundant roots; scattered stones and cobbles of basalt; calcareous; gradual, wavy boundary.

A14 9 to 15 inches, like A13 horizon but silty clay; common, light-gray, weathered basalt pebbles 2 to 8 millimeters in diameter.

A15 15 to 25 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 3/2) when dry; very many slickensides that form angular, irregularly shaped peds with 2 long axes not parallel to the surface; peds break to moderate, medium and fine, blocky structure; extremely hard, very firm, very sticky, very plastic; plentiful roots; few, fine, white specks that are carbonate concretions, very fine, tiny, black shot less than 1/2 millimeter in diameter; common, light-gray and nearly white, weathered grains of basalt ranging from 2 to 8 millimeters in diameter; gradual, wavy boundary.

A16 25 to 35 inches, same color and texture as A15 horizon but has weak, coarse and medium, subangular blocky structure; extremely hard, very firm, very sticky, very plastic; few, thin, patchy skins of clay on vertical surfaces; many slickensides; few, fine roots; scattered, hard, weathered stones and cobbles of basalt; few, fine, white or pink, carbonate concretions; calcareous; gradual, wavy boundary.

Aca 35 to 39 inches, same color and texture as A15 horizon but is massive; extremely hard, very firm, very sticky, very plastic; common slickensides and many shiny surfaces that may be clayskins but probably are only slickensides; few, fine roots; some soft, chalky, carbonate segregations as large as 5/8 inch; common, fine, pink mottles less than 2 millimeters in diameter that are mainly carbonate concretions; calcareous; abrupt, irregular boundary.

R 39 inches +, hard, weathered boulders and stones of basalt.

Climatic data (Ashfork, Ariz.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	36	39	44	52	59	68	75	73	67	57	45	38	54
Mean precipitation, 1931-52 (inches)	1.0	1.3	1.0	1.0	0.3	0.4	1.6	2.5	1.6	0.8	0.6	1.4	13.5

Annual precipitation more than 6.8 and less than 20.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	Organic matter C/N m	Free iron oxides Fe_2O_3 %
0-1	A11	0.5	0.6	0.3	1.6	4.2	49.8	43.0	28.6	26.4	38		0.89	15	1.5
1-4	A12	.3	.4	.3	1.3	3.5	50.0	44.2	26.2	28.3	9	1.78	.63	12	1.7
4-9	A13	.4	.4	.4	1.4	3.2	46.8	47.4	25.2	25.8	0	1.80	.61	13	1.4
9-15	A14	.4	.3	.3	1.2	3.2	48.0	46.6	24.9	27.1	1	1.86	.58	13	1.5
15-25	A15	.2	.2	.2	1.2	3.3	47.5	47.4	24.5	27.1	0	1.86	.52	14	1.6
25-35	A16	.2	.2	.2	1.0	3.1	47.2	48.1	24.0	27.0	0	1.91	.50	10	1.6
35-39	Aca	.4	.8	.6	1.6	2.0	42.4	52.2	17.0	28.3	<1	1.86	.57	18	1.5
39+	R							47.6							

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. s	pH 1:1	Field H_2O %	$CaCO_3$ equiv. % n
50.8	39.8	8.2	1.1	0.10	1.59	98	7.5		
						100	7.6	4.0	2
						100	7.7	6.0	2
						100	7.7	3.8	3
						100	7.7	5.6	3
						100	7.7	5.8	2
						100	7.8	5.0	10

*Exchange acidity.

Profile No. 46

Area: Yavapai County, Arizona.

Vegetation: About 30 percent cover of tobosa grass, Opuntia sp., yucca, mesquite, cholla, whitethorn; scrubby juniper rare; many barren spots.

Parent material: Weathered olivine basalt, cinders, and ash.

Topography: About 2-1/2 percent slope toward north; plateau.

A11 0 to 1 inch, very dark grayish-brown (10YR 3/2) stony silty clay loam, brown (7.5YR 5/2) when dry; moderate, medium, platy breaking to strong, fine and very fine, granular structure; hard, friable, very sticky, very plastic; very few roots; surface 1/4-inch is a soft crust; abrupt, smooth boundary.

A12 1 to 4 inches, very dark grayish-brown (10YR 3/2) stony silty clay loam, dark brown (7.5YR 4/2) when dry; strong, medium and fine, subangular blocky structure; extremely hard, firm, very sticky, very plastic; abundant roots; clear, wavy boundary.

A13 4 to 10 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 4/2) when dry; moderate, very coarse, prismatic, breaking to moderate, coarse and medium, subangular blocky structure; extremely hard, very firm, very sticky, very plastic; abundant roots; gradual, wavy boundary.

C1 10 to 17 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 4/2) when dry; moderate, very coarse, prismatic, breaking to weak, coarse and medium, subangular blocky structure; extremely hard, extremely firm, very sticky, very plastic; common slickensides; plentiful roots; calcareous; gradual, wavy boundary.

C2 17 to 29 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 4/2) when dry; weak, coarse, blocky structure; extremely hard, extremely firm, very sticky, very plastic; common to many slickensides; plentiful, fine roots; few, fine, black concretions; white carbonate concretions ranging from 1 to 3 millimeters in diameter; gradual, wavy boundary.

C3 29 to 34 inches, dark-brown (7.5YR 3/2) silty clay, dark brown (7.5YR 4/2) when dry; weak, coarse and medium, blocky structure; extremely hard, very firm, very sticky, very plastic; common slickensides; few black concretions less than 1 millimeter in diameter; common, hard, weathered pebbles and stones of basalt; occasional pebbles of quartz and quartzite; calcareous; abrupt, irregular boundary.

R 34 inches +, hard, weathered stones and boulders of olivine basalt.

Climatic data (Cordes, Ariz.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1932-52 (deg. F.)	43	45	50	58	65	73	80	79	74	63	52	46	61
Mean precipitation, 1931-52 (inches)	1.2	1.7	1.0	0.7	0.2	0.2	1.3	2.1	1.3	0.7	0.8	1.7	12.9

Annual precipitation more than 6.7 and less than 19.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-1	A11	0.7	1.4	1.2	2.6	8.5	54.3	31.3	45.0	19.3	4		1.24	12	1.8
1-4	A12	1.2	1.3	1.1	2.4	8.1	50.7	35.2	40.5	19.7	9		1.22	13	1.8
4-10	A13	.7	1.2	.9	2.1	6.8	45.5	42.8	33.1	20.3	1	1.82	.90	13	1.9
10-17	C1	.6	1.0	.8	1.9	5.8	47.1	42.8	32.6	21.3	<1	1.95	.56	12	1.8
17-29	C2	.7	1.3	.9	1.8	5.4	46.9	43.0	31.8	21.5	0	1.98	.52	11	1.9
29-34	C3	.6	1.1	.8	1.7	5.2	47.2	43.4	31.6	21.8	12	1.92	.62	13	1.8

Cation exch. cap. 5	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. 5	pH 1:1	Field H_2O %	$CaCO_3$ equiv. % n
31.5	16.4	8.0	5.6	0.09	1.40	82	6.0		
36.2	18.0	8.5	8.6	.16	.98	76	5.2		
42.0	26.4	9.9	4.6	.28	.85	89	6.3	3.5	
	32.1	8.2	---	.74	.67	100	7.5	3.1	2
							7.7	3.2	2
							7.7	3.0	2

*Exchange acidity.

Chapter 10. Inceptisols

The Inceptisols are soils with one or more of the diagnostic horizons that are thought to form rather quickly and that do not represent significant illuviation or eluviation or extreme weathering. They are most often found on young but not recent land surfaces; hence, the name Inceptisol, derived from the Latin inceptum, for beginning.

The order includes many of the soils that have been called Brown Forest soils, Subarctic Brown Forest soils, Tundra, Ando soils, Sols Bruns Acides, Lithosols and Regosols, and a number of the strongly gleyed associated soils that have been called Humic Gley and Low-Humic Gley soils.

The order includes soils that are usually moist and that have no spodic, argillic, natric, calcic, gypsic, salic, or oxic horizon, or plaggen epipedon, but that have conductivity of the saturation extract of less than 1 millimho per cm. at 25° C. and that have one or more of the following: a histic, umbric, or ochric epipedon, a cambic horizon, a fragipan, or a duripan. If the clay fraction is dominated by allophane, and the silt and sand by ash and pumice, a mollic epipedon may be present. The histic epipedon is diagnostic for this order only if the N value is less than 0.5 in some horizon between 20 and 50 cm. (8 and 20 inches). An ochric epipedon is permitted if there are other diagnostic horizons, but is not itself diagnostic. The soils of the order may therefore have either a dark- or light-colored surface horizon. So far as is known, all Inceptisols have either an umbric or mollic epipedon, or a cambic horizon. There must therefore be an appreciable accumulation of organic matter or there must be some evidence that the parent material has been altered by weathering. The weathering cannot be so intensive that all weatherable minerals are lost from the sand or silt fraction, or that all allophane and 2:1 lattice clays are absent. This follows from the definitions of the cambic and oxic horizons.

Since argillic and spodic horizons are absent, there cannot be evidences of significant illuviation. Textural differences may be present between horizons, if parent materials are stratified, or if clay has been differentially formed in place. But soils are excluded if they have evidences of illuviation in the finer textured horizons sufficient to make an argillic horizon. Typically, textures are uniform or nearly so. To depths of at least 50 cm. (20 inches), textures must be as fine or finer than loamy very fine sand if the only diagnostic horizons are an ochric epipedon and a cambic horizon. Sand and loamy sand textures may be found throughout the upper 50 cm. if the epipedon is umbric or mollic.

The Inceptisols are normally found in humid climates but range from the Arctic to the Tropics. They are also common in alpine areas. A few may occur in arid climates in positions where there is some natural irrigation.

The native vegetation is most often a forest, but it may be a boreal or even a tropical rain forest. Some soils in the tundra may be included. A few of the Inceptisols have developed under grass. Some have had a grass cover under an open forest canopy or have had mixtures of coarse grasses and sedges.

Four suborders of Inceptisols are recognized and are discussed in the following pages.

AQUEPTS (3.1)

The Aquepts are the Inceptisols that are saturated with water at some season or that have artificial drainage, and that have, at depths of less than 50 cm. (20 inches), one or more of the following: A histic epipedon; sodium saturation of more than 15 percent in the surface horizon and decreasing saturation with depth below 50 cm.; colors on ped faces, if peds are present, or dominant in matrix if peds are absent, as follows: Chromas of 3 or less in hues between 10YR and 10Y if there are distinct or prominent mottles, and of 1 or less if such mottles are lacking; chromas of 2 or less in hues as red or redder than 10YR if there are mottles and chromas of less than 1 if there are no mottles; hues bluer than 10Y; colors determined by uncoated sand grains.

The Aquepts may therefore have umbric or ochric epipedons. They may also have fragipans or duripans, and they will normally have a cambic horizon. These are among the criteria used to define the great groups of Aquepts. It is possible that some Aquepts will have mollic epipedons when the parent material is volcanic.

Key to Aquepts

3.14 Aquepts lacking a fragipan and having mean annual temperature less than 8.3 C. (47° F.), and having mean summer temperature less than 15.5° C. (60° F.) if there is an Ap, or less than 10° C. (50° F.) if there is an O horizon. (These temperature limits are tentative.)

Cryaquept, p. 138

3.140 Cryaquepts with an umbric epipedon and having chromas of 2 or less in hues as red or redder than 10YR, or of 3 or less in hues between 10YR and 10Y, or hues bluer than 10Y throughout all horizons between 15 and 50 cm. (6 and 20 inches); having permafrost at 75 cm. (30 inches) or less; and lacking more than one layer of buried peat more than 5 cm. (2 inches) thick.

Orthic Cryaquept, p. 138

3.14-10 Other Cryaquepts with a histic epipedon, and with permafrost at depths of 75 cm. (30 inches) or less.

Histic Cryaquept, p. 138

3.14-3.31 Other Cryaquepts with an umbric epipedon and having, in some horizon between 15 and 50 cm. (6 and 20 inches), chromas stronger than those of the orthic subgroup; and with permafrost at 75 cm. (30 inches) or less.

Cryumbreptic Cryaquept, p. 139

3.14-3.12 Other Cryaquepts with an umbric epipedon and with chromas and hues of orthic subgroup but with no permafrost within 75 cm. (30 inches).

Umbreptic Cryaquept, p. 139

3.11 Other Aquepts with 15 percent or more extractable sodium in the surface horizon, and with sodium saturation decreasing with depth below 50 cm. (20 inches).

Halaquept, p. 137

3.12 Other Aquepts with an umbric, mollic, or histic epipedon and with no fragipan.

Umbraquept, p. 137

3.120 Umbraquepts with an umbric epipedon; with chromas of 2 or less in hues of 5Y or redder, or hues bluer than 5Y, throughout 60 percent or more of the mass of all horizons between 15 and 75 cm. (6 and 30 inches); with an N factor less than 0.9 between 50 and 80 cm. (20 and 32 inches); with mottles within 30 cm. below the base of the umbric epipedon if the chromas to this depth are 1 or more in the hues redder than 5Y; and with less than 60 percent allophane in the clay fraction or less than 60 percent volcanic ash in the silt and sand fraction.

Orthic Umbraquept, p. 137

3.12-10 Other Umbraquepts with a histic epipedon.

Histic Umbraquept

3.12-3.2-5 Other Umbraquepts with a mollic epipedon; with 60 percent or more allophane in the clay fraction or 60 percent or more volcanic ash in the silt and sand fraction.

Mollic Andic Umbraquept, p. 137

3.12-3 Other Umbraquepts with an umbric epipedon and with chromas higher than those of the orthic subgroup and having some mottles in the first 30 cm. (12 inches) below the umbric epipedon if chromas are 1 or more in hues redder than 5Y.

Umbreptic Umbraquept, p. 138

3.13 Other Aquepts with a fragipan.

Fragaquept, p. 138

3.130 Fragaquepts with temperatures higher than those of Cryaquepts; with an ochric epipedon; and, throughout 60 percent or more of the mass of all horizons between 15 cm. (6 inches) and the fragipan, chromas of 2 or less in hues of 5Y or redder.

Orthic Fragaquept, p. 138

3.13-10 Other Fragaquepts with a histic epipedon.

Histic Fragaquept, p. 138

3.13-3.12 Other Fragaquepts with an umbric epipedon and with chromas of the orthic subgroup.

Umbric Fragaquept, p. 138

3.13-3.4 Other Fragaquepts with an ochric epipedon and with chromas higher than those of the orthic subgroup.

Ochreptic Fragaquept, p. 138

3.13-3.14 Other Fragaquepts with temperatures of the Cryaquepts.

Cryic Fragaquept, p. 138

3.15 Other Aquepts with an ochric epipedon.

Ochraquept, p. 139

Halaquepts (3.11)

This group is provided temporarily but may not be needed. Soils that were thought to fit this class may prove to be Mollisols rather than Inceptisols.

Umbraquepts (3.12)

The Umbraquepts are chiefly the soils that have a thick, dark, acid A1 horizon on a gray, mottled cambic horizon. Soil temperatures are cool to warm. The soils of this character have been called Humic Gley soils.

The Umbraquepts have mean annual temperatures of more than 8.3° C. (47° F.), or mean summer temperatures of more than 15.5° C. (60° F.) if with an Ap, and more than 10° C. (50° F.) if with an O horizon. They have an umbric, mollic, or histic epipedon, but no fragipan. At a depth of less than 50 cm. (20 inches) chromas of ped faces, or dominant chromas in the matrix, if peds are absent, are as follows:

(1) In hues of 10YR or redder, chromas of 2 or less if mottled, and less than 1 if not mottled; or

(2) In hues between 10YR and 10Y, chromas of 3 or less if with distinct or prominent mottles, and 1 or less if lacking mottles; or

(3) Any chroma in hues bluer than 10Y.

Unbraquepts may have any texture, but they may not have the gilgai, slickensides, or structure diagnostic for Vertisols if they have more than 35 percent expanding lattice clay. Bedrock (R) may be shallow or deep. Base saturation of the umbric epipedon is normally less than 50 percent. The central concept of the Umbraquepts is reflected by the orthic subgroup. Other subgroups include the permissible variations, but only a few subgroup definitions can be proposed at this time.

Orthic Umbraquepts (3.120)

The Orthic Umbraquepts are those that have an umbric epipedon. They have the colors diagnostic of the Umbraquepts throughout all horizons to 75 cm. (30 inches) and, in addition, have low chromas in 60 percent or more of the soil mass to this depth. They have no histic epipedon, and have N values of less than 0.9 between depths of 50 and 80 cm. (20 and 32 inches). If the horizon immediately below the umbric epipedon has chromas of 1 or more in hues of 5Y or redder, it has some mottles within the first 30 cm. (12 inches) below the epipedon. Orthic Umbraquepts have less than 60 percent allophane in the clay fraction and less than that percentage of volcanic ash and pumice in the silt and sand fraction (see Andept).

Mollic Andic Umbraquepts (3.12-3.2-5)

The subgroup is provided tentatively for Umbraquepts that have dominance of volcanic ash and pumice, or of allophane (see Andept), and a mollic epipedon.

Umbreptic Umbraquepts (3.12-3.3)

This subgroup includes the Umbraquepts that have chromas stronger than those diagnostic for the Aquepts in some part of the upper 50 cm. (20 inches) or that have the low chromas (less than 2 or 3 depending on hue) in less than 60 percent of the mass in some horizon above 75 cm. (30 inches).

Fragaquepts (3.13)

The Fragaquepts are the Aquepts that have a fragipan. They may have an umbric, histic, or ochric epipedon, but because they have a fragipan, they rarely or never have either sand or clay textures.

For the most part, the Fragaquepts are developed in siliceous loamy parent materials. Textures range from sandy loams to clay loams. Carbonates may have been present in small amounts in the parent material. Mineralogy is normally mixed, with some micas, some feldspars, and some 2.1 lattice clays, as well as appreciable amounts of quartz. Glacial drift, loess, alluvium, and solifluction deposits are common parent materials.

The Fragaquepts are largely found in cool or temperate humid climates. The native vegetation is boreal forest or deciduous hardwood forests, such as the oak-hickory association. The central concept is reflected by the orthic subgroup. Other subgroups exist, but only four are partially defined here.

Orthic Fragaquepts (3.130)

Orthic Fragaquepts are the Fragaquepts that have an ochric epipedon and that have the colors diagnostic of the Aquepts in all horizons below the plow layer or, if there is no plow layer, below 15 cm. and down to a depth of 75 cm. (30 inches) or more. They have mean annual temperatures of 8.3° C. (47° F.) or more, or mean summer temperatures of more than 15.5° C. (60° F.) if cultivated, or more than 10° C. (50° F.) if with an O horizon. The temperature limits given here are tentative.

Profile 47, p. 147, is an example of the Orthic Fragaquept. Though the horizon from 8 to 18 inches has some of the properties of an argillic horizon, it lacks clay skins. It seems to be comparable to the cambic horizon of Profile 24, except for color, and its clay content is due in large part to the formation of clay in place.

Umbric Fragaquepts (3.13-3.12)

This subgroup is provided temporarily for Fragaquepts that have an umbric epipedon. These soils have not been identified in the United States.

Histic Fragaquepts (3.13-10)

This subgroup is provided for Fragaquepts that have a histic epipedon.

Cryic Fragaquepts (3.13-3.14)

This subgroup is provided tentatively for the Fragaquepts that have no histic epipedon, but that have mean annual temperatures colder than 8.3° C. (47° F.), and summer temperatures of less than 10° C. (50° F.) if with an O horizon. or less than 15.5° C. (60° F.) if cultivated.

Ochreptic Fragaquepts (3.13-3.4)

This subgroup includes the Fragaquepts that have an ochric epipedon and that have chromas in some horizon within 75 cm. (30 inches) that lie outside the range of chromas diagnostic for Aquepts. There may be a thin horizon just below the plow layer that has chromas of more than 2 in hues of 10YR or redder. Or there may be chromas of 2 in hues of 10YR without mottles.

Profile 48, p. 148, illustrates the Ochreptic Fragaquept. The Ap in this soil is 1 unit darker than many of the soils of this subgroup. The chroma of the horizon from 9 to 16 inches is too high for the orthic subgroup, as it exceeds 2 in the 10YR hue. The percentage of carbonates in the C horizon is about as high as has been found. More commonly, none are present in the parent material.

Cryaquepts (3.14)

The Cryaquepts are the Aquepts that have mean annual temperatures of less than 8.3° C. (47° F.), and mean summer temperatures of less than 15.5° C. (60° F.) if the soil is cultivated, or less than 10° C. (50° F.) if the soil has an O horizon, The temperature limits are tentative and may need to be changed. Soils of this class have been called Tundra, Half Bog, and Alpine Meadow.

These wet soils of cold places have been little studied, and the following definitions of subgroups are tentative.

Orthic Cryaquepts (3.140)

This subgroup includes Cryaquepts with an umbric epipedon; with permafrost within 75 cm. (30 inches); with colors diagnostic for the Aquepts throughout all horizons between 15 and 50 cm. (6 and 20 inches); with no fragipan; and with not more than one layer of buried peat more than 5 cm. (2 inches) thick.

The soil may or may not have an O, but if the O is present it must be too thin to constitute a histic epipedon. The A1 or Ap is umbric. Below the A1 or Ap the chromas are low, and mottles are present if the chromas are 1 or more. At 75 cm. or less the permafrost begins.

Because weathering is so slow at low temperature, cambic horizons are probably absent in most Orthic Cryaquepts. Base saturation is not diagnostic in these soils, but typically it is very low and carbon-nitrogen ratios are very wide. This subgroup probably includes many Tundra soils.

Histic Cryaquepts (3.14-10)

This subgroup includes all Cryaquepts with a histic epipedon and with permafrost at 75 cm. or less. It is thought that these soils are common in arctic regions and extend well into the tundra. Ruptic intergrades seem probable where the soils have polygonal forms.

Cryumbreptic Cryaquepts (3.14-3.31)

This suborder is provided for soils that have a horizon in which chromas are higher than those diagnostic for the Aquepts, but that have permafrost at depths of 75 cm. (30 inches) or less. Some horizons have chromas of more than 2 in hues of 10YR or redder, or more than 3 in hues between 10YR and 10Y if mottling is present. If there is no mottling, the chromas may be 1 to 2 in hues of 10YR or redder, or 1 to 3 in hues between 10YR and 10Y. Such a horizon may lie at any depth between the umbric epipedon and 50 cm. (20 inches).

Umbreptic Cryaquepts (3.14-3.12)

This subgroup differs from the orthic in that it lacks permafrost within 75 cm. (30 inches). The permafrost may be deeper, or lacking entirely. The soils have the colors of an umbric epipedon and of the orthic subgroup.

Ochraquepts (3.15)

The Ochraquepts include some of the soils formerly called Half Bog, Humic Gley, and Low-Humic Gley soils. They are the Aquepts that have an ochric epipedon and a cambic horizon, but no fragipan. They are apt to be confused with Haplaquents, from which they differ only in having a cambic horizon. In the field, recognition of the Ochraquepts may depend on the presence of peds in the cambic horizon. In the Haplaquents, rock structure may be present but is not always visible. The age of the parent materials will also provide field clues. More commonly, some evidence of horizons is visible. Immediately below the thin A1 there is often a horizon with chromas of 1 to 2 but with no mottles; this horizon has the position and color of an eluvial A2 and is comparable to the horizon in profile 49 that is between 8 and 18 inches. Profile 49 is an example of an Ochraquept but probably should not be considered an Orthic Ochraquept, as the A1 approaches an umbric epipedon.

ANDEPTS (3.2)

The Andepts include the Inceptisols that have a high content of allophane, volcanic ash, or both. In early stages of weathering of volcanic ash or ash and pumice in humid climates, allophane seems to be the clay mineral that is formed from the Arctic to the Tropics.

Many of the laboratory measurements of properties of these soils have little meaning. Particle-size distribution cannot be measured. Base saturation determinations are questionable in meaning. This is one of the reasons that soils with a mollic epipedon are included with the Andepts, but not with other kinds of Inceptisols. The Andepts are tentatively defined as having 60 percent or more of allophane in the clay fraction or 60 percent or more of volcanic ash in the silt and sand, but measures of allophane percentages are very rough. The 60 percent limit means only that allophane seems dominant in the clay.

The Andepts may have an ochric, mollic, or umbric epipedon. If the epipedon is ochric, the soils must have a cambic horizon. Actually, many if not most, of the Andepts have received repeated ash falls, and buried A1 horizons are to be expected. In some, it seems the surface and the buried A1 horizons merge, giving rise to very thick epipedons. This situation is so common that it is possible that cumulic subgroups should not be recognized.

The Andepts grade into many other kinds of soil, if not all. The classification proposed here is very incomplete. Criteria for many subgroups cannot even be suggested for criticism at present.

The common characteristics of the Andepts are the presence of allophane or ash, low bulk density, and chromas too high for Aquepts.

Five great groups are being proposed. The key and tentative definitions follow.

Key to Andepts

3.21 Andepts with no duripan but with mean annual temperatures less than 8.3° C. (47° F.), and with mean summer temperatures less than 15.5° C. (60° F.) if cultivated and lacking an O horizon, an temperatures less than 10° C. (50° F.) if with an O horizon.

Cryandept, p. 140

3.22 Other Andepts with duripan.

Durandept, p. 140

3.220 Durandepts with umbric epipedon and with temperatures higher than those defined for Cryandepts.

Orthic Durandept, p. 140

3.22-5 Other Durandepts with mollic epipedon.

Mollic Durandept, p. 140

322-1 Other Durandepts with ochric epipedon.

Entic Durandept, p. 140

3.23 Other Andepts with an ochric epipedon.

Ochrandept, p. 140

3.24 Other Andepts with an umbric or mollic epipedon, and with clays that do not dehydrate irreversibly into gravel-sized aggregates.

Umbrandept, p. 140

3.240 Umbrandepts with an umbric epipedon more than 15 cm. (6 inches) thick and with a cambic horizon.

Orthic Umbrandept, p. 141

3.24-5 Other Umbrandepts with mollic epipedon.

Mollic Umbrandept, p. 141

3.24-1 Other Umbrandepts with no cambic horizon, or with umbric epipedon less than 15 cm. thick.

Entic Umbrandept, p. 141

3.25 Other Andepts with clays that dehydrate irreversibly into gravel-sized aggregates.

Hydrandept, p. 141

Cryandepts (3.21)

The Cryandepts are the cold Andepts that have no duripan. These soils have been included with Tundra soils. They have mean annual temperatures of less than 8.3° C. (47° F.), and mean summer temperatures of less than 15.5° C. (60° F.) if they are being cultivated and have no O horizon, or mean summer temperatures of less than 10° C. (50° F.) if an O horizon is present.

No subgroups are defined here, but it seems likely that those Cryandepts with an umbric epipedon should be considered orthic, and those with an ochric epipedon will be entic.

Profile 50, p. 150, is presented as an example of what probably should be the orthic subgroup. The carbon and nitrogen values, as well as horizontal streaks, suggest that there have been several ash falls. There is no reason to put high credence in the measured clay content.

Durandepts (3.22)

The Durandepts are those Andepts that have a duripan. The pans are most commonly found at depths ranging from 50 to 75 cm. (20 to 30 inches) and are generally formed in coarse-textured materials (pumice or gravel) that underlie ash. The cement seems to silica or a silicate, but it has not been identified. One sample of pure cement, in the form of a pendant, has been shown to be silicon dioxide, but this is only suggestive. The duripans may be weakly or strongly cemented, and the cementation may be somewhat weaker when wet than when dry. There is often a thin surface layer of a darker colored cement sealing the surface of the pan. The colors suggest the presence of iron, manganese, or both, in this part of the pan.

The solum above the pan may include an umbric, mollic, or ochric epipedon, and a cambic horizon.

Soils of this group are known in Chile, and evidence indicates they occur in Japan and Iceland. They have not been identified as such in the United States, though they occur.

If Durandepts occur that have the temperatures of Cryandepts, a cryic subgroup may be wanted, but it is not here defined. At this writing, it seems reasonable to suggest that the central concept of the great group should have an umbric epipedon, because this horizon is so widespread in the Andepts.

Orthic Durandepts (3.220)

The Orthic Durandepts are those Durandepts that have an umbric epipedon, and a cambic horizon above a duripan. Because the duripan impedes movement of water, the soils of this subgroup are expected to have temporary perched ground water. Mottling in the cambic horizon is permitted but not required. However, chromas of the cambic horizon are expected to be higher than those diagnostic for Aquepts.

The Orthic Durandepts should have temperatures warmer than those specified for cryic soils, Cryaquerts and Cryudents, for example. If Durandepts occur that have temperatures as cold as for those groups, at least a cryic subgroup will be needed.

Mollic Durandepts (3.22-5)

This subgroup includes Durandepts that have a mollic epipedon, but that otherwise resemble the orthic subgroup.

Entic Durandepts (3.22-1)

This subgroup is provided tentatively for those Durandepts with an ochric epipedon. It is believed that the duripan may form in pumice before the umbric epipedon has had time to form, and that the absence of the umbric or mollic epipedon is evidence of early stages of soil development. No distinct cambic horizon should be evident in soils of this subgroup.

Ochrandepts (3.23)

The Ochrandepts are Andepts with no duripan, but with an ochric epipedon and a cambic horizon. At one extreme the solum is dominantly relatively fresh ash, weathered enough to have brown or red colors, and at the other, the glass is very strongly weathered and contains appreciable amounts of either kaolin or free oxides.

So far as is known, the vegetation is forest, coniferous to tropical rain forest. These soils have never fitted well into other classifications. In Hawaii they have been called Latosolic Brown Forest Soils.

Reasonable subgroups cannot be defined at this time. It is felt that those with very small allophane and oxide contents should be an entic subgroup. Those with appreciable kaolin content and low pH values should be ultic subgroups, and those with large free sesquioxide content should be oxic subgroups.

Umbrandepts (3.24)

The Umbrandepts include the soils that have been called Ando soils. They have a relatively thick, dark surface horizon that may be either an umbric or mollic epipedon. They may or may not have a cambic horizon; they do not have a duripan.

The umbric and mollic epipedons are combined here, partly because of uncertainties about the validity of methods for measuring base saturation, and partly because the influence of the allophane and ash are thought to be more significant.

Buried A1 horizons are very common in these soils. Sometimes the A1 horizons are separated by relatively fresh ash, but at times it appears that the A1 horizons developed in a number of ash falls have merged to form a single very thick A1.

The content of organic matter often seems very high, as it is normally measured. An organic carbon content of more than 10 percent seems very common; organic-matter content may approach 30 percent in well-drained soils. If organic matter were expressed on a volume basis, rather than on a basis of weight, the values might be comparable to those of some other mineral soils. An impression of extremely high organic-matter content is gained when the low bulk densities are neglected. Bulk densities of 0.3, or even less, are not uncommon in the Andepts.

The subgroup definitions that follow are presented tentatively.

Orthic Umbrandepts (3.240)

This subgroup includes Andepts that have an umbric epipedon, and a cambic horizon. The umbric epipedon should be more than 15 cm. (6 inches) thick. Base saturation is low, if measured by the sum of cations. Carbon-nitrogen ratios are wider than 17, and may be as wide as 25 or more.

Profile 5, p. 70, is a representative of the orthic subgroup. The lack of correlation between percentages of clay, exchange capacities, and moisture held at 15 bars, suggests the difficulty of dispersion in these soils.

Mollic Umbrandepts (3.24-5)

This subgroup includes the Umbrandepts that have epipedons meeting the requirements of a mollic epipedon. Carbon-nitrogen ratios commonly range from 10 to 12 in cultivated soil. The pH values are commonly above 6, but the base saturation may vary according to the method used. Secondary carbonates are sometimes present in the lower horizons.

It is possible that integrade subgroups to the various suborders of Mollisols will be wanted; but they cannot be defined at present.

Profile 52, p. 151, is an example of a Mollic Umbrandept. It will be noted that the mechanical analysis has no meaning. Base saturation figures have questionable meaning, but large amounts of calcium and potassium are present.

Entic Umbrandepts (3.24-1)

This subgroup includes the Umbrandepts that have no evidences of a cambic horizon, or have such a thin solum that the umbric epipedon is less than 15 cm. thick (6 inches). Soils with a very thick A1 horizon, more than 50 cm. (20 inches), are excluded.

Hydrandepts (3.25)

The Hydrandepts are found in perhumid climates where periods as long as 1 week without having rain are rare.

With almost daily rain, the allophane forms a gel. If dried to air dryness, the allophane hardens irreversibly into sand- and gravel-sized aggregates. The soils of this group have been called Hydrol Humic Latosols.

The soils are not extensive in the world and are reported only in Hawaii. At this writing definitions of subgroups are not possible.

Profile 53, p. 152, is an example of this great group. It will be noted that pH values in KCl are as high or higher than those in water, which indicates a net positive charge in the soil. This property, together with the very low silica-sesquioxide ratios of the soil, suggest that the profile represents an oxic subgroup rather than an orthic.

UMBREPTS (3.3)

The Umbrepts are Inceptisols that have no more than minor amounts of allophane or volcanic ash, and that have umbric epipedons that must be 25 cm. (10 inches) or more thick unless the soil has the low temperatures of the cryic groups. Umbrepts may have an anthropic epipedon, and usually have a cambic horizon. They do not have a mollic epipedon or an argillic, spodic, or oxic horizon. They may be deep or shallow to rock. Textures are most apt to be sandy or loamy.

Most Umbrepts are found in humid climates and have low or very low base saturation. They may have developed under forest, but commonly they have had a grass cover between scattered trees or, in alpine and arctic regions, mixed grasses and forbs. Others are thought to have an anthropic epipedon, and the significant vegetation may have been cultivated crops.

The Umbrepts include soils that have been called Tundra soils, and Brown Forest soils. Three great groups can be tentatively defined at present. The key and definitions of these great groups and their subgroups follow. A fourth great group may be needed for the soils of tropical and subtropical regions. This group could be defined as having kaolin and free oxides dominant in the clay fraction. The need for such a group will be influenced by any changes in the definitions of the cambic and oxic horizons.

Key to Umbrepts

3.31 Umbrepts with mean annual temperature less than 8.3° C. (47° F.), and, if cultivated or without an 0 horizon, having mean summer temperature in the upper 50 cm. (20 inches) of less than 15.5° C. (60° F.), or having mean summer temperature less than 10° C. (50° F.) if with an 0 horizon.

Cryumbrept, p. 142

3.310 Cryumbrepts with an umbric epipedon and a cambic horizon; with no mottles within 1 meter of the surface that have chromas of 2 or less; and with less than 40 percent calcium carbonate in the horizon immediately below the cambic horizon.

Orthic Cryumbrept, p. 142

3.31-1 Other Cryumbrepts with no cambic horizon.

Entic Cryumbrept, p. 142

3.31-3.1 Other Cryumbrepts with mottles within 1 meter of the surface that have chromas of 2 or less.

Aquic Cryumbrept, p. 142

3.31-5.1 Other Cryumbrepts with more than 40 percent calcium carbonate below the umbric epipedon or the cambic horizon.

Rendollic Cryumbrept, p. 142

3.33 Other Umbrepts with an umbric epipedon.

Haplumbrept, p. 142

3.330 Haplumbrepts with an umbric epipedon between 25 and 50 cm. (10 and 20 inches) thick, and with a cambic horizon; with no mottles within 1 meter of the surface that have chromas of 2 or less; with less than 40 percent calcium carbonate in the horizon immediately below the cambic horizon; and with no hard bedrock (R) within 50 cm. (20 inches).

Orthic Haplumbrept, p. 142

3.33-1.21 Other Haplumbrepts with no cambic horizon; with sand or loamy sand textures; and with 95 percent or more of quartz, tourmaline, zircon, rutile, or similar unweatherable minerals.

Quarzopsammentic Haplumbrept, p. 143

3.33-1.22 Other Haplumbrepts with no cambic horizon; with sand or loamy sand textures; and with less than 95 percent quartz in the sand fraction.

Orthopsammentic Haplumbrept, p. 143

3.33-1.1 Other Haplumbrepts with no cambic horizon but with mottles within 1 meter of the surface that have chromas of 2 or less.

Aquentic Haplumbrept, p. 143

3.33-1 Other Haplumbrepts with no cambic horizon; with no mottles within 1 meter of the surface that have chromas of 2 or less; and with no hard bedrock (R) within 50 cm. (20 inches).

Entic Haplumbrept, p. 143

3.33-3.1 Other Haplumbrepts with a cambic horizon and with mottles that have chromas of 2 or less within 1 meter of the surface.

Aquic Haplumbrept, p. 143

3.33-R Other Haplumbrepts with hard bedrock (R) within 50 cm. (20 inches) of the surface.

Lithic Haplumbrept, p. 143

3.34 Other Umbrepts with anthropic epipedon.

Anthrumbrept, p. 143

Cryumbrepts (3.31)

The Cryumbrepts are soils of cold regions, either alpine or arctic. They have a thick, dark surface horizon, generally with low base saturation and wide carbon-nitrogen ratios. Those that occur in arctic and subarctic regions have been called Tundra soil. Those in alpine areas have had no convenient name.

The epipedon is umbric, but is not necessarily so thick as that in the other umbrepts. There is usually, but not necessarily, a cambic horizon. Bedrock may be shallow or deep. The soils have no argillic or spodic horizon, nor do they have the gray colors within 50 cm. (20 inches) of the surface that are diagnostic of the Aquepts. The mean annual temperatures of the soil are less than 8.3° C. (47° F.), and the mean summer temperatures of the upper 50 cm. are less than 15.5° C. (60° F.) if the soils are being cultivated or have no O horizon, and less than 10° C. (50° F.) if there is an O horizon. These temperature limits are tentative and may be changed.

The soils of cold places have had relatively little study. The subgroup definitions that follow are presented tentatively and may need to be changed.

Orthic Cryumbrepts (3.310)

This subgroup includes Cryumbrepts that have an umbric epipedon and a cambic horizon. They have no mottles with chromas of 2 or less within 1 meter of the surface, and the horizon that underlies the cambic horizon has less than 40 percent calcium carbonate equivalent. The temperature limits are the same as those of the Cryumbrepts, but a requirement of permafrost within 75 cm. (30 inches) may need to be added.

Entic Cryumbrepts (3.31-1)

This subgroup is provided for Cryumbrepts that have no cambic horizon and that have less than 40 percent calcium carbonate in the C or R. It is possible that a lithic subgroup is needed for these Cryumbrepts that lack a C horizon and have only R below the epipedon.

Profile 54, p. 153, is an example of this subgroup. The solum seems to be truncated by permafrost. The organic-matter rich horizon just above the frozen earth is very common and may be the result of frost churning.

Aquic Cryumbrepts (3.31-3.1)

This subgroup includes the Cryumbrepts that have mottles with chromas of 2 or less within 1 meter of the surface.

Rendollic Cryumbrepts (3.31-5.1)

This subgroup includes the Cryumbrepts that have more than 40 percent calcium carbonate equivalent in the horizon that underlies the epipedon or the cambic horizon.

Haplumbrepts (3.33)

The Haplumbrepts have an umbric epipedon more than 25 cm. (10 inches) thick that rests on a cambic horizon or a C or R. They differ from the Cryumbrepts in soil temperature. They have mean annual temperature above 8.3° C. (47° F.); or, if being cultivated or lacking an 0 horizon, have summer temperature of more than 15.5° C. (60° F.); or if they have an 0 horizon, have summer temperatures of more than 10° C. (50° F.).

The native vegetation is commonly grass, or a grass cover between scattered trees. Parent materials are generally of mixed mineralogy but have a high silica content. Granites are perhaps most common among the parent materials. The definitions of the subgroups that follow are presented tentatively. There are too few of these soils in the United States to permit thorough testing.

Orthic Haplumbrepts (3.330)

The Orthic Haplumbrepts are those Haplumbrepts that have an umbric epipedon between 25 and 50 cm. (10 and 20 inches) in thickness that rests on a cambic horizon. There are no mottles with chromas of 2 or less within 1 meter of the surface, no hard bedrock (R) within 50 cm., and the horizon below the cambic horizon has less than 40 percent calcium carbonate equivalent.

Profile 55, p. 154, is an example of an Orthic Hapludent. The soil has an umbric epipedon 13 inches thick. Base saturation is extremely low throughout the soil.

Entic Haplumbrepts (3.33-1)

This subgroup includes the Haplumbrepts that have no cambic horizon, no mottles with chromas of 2 or less within 1 meter of the surface, and no hard bedrock (R) within 50 cm. (20 inches). They do have an umbric epipedon, and textures of the fraction less than 2 mm. in size are as fine or finer than loamy very fine sand.

In these soils, structure of the parent rock is usually evident in the horizon immediately below the epipedon.

Aquentic Haplumbrepts (3.33-1.1)

This subgroup includes Haplumbrepts that have no cambic horizon, but that have mottles with chromas of 2 or less within 1 meter of the surface. They have textures finer than loamy fine sand in some part of the umbric epipedon.

Quarzopsammentic Haplumbrepts (3.33-1.21)

This subgroup includes Haplumbrepts that have no cambic horizon, but that do have an umbric epipedon and have textures as coarse or coarser than loamy fine sand to depths of 50 cm. (20 inches) or more. The sand is 95 percent or more quartz, rutile, tourmaline, zircon, or similar unweatherable minerals.

Orthopsammentic Haplumbrepts (3.33-1.22)

This subgroup includes Haplumbrepts that have no cambic horizon, but that do have an umbric epipedon with a texture as coarse or coarser than loamy fine sand to depths of 50 cm. (20 inches) or more. The sand is less than 95 percent quartz or similar unweatherable minerals.

Aquic Haplumbrepts (3.33-3.1)

This subgroup includes Haplumbrepts that have a cambic horizon and that have mottles with chromas of 2 or less within 1 meter of the surface. The textures of the cambic horizon at least, and usually of the solum, are finer than loamy fine sand. Hard bedrock (R) is at depths of more than 50 cm. (20 inches).

Lithic Haplumbrepts (3.33-R)

This subgroup includes the Haplumbrepts that have hard bedrock (R) at depths of less than 50 cm. (20 inches). Normally, in these soils, there is only a very thin or no cambic horizon.

Anthrumbrepts (3.34)

This great group is provided tentatively for soils with an anthropic epipedon and a cambic horizon. An agric horizon may be present, but it is not required. The soils are not known in the United States, and definitions of the subgroups are not attempted here.

OCHREPTS (3.4)

The Ochrepts are soils that have been called Sols Bruns Acides, as well as a number that have been called Regosols and Lithosols.

They are characterized by a thin A1 or Ap, resting on a cambic horizon. Some, but not all, have fragipans below the cambic horizon. A few have an umbric epipedon by definition, because the solum is very thin. In these the umbric epipedon is less than 25 cm. (10 inches) thick. Such soils with an umbric epipedon are included with the Ochrepts because soils that have an ochric epipedon when virgin may, by plowing a few times to a depth of 8 or 9 inches, be given an umbric epipedon. It is the intent of this system to avoid changes in classification that result from normal plowing and cultivation for short periods.

The Ochrepts are found in humid to subhumid regions from the Arctic to the Tropics. Five great groups are defined here in the pages that follow. A sixth may be needed for soils in tropical and subtropical regions. It could be defined as having a dominance of kaolin and free oxides in the clay fraction. The need for such a group will be influenced by any changes in the definitions of cambic and oxic horizons.

Key to Ochrepts

3.41 Ochrepts that have mean annual temperatures of less than 8.3° C. (47° F.), and mean summer temperatures of less than 15.5° C. (60° F.) if cultivated or lacking an 0 horizon, or less than 10° C. (50° F.) if with an O horizon. They have no fragipan.

Cryochrept, p. 144

3.410 Cryochrepts with a cambic horizon and with no mottles within 1 meter that have chromas of 2 or less.

Orthic Cryochrept, p. 144

3.41-3.1 Other Cryochrepts that have, within 75 cm. (30 inches), mottles that have chromas of 2 or less.

Aquic Cryochrept, p. 144

3.43 Other Ochrepts with carbonates in the cambic horizon or in the C, and with base saturation of more than 80 percent in the cambic horizon and the C. Always moist in some part of the solum, or solum is dry for only short periods of less than 60 days. Do not have a fragipan.

Eutrochrept, p. 144

3.430 With carbonates in the cambic horizon but with less than 40 percent carbonates below the cambic horizon. With no mottles within 75 cm. (30 inches) of the surface that have chromas of 2 or less.

Orthic Eutrochrept, p. 144

3.43-3.1 Eutrochrepts with mottles that have chromas of 2 or less within 75 cm. (30 inches) and less than 40 percent carbonates in the C.

Aquic Eutrochrept, p. 145

3.43-3.44 Other Eutrochrepts with no carbonates in the cambic horizon.

Dystric Eutrochrept, p. 145

3.43-5.1 Other Eutrochrepts with 40 percent or more carbonates in the C.

Rendollic Eutrochrept, p. 145

3.44 Other Ochrepts that are always moist in the solum, or solum is dry for periods of less than 60 days. Do not have fragipan.

Dystrochrept, p. 145

3.440 Dystrochrepts that have a cambic horizon; that have no mottles with chromas of 2 or less within 75 cm. (30 inches); that have a cambic horizon with less than 30 percent base saturation.

Orthic Dystrochrept, p. 145

3.44-9 Other Dystrochrepts with a horizon that meets all requirements of an oxic horizon except for presence of weatherable minerals in silt and sand or 2:1 lattice clay in the cambic horizon.

Oxic Dystrochrept

3.44-3.12 Other Dystrochrepts with mottles that have chromas of 2 or less within 75 cm. (30 inches) and with an Ap that has a moist value of 4 or less or with an A1 that is thicker than 7.5 cm. (3 inches) and that has a moist value of 3 or less.

Umbraqueptic Dystrochrept, p. 145

3.44-1.1 Other Dystrochrepts with mottles within 75 cm. (30 inches) that have chromas of 2 or less.

Aquic Dystrochrept, p. 145

3.44-3.43 Other Dystrochrepts that have base saturation over 30 percent in the cambic horizon.

Eutric Dystrochrept, p. 145

3.45 Other Ochrepts that have no fragipans, and that have periods of 60 days or more when the solum is dry.

Ustochrept, p. 145

3.450 Ustochrepts that have no mottles with chromas of 2 or less within the cambic horizon and within 75 cm. (30 inches) and that have less than 40 percent lime in the horizon below the cambic horizon.

Orthic Ustochrept, p. 145

3.45-3.1 Other Ustochrepts that have mottles with chromas of 2 or less within the solum and within 75 cm. (30 inches).

Aquic Ustochrept, p. 145

3.46 Other Ochrepts that have a fragipan.

Fragochrept, p. 145

3.460 Fragochrepts that have no distinct or prominent mottling in the upper 30 cm. (12 inches) and are free of detectable allophane.

Orthic Fragochrept, p. 146

3.46-3.2 Other Fragochrepts with allophane.

Andic Fragochrept, p. 146

Cryochrepts (3.41)

This group includes soils that have been called Subarctic Brown Forest soils and comparable soils of arctic and alpine regions. The soils have an ochric epipedon and a cambic horizon. Some may have deep permafrost. Most of these soils have developed under boreal forests on land surfaces no older than the last stages of the Wisconsin (Würm) glaciation. The subgroup definitions that follow are tentative.

Orthic Cryochrepts (3.410)

This subgroup includes Cryochrepts that have an ochric epipedon, and a cambic horizon with chromas higher than those diagnostic for Aquepts. Permafrost may be present or absent. The upper 75 cm. (30 inches) is free of mottles that have chromas of 2 or less.

Aquic Cryochrepts (3.41-3.1)

The soils of this subgroup are similar to those of the orthic subgroup but they have within 75 cm. (30 inches) mottles that have chromas of 2 or less.

Eutrochrepts (3.43)

The Eutrochrepts include most soils that have been called Brown Forest soils, and some that have been called Regosols. They have an ochric epipedon, normally with granular structure. The cambic horizon generally has chromas of 3 or 4, but chromas higher than those diagnostic for Aquepts. Normally, the cambic horizon also has a weak or moderate granular structure because of high biotic activity. Carbonates are often present in the cambic horizon, but they have been partially leached. If carbonates are absent in the cambic horizon, the base saturation is high, more than 80 percent, and there are carbonates in the C horizon.

The Eutrochrepts are in humid climates having short or no dry seasons. The solum may be dry for short periods of less than 60 days, but commonly the solum is always moist in some part. The natural vegetation is usually deciduous hardwood forest.

Orthic Eutrochrepts (3.430)

This subgroup includes Eutrochrepts that have carbonates in the cambic horizon, but that have less than 40 percent carbonates in the C. They have no mottles with chromas of 2 or less within the upper 75 cm. (30 inches).

Aquic Eutrochrepts (3.43-3.1)

This subgroup is provided for Eutrochrepts that are comparable to the orthic subgroup but that have, within the upper 75 cm. (30 inches), mottles with chromas of 2 or less.

Dystric Eutrochrepts (3.43-3.44)

This subgroup includes Eutrochrepts that lack carbonates in the cambic horizon. They have the high base saturation of the Eutrochrepts and have less than 40 percent carbonates in the C.

Rendollic Eutrochrepts (3.43-5.1)

This subgroup includes the Eutrochrepts that have more than 40 percent calcium carbonate equivalent in the C. It includes soils that have generally been called Rendzinas, but that have too thin an A1 for the mollic epipedon of the Rendolls.

Dystrochrepts (3.44)

The Dystrochrepts are the brown, acid, forest soils of humid climates that lack illuvial horizons. They have been called Sols Bruns Acides without fragipans in recent years. Some have been called Lithosols and Regosols. The virgin profiles usually have an ochric epipedon and a cambic horizon. Hard bedrock may be shallow or deep. Because a number of these soils have an ochric epipedon that becomes umbric on plowing, those with a thin umbric epipedon, less than 25 cm. (10 inches) thick, are included with the Dystrochrepts.

The Dystrochrepts are usually moist, and except for short periods of less than 60 days, are moist within some part of the solum at all times. They have an ochric epipedon, or they may have an Ap less than 25 cm. thick that constitutes an umbric epipedon if the solum is less than 75 cm. thick. They have a cambic horizon with a texture finer than loamy fine sand in at least some part. The sand and silt fraction of the cambic horizon contains weatherable minerals, such as micas or feldspars, or the clay fraction has some 2:1 lattice clays, or both. Base saturation in the cambic horizon is less than 80 percent, and usually much less.

Except where the Dystrochrepts have developed in unconsolidated parent materials, bedrock (R) usually can be expected by 50 to 75 cm. Parent materials generally are of mixed mineralogy, but siliceous. The native vegetation is usually a deciduous hardwood forest.

Orthic Dystrochrepts (3.440)

This subgroup includes Dystrochrepts that have base saturation (by sum of cations) of less than 30 percent in the cambic horizon, and that have no mottles with chromas of 2 or less within the upper 75 cm. (30 inches). The sand and silt fractions contain feldspars, micas, or other weatherable minerals in more than traces, or the clay fraction is dominated by 2:1 lattice clays.

Profile 34, p. 99, is an example of this subgroup. Chemical and mineralogical analyses of this soil are given in table 14.

Umbraqueptic Dystrochrepts (3.44-3.12)

This subgroup includes Dystrochrepts that have evidences of wetness and an epipedon that is umbric or that is marginal to umbric. The soils have mottles with chromas of 2 or less within the upper 75 cm. (30 inches) and have either an Ap with a moist value of 4 or less or an A1 that is thicker than 7.5 cm. (3 inches) and has a moist value of 3 or less.

Aquic Dystrochrepts (3.44-3.1)

This subgroup includes Dystrochrepts that have mottles with chromas of 2 or less within the upper 75 cm. (30 inches) and, in addition, have either an Ap with moist values of more than 4 or an A1 that is thinner than 7.5 cm. (3 inches) or has a moist value of more than 3.

Eutric Dystrochrepts (3.44-3.43)

This subgroup includes Dystrochrepts that have base saturation of more than 30 percent (by sum of cations) in the cambic horizon.

Ustochrepts (3.45)

The Ustochrepts are Ochrepts that have no fragipan, but during extended periods, more than 60 days, their solum is dry. The Ustochrepts are most commonly found in Mediterranean climates, but a winter dry season in regions free of frost is not precluded. Few of these soils occur in the United States, and the subgroup definitions that follow are presented tentatively, and are probably very incomplete.

Orthic Ustochrepts (3.450)

This subgroup includes Ustochrepts that have no mottles with chromas of 2 or less within 75 cm. (30 inches) of the surface, and that have less than 40 percent calcium carbonate equivalent in the C. It seems likely that calcic horizons should be absent. If present, a calcic horizon might be a basis for definition of a calcorthidic or calcustollic subgroup.

Aquic Ustochrepts (3.45-3.1)

This subgroup includes Ustochrepts that have mottles with chromas of 2 or less in the upper 75 cm. (30 inches) of the soil.

Fragochrepts (3.46)

The Fragochrepts are the Ochrepts with fragipans. They are commonly associated with the Dystrochrepts but are on gentler slopes. Otherwise, genetic factors are similar. The fragipans seem always to have appreciable amounts of very fine sand or silt. Consequently, parent materials of Fragochrepts generally have comparable amounts of these size fractions.

The soils generally have an ochric epipedon and a thin cambic horizon. The fragipan's upper surface is most commonly at depths between 40 and 75 cm. (16 and 30 inches). Just above the fragipan there may be a thin grayish horizon (A'2) through which water commonly moves laterally. The Fragochrepts on the strongest slopes normally lack this horizon.

The Fragochrepts have been called Sols Bruns Acides with fragipans in recent years.

Orthic Fragochrepts (3.460)

This subgroup includes Fragochrepts that lack detectable allophane and that have no distinct or prominent mottles in the upper 30 cm. (12 inches). Generally, if mottling is shallower than this, the chromas become too low for the Ochrepts, so that no aquic subgroup is being defined at this time.

Profile 24, p. 89, is an example of the soils of this subgroup. Chemical and mineralogical analysis of this soil are given in table 14.

Andic Fragochrepts (3.46-3.2)

This subgroup includes Fragochrepts that have detectable amounts of allophane. So far as is known, all of these have volcanic ash in the silt fraction as well.

Profile 56, p. 155, is given as an example of this subgroup. The parent material is loess with some volcanic ash. Allophane seems important in the clay fraction, but mica (illite), vermiculite, and kaolin seem to constitute the major part of the clay.

Profile Descriptions for Chapter 10

(Colors for moist soil unless otherwise stated)

Profile No. 47 (Lab. data by Ohio Agr. Expt. Sta.)
Area: Ashatabula County, Ohio.
Vegetation: Idle land. Grass, weeds, briars.
Parent material: Calcareous silt loam till over dark shale and thin sandstone.
Topography: Less than 1 percent slope; Wisconsin till plain; elevation 955 feet.

Ap 0 to 8 inches, dark grayish-brown (2.5Y 4/2) silt loam; weak, medium and coarse, granular structure; friable; abundant roots; abrupt boundary.

B 8 to 18 inches, pale-yellow (5Y 7/3), light silty clay loam; common, fine mottles of olive yellow (2.5Y 6/6), strong brown (7.5YR 5/8), and yellowish brown (10YR 5/8); weak, fine and medium, subangular blocky structure; friable; few roots; clear, wavy boundary.

A'2 18 to 22 inches, pale-yellow (5Y 7/3) silt loam; many, fine, distinct mottles of strong brown (7.5YR 5/8), and yellowish-brown (10YR 5/8) mottles; weak, fine and medium, subangular blocky structure; friable; clear, wavy boundary.

B'21x 22 to 26 inches, grayish-brown (2.5Y 5/2) silt loam; many, fine, distinct mottles of yellowish brown (10YR 5/8), and olive gray (5Y 5/2); some black coatings of manganese; weak, very coarse, prismatic structure with massive interiors; extremely firm in place, firm when removed; few roots on faces of prisms; gradual boundary.

B'22x 26 to 41 inches, olive-brown (2.5Y 4/4) silt loam; common, medium, and distinct mottles of yellowish brown (10YR 5/6) and gray (5Y 5/1); faces of prisms are gray (5Y 5/1); moderate, very coarse, prismatic structure breaking to weak, platy structure; very firm in place, firm when removed; few roots on faces of prisms; diffuse boundary.

B'3 41 to 60 inches, olive-brown (2.5Y 4/4) silt loam; many to common, medium, distinct mottles of yellowish brown (10YR 5/8), light olive brown (2.5Y 5/6), and gray (5Y 5/1); weak, coarse, prismatic structure breaking to weak, platy structure firm in place, friable when removed; calcareous; diffuse boundary.

C1 60 to 96 inches, olive-brown (2.5Y 4/4) silt loam; numerous coarse fragments and many cobbles of olive-brown sandstone; some fragments of black shale and pebbles of igneous rock; calcareous.

Remarks: Colors of the horizons between depths of 18 and 60 inches are for soil that is somewhere between moist and dry.

Climatic data (Jefferson, Ohio*)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	29	28	36	46	58	68	72	71	64	54	41	31	50
Mean precipitation, 1930-47 (inches)	2.6	2.5	3.0	3.3	3.8	4.1	3.8	3.1	3.4	3.2	3.1	2.6	38.5

Annual precipitation more than 31.5 and less than 45.5 inches during 9 years out of 10.

*Temperature composed of a 9-year record from Jefferson and a 9-year record from Geneva

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Fine clay <.0002	Total sands	>2	B.D. (gm. per cc.) a	Organic matter C % w	C/N	$CaCO_3$ equiv. % a
0-8	Ap	3.0	2.3	1.3	5.8	6.4	60.0	21.2	4.7	18.8		1.02	4.4		
8-18	B	2.0	1.7	1.0	4.2	5.3	58.2	27.6	9.7	14.2		1.41			
18-22	A'2	1.5	1.9	1.4	7.8	9.1	58.8	19.5	7.4	21.7		1.45			
22-26	B'21x	2.6	3.0	1.8	6.6	6.2	54.4	25.4	8.6	20.2		1.60			
26-41	B'22x	2.6	3.4	1.9	7.7	6.8	55.5	22.1	7.2	22.4		1.66			
41-60	B'3	2.4	3.0	1.5	6.7	6.2	54.2	26.0	5.6	19.8		1.75			6.2
60-84	C1	8.7	6.4	2.1	5.9	5.9	56.9	14.1	3.5	29.0					3.0
84-96	C2	7.4	6.0	2.4	8.3	8.4	58.8	8.7	2.4	32.5					3.6

Cation exch caps	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. %	pH 1:1
19.5	0.5	0.3	18.8		0.20	4	4.6
12.9	1.7	.6	10.8		.11	16	5.0
9.3	2.2	2.4	6.4		.09	31	5.2
15.6	7.9	2.3	5.1		.19	67	5.7
13.2	8.4		2.5		.13	82	6.9
							8.0
							8.1
							7.9

*Exchange acidity.

Profile No. 48

Area: Tomkins County, New York.
Vegetation: Weeds; scattered, planted seedlings of Scotch pine.
Parent material: Calcareous, glacial till.
Topography: 3 percent slope, facing north.

Ap 0 to 9 inches, very dark grayish-brown (10YR 3/2) channery clay loam; mixed, weak, fine, subangular blocky and moderate, medium, granular structures; friable; many fine roots; clear, smooth boundary.

Bg 9 to 16 inches, grayish-brown (10YR 5/2) to brown (10YR 5/3) channery loam; common, medium, distinct mottles of yellowish brown (10YR 5/4-5/6) and many less distinct, medium, faint mottles; very weak, fine, subangular blocky structure; friable; few, fine roots; clear, smooth boundary.

C1x 16 to 21 inches, dark grayish-brown (10YR 4/2) channery loam; flat-topped prisms, 2 to 6 inches wide, are separated by grayish-brown (10YR 5/2) silt that has many, medium mottles of yellowish brown (10YR 5/6); prism interiors are dark grayish brown (10YR 4/2) and have crude, grayish-brown (10YR 5/2), discontinuous planes of fracture that produce very weak, medium, angular blocky structure; very firm; gradual, smooth boundary.

C2x 21 to 26 inches, dark grayish-brown (10YR 4/2) channery loam; strong prisms, 4 to 8 inches wide, are separated by vertical bands of olive-gray (5Y 5/2) silt loam that are from 1/4 to 3/4 of an inch in width; outer parts of prisms, adjacent to the olive-gray bands of silt, are strong brown (7.5YR 5/6) in color and from 1/8 to 1/4 of an inch in thickness; very firm; diffuse boundary.

C3x 26 to 56 inches, horizon very similar to C2x, but vertical cleavage decreases with depth, and the structure grades to weak prismatic; prisms are 18 to 30 inches wide at lower part of horizon; thin, very dark brown films are on the discontinuous cleavage faces within the prisms; films increase in abundance with depth.

C4x 56 to 78 inches, grayish-brown (2.5Y 5/2) channery loam; prisms are 18 to 36 inches wide and have light-gray (5Y 6/1) faces; prism interiors have common, fine, faint mottles; very firm; massive; clear, wavy boundary.

C5 78 to 84 inches +, grayish-brown (2.5Y 5/2) channery loam; weak, medium and thick, platy structure; few, fine, faint mottles; calcareous.

Climatic data (Ithaca, N. Y.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	26	24	23	45	57	66	71	69	62	51	40	29	48
Mean precipitation, 1931-52 (inches)	1.9	1.9	2.9	2.7	3.7	3.3	4.1	3.5	3.3	2.9	2.6	2.4	35.1

Annual precipitation more than 26.5 and less than 43.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	Organic matter C/N (k)	Free iron oxides Fe_2O_3 %
0-9	Ap	2.0	2.9	3.1	6.8	10.4	46.5	28.3	33.2	27.8	5		3.57	11	2.0
9-16	Bg	6.3	6.7	5.3	10.0	12.9	44.5	14.3	38.2	25.1	32		.51	8	1.4
16-21	C1x	7.4	6.9	5.1	9.4	11.9	44.5	14.8	35.6	26.3	40		.38	6	1.5
21-26	C2x	7.9	7.0	4.0	7.4	9.6	47.5	16.6	29.4	32.2	40		.26	--	1.5
26-56	C3x	4.8	5.2	4.2	8.2	9.7	46.8	21.1	31.0	30.1	24		.16	--	1.0
56-78	C4x	6.8	6.6	5.0	10.0	12.5	46.2	12.9	37.0	27.6	25		.17	--	1.5
78-84	C5	7.8	7.5	5.3	10.6	13.2	41.5	14.1	41.3	20.0	28		.14	--	1.1

Cation exch. cap. (g)	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % (g)	pH 1:1	$CaCO_3$ equiv. % (h)	Moisture tensions 1/10 atmos. %	Moisture tensions 15 atmos. %	Cation exch. cap. (b)	Clay mineralogy Mi.	Vm.	Chl.
29.5	10.0	2.3	16.7	0.1	0.4	43	5.5	---	44.3	16.3	---	xxx	xx	x
11.1	3.4	.9	6.6	.1	.1	40	5.6	---	24.6	6.5	---	---	--	--
10.1	3.1	1.0	5.8	.1	.1	42	5.5	---	22.7	6.1	---	---	--	--
9.6	3.4	1.0	5.0	.1	.1	48	5.6	---	22.2	6.3	---	---	--	--
8.9	4.7	1.3	2.7	.1	.1	70	6.0	---	22.6	8.7	---	xxxx	xx	xx
8.2	3.4	1.1	3.5	.1	.1	57	5.8	---	20.5	5.9	---	---	--	--
---	---	---	---	---	---	--	8.0	5.7	18.0	4.2	15.2	xxxx	x	xx

*Exchange acidity.

Profile No. 49

Area: Hampshire County, Massachusetts.
Vegetation: Pasture.
Parent material: Glacial till from granite, gneiss, and schist.
Topography: Flat; slight depression; elevation 650 feet.

A1 0 to 8 inches, black (5YR 2/1) fine sandy loam; weak to moderate, medium, granular structure; very friable, slightly sticky, slightly plastic; many, fine, fibrous roots; coarse fragments make up less than 3 percent of soil volume; abrupt, wavy boundary.

A2g 8 to 18 inches, dark-gray (5Y 4/1) gravelly loamy coarse sand; some of the A1 layer intrudes into this horizon; single grain; very friable; few, fine, fibrous roots; coarse fragments make up 15 to 20 percent of soil volume; wavy boundary.

B2g 18 to 28 inches, dark grayish-brown (10YR 4/2 to 2.5Y 4/2) gravelly loamy sand; common to many, medium to coarse mottles of brown to dark brown (7.5YR 4/4) and few, medium mottles of dark yellowish brown (10YR 4/4) to olive brown (2.5Y 4/4); pressed color is dark grayish brown (10YR 4/2); massive but with a tendency toward platiness; very few roots; coarse fragments, mainly gravel ranging from 1/4 to 1 inch in diameter make up 30 percent of soil volume; also fragments of stone capped with very fine sand, silt, and possibly clay; abrupt wavy boundary.

Cg 28 to 34 inches +, olive-gray (5Y 5/2) gravelly loamy coarse sand; common, medium, distinct mottles of dark yellowish brown (10YR 4/4); massive, breaking to single grain; nonsticky, nonplastic; coarse, subangular fragments as much as 1 1/2 inches in diameter make up 15 to 20 percent of soil volume.

Remarks: A few cobbles and large stones consisting mainly of fine-grained granite occur throughout the profile.

*Temperature data from Worcester.

Climatic data (Ware, Mass.*)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	26	26	35	46	57	66	71	69	62	52	40	29	48
Mean precipitation, 1931-52 (inches)	3.3	2.8	3.5	3.1	3.8	4.7	4.2	3.7	4.1	2.7	3.7	3.2	42.7

Annual precipitation more than 30.8 and less than 54.6 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	C/N (k)	Free iron oxides Fe_2O_3 %
0-8	A1	4.4	14.3	10.0	17.0	11.4	34.1	8.8	39.8	14.1	35		8.86	20	0.3
8-18	A2g	17.9	28.2	13.5	15.3	7.9	14.0	3.2	22.2	6.6	3		.20	11	.5
18-28	B2g	8.3	16.0	13.2	25.0	16.3	19.4	1.8	40.7	7.3	26		.04	13	.2
28-34+	Cg	9.7	25.1	16.8	22.6	10.6	12.3	2.9	27.4	5.8	41		.11	--	.6

Particle size distribution (mm.) (%) Pipette and hexametaphosphate.

Cation exch. cap. (b)	Ca	Mg	H*	Na	K	Base sat. % (b)	pH 1:1	Base sat. % (s)	Cation exch. cap. (s)	Moisture tensions 1/10 atmos. %	15 atmos. %	$CaCO_3$ equiv. % (n)
24.2	8.9	1.6	24.0	0.1	0.3	45	5.1	31	34.9	48.4	14.0	---
2.6	1.1	.2	1.7	<.1	.1	54	6.1	45	3.1	14.5	1.5	---
2.0	1.2	.2	1.2	<.1	<.1	70	6.7	54	2.6	10.0	.7	<1
2.0	1.1	.2	.8	<.1	<.1	65	6.3	62	2.1	8.5	1.3	---

Extractable cations, meq./100 gm.: Ca, Mg, H*, Na, K.

*Exchange acidity.

Profile No. 50

Area: Aleutian Islands, Alaska.
Vegetation: Crowberry, mosses, and sedges completely cover ground and boulders.
Parent material: Volcanic agglomerate and ash.
Topography: Flat ridgetop; upland.

O1 5 to 0 inch, dark reddish-brown peaty mat.
A11 0 to 5 inches, dark reddish-brown (5YR 2/2) or nearly black, humus-rich silty fine sandy loam; the slick, moist soil is held together by many roots.
A12 5 to 10 inches, dark reddish-brown (5YR 3/2) silty sandy loam; granular structure.
A13 10 to 15 inches, dark-brown (7.5YR 4/2) silty sandy loam.
C1 15 to 30 inches, horizontally streaked dark-brown (7.5YR 4/2) and yellowish-brown (10YR 5/4) silty fine sandy loam; the horizontal streaks suggest ash layers.
C2 30 inches +, yellowish-brown (10YR 5/4) silty sandy loam.

Climatic data (Adak, Alaska)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1943-59 (deg. F.)	33	33	34	37	40	44	49	51	48	42	37	34	40
Mean precipitation, 1943-59 (inches)	6.9	5.6	6.4	4.5	5.0	3.5	3.0	4.4	5.7	7.1	7.6	8.1	67.8

Annual precipitation more than 41.6 and less than 94.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % c	C/N k
0-5	A11	7.3	6.8	6.1	17.5	18.9	39.0	4.4		19.6	4		7.1	15
5-10	A12	10.1	9.3	5.5	13.2	13.4	44.1	4.4		26.8	5		13.3	26
10-15+	A13 and C1	3.6	7.5	8.2	18.1	18.2	42.5	1.9		22.9	0.5		4.83	15
30+	C2	6.0	5.8	6.9	21.9	12.6	42.4	4.4		28.0	4		3.58	16

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. s	pH 1:1
51.3	2.1	1.7	47.0		0.4	8	4.1
79.1	1.1	.8	76.9		.3	3	4.8
29.9	.3	.2	29.3		.1	2	5.0
26.2	.3	.2	25.6		.1	2	5.2

*Exchange acidity.

Profile No. 52

Area: Hawaii Island, Hawaii.

Vegetation: Mostly bermudagrass (Cynodon dactylon); other are rattail (Sporobolus capensis), wild oat (Avena fatua), joee (Stachytarpheta cayannensis), ilima (Sida fallax), cactus (Opuntia megacantha), Formosan koa (Acacia confusa), aalii (Dodonaea eriocarpa).

Parent Material: Basic, volcanic ash.

Topography: 12 percent slope facing southwest, convex; intermediate slopes of Kohala mountain; elevation 3,220 feet.

A11 0 to 2 inches, very dark brown (7.5YR 2/2), dark brown (7.5YR 3/2) when dry; weak, medium and fine, platy, breaking to very fine, granular structure; soft, very friable, nonsticky, nonplastic; many roots; many, very fine, pores; abrupt, smooth boundary.

A12 2 to 5 inches, very dark brown (7.5YR 2/2), dark brown (7.5YR 3/3) when dry; weak, medium and fine, subangular blocky, breaking to weak, very fine, granular structure; slightly hard, very friable, nonsticky, nonplastic; many roots; many, very fine, interstitial pores; few, very hard pebble-size fragments of lava; clear, smooth boundary.

B21 5 to 8 inches, dark brown (7.5YR 3/2), brown (7.5YR 4/4) when dry; very weak, medium, fine subangular blocky structure; slightly hard, very friable, nonsticky, very slightly plastic; many roots; many, very fine, tubular pores; few, very hard, pebble-size fragments of lava; clear, smooth boundary.

B22 8 to 23 inches, dark brown (7.5YR 3/3), strong brown (7.5YR 5/6) when dry; very weak, coarse and medium, subangular blocky structure; soft, very friable, nonsticky, very slightly plastic; common roots; common, very fine pores and few, fine and medium, tubular pores; few, very firm, pebble-size fragments of lava; gradual, smooth boundary.

B23 23 to 35 inches, dark brown (7.5YR 3/3), brown (7.5YR 4/4) when dry; very weak, coarse and medium, prismatic structure; slightly hard, very friable, nonsticky, very slightly plastic; few roots; common, very fine pores and few, fine and medium, tubular pores; few, very hard, pebble- to cobble-size fragments of lava; clear, wavy boundary.

B24 35 to 47 inches +, dark brown (7.5YR 3/3), brown (7.5YR 4/4) when dry; very weak, coarse and medium, prismatic structure; slightly hard, very friable, very slightly sticky, very slightly plastic; few roots; common, very fine pores and fine, and few, medium and coarse, tubular pores; common, very hard, pebble- to stone-size fragments of lava, increasing in abundance with increasing depth.

Remarks: The soil is strongly magnetic throughout the profile.

Climatic Data (Kamuela, Hawaii)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1928-52 (deg. F.)	63	63	62	63	64	65	66	67	67	67	66	64	65
Mean precipitation, 1919-52 (inches)	4.9	3.7	4.9	4.6	2.8	2.0	2.9	2.9	1.9	2.4	3.6	4.4	40.9

Annual precipitation more than 20.9 and less than 60.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) u	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-2	A11	1.0	1.7	2.5	17.4	26.4	47.0	4.0	53.7	32.5	--		13.00	11	8.2
2-5	A12	.7	1.0	2.2	22.9	24.0	48.8	.4	68.3	21.6	--	0.71	5.06	8	10.7
5-8	B21	Silt and clay flocculated out of sample.									--		4.76	9	12.2
8-23	B22	1.1	1.5	2.7	23.1	25.2	43.8	2.6	56.8	30.4	--		4.30	11	12.3
23-35	B23	1.0	1.2	2.1	12.3	21.6	56.7	5.1	49.7	37.7	--	.66	3.21	12	13.2
35-47+	B24	1.1	1.3	1.8	9.5	23.5	58.2	4.6	48.0	40.5	--		2.87	11	14.2

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H**	Na	K	pH 1:1	pH 1N KCl 1:1	Base sat. % s	Field moisture %	Moisture tensions: 1/3 atmos. %	15 atmos. %	Elemental analyses* (mols/100 gm.): SiO2 g	Al2O3 g	Fe2O3 g	SiO2/Al2O3 & Fe2O3
80.8	34.4	6.6	33.9	0.36	5.51	6.2	5.7	58		47.1	29.9	0.4603	0.2064	0.0819	1.60
71.8	32.8	7.2	25.7	.27	5.81	7.5	6.6	64	21.9	41.5	29.1	.4759	.2464	.0966	1.39
74.1	37.7	5.7	24.2	.27	6.26	7.6	6.9	67		46.1	32.8	.4736	.2543	.1009	1.33
80.8	43.4	7.3	23.3	.39	6.42	7.6	6.8	71		61.4	48.3	.4789	.2543	.1079	1.32
90.8	32.9	22.6	31.7	1.17	2.47	7.4	6.7	65	43.8	77.4	59.2	.4233	.2637	.1172	1.11
79.2	33.5	13.2	27.8	.97	3.71	7.4	6.7	65		82.1	60.8	.4133	.2653	.1251	1.06

*Elemental analyses by Univ. Hawaii Dept. Agronomy and Soil Science, Hawaii Agr. Expt. Sta., Honolulu.
**Exchange acidity.

Profile No. 53

Area: Hawaii Island, Hawaii.
Vegetation: Sugar cane; (natural) Ohia, tree-fern.
Parent material: Basic, volcanic ash.
Topography: 3 percent slope toward east; undulating to rolling, low, windward, slopes of Mauna Kea; 350 feet elevation.

Ap 0 to 16 inches, dark-brown (10YR 3/3) clay; mixed in cultivation with dark reddish-brown (5YR 3/4), weak, medium, subangular blocky, breaking to weak, very fine and fine, granular structure; friable, sticky, plastic; moderately smeary; abundant roots; many very fine and fine pores; few, firm, ash nodules; abrupt, smooth boundary.

B21 16 to 21 inches, dark reddish-brown (5YR 3/3) clay; reddish-brown (5YR 4/4) streaks on ped faces; weak, medium and moderate, very fine, subangular blocky structure; friable, sticky, plastic; smeary; abundant roots; many very fine and fine, common, medium, and few, coarse, tubular pores (see Remarks); thick, gelatinous films on ped faces; few, firm, smeary, ash nodules; abrupt, smooth boundary.

B22 21 to 23 inches, like B21 but dark reddish-brown (2.5YR 3/4); plentiful, roots.

A1b1 23 to 26 inches, dark-brown (7.5YR 3/2) clay; reddish-brown (5YR 4/4) streaks on ped faces; small pockets of dark reddish brown (2.5YR 3/3); weak, fine and medium, prismatic, breaking to moderate, very fine, subangular blocky structure; fine roots; gelatinous films on ped faces; few, firm, ash nodules; abrupt, smooth boundary.

B21b1 26 to 30 inches, dark reddish-brown (5YR 3/4) clay; reddish-brown (5YR 4/4) streaks on ped faces; small pockets of dark reddish brown (2.5YR 3/4) and dark brown (10YR 3/3); weak, fine and medium, prismatic, breaking to moderate, very fine, subangular blocky structure; friable, sticky, plastic; smeary; plentiful, fine roots; gelatinous films on ped faces; few, firm, ash nodules; abrupt, smooth boundary.

B22b1 30 to 32 inches, like B21b1 horizon but dark reddish brown (2.5YR 3/4); small pockets of dark brown (7.5YR 3/2); weak, medium, subangular, breaking to moderate, fine, subangular blocky structure.

A1b2 32 to 33 inches, dark-brown (7.5YR 3/2) clay; reddish-brown (5YR 4/4) streaks on ped faces; small pockets of 5YR 3/4; moderate, very fine, subangular blocky structure; friable, sticky, plastic; smeary; few, fine roots; thick, gelatinous films on ped faces; few, firm, ash nodules; abrupt, smooth boundary.

B21b2 33 to 37 inches, dark reddish-brown (5YR 3/4) clay; reddish-brown (5YR 4/4) streaks on ped faces; weak, fine, and medium prismatic, breaking to moderate, very fine, subangular blocky structure; friable, sticky, plastic; smeary; few roots; thick, gelatinous films on ped faces; few, firm, dark reddish-brown (2.5YR 3/4), ash nodules; clear, smooth boundary.

B22b2 37 to 49 inches, like B21b2 except has small pockets of dark brown (7.5YR 3/2) and numerous pockets of strong, very fine, subangular blocky structure.

Remarks: Many, very fine and fine, common, medium pores and a few coarse, tubular pores below 21 inches.

Climatic data (Hilo, Hawaii)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	70	71	71	72	73	74	75	75	75	75	73	71	73
Mean precipitation, 1921-50 (inches)	14.1	9.5	15.7	13.3	9.0	6.8	9.9	11.9	10.4	11.0	12.4	16.0	140.0

Annual precipitation more than 94.8 and less than 185.2 inches during 9 years out of 10.

Depth, inches	Horizon	B. D. (gm. per cc.) c	Organic matter C % w	Organic matter C/N k	Free iron oxides Fe_2O_3 %	Field H_2O %	Moisture tensions 1/3 atmos. %	Moisture tensions 15 atmos. %
0-16	Ap	0.33	5.30	13	22.0	312.8	110	69
16-21	B21	--	3.06	14	23.2	--	156	105
21-23	B22	--	2.00	16	26.9	--	104	99
23-26	A1b1	--	3.23	15	22.8	--	215	123
26-30	B21b1	--	3.08	14	25.0	--	202	124
30-32	B22b1	--	2.26	14	26.0	--	179	105
32-33	A1b2	--	2.28	14	23.6	--	168	99
33-37	B21b2	--	2.90	14	24.4	--	230	129
37-49	B22b2	.54	3.23	14	25.3	114.1	283	149

Cation exch. cap. s	Extractable cations, meq./100 gm. Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	pH 1N KCl	Elemental analyses (mols/100 gm.)** SiO_2 g	Al_2O_3 g	Fe_2O_3 g
67.6	2.0	1.8	63.6	0.07	0.14	6	5.8	5.6	0.2097	0.2386	0.1726
68.4	2.2	.6	65.5	.04	.06	4	6.1	6.2	.1461	.3375	.1644
54.2	1.8	.3	52.1	.02	.02	4	6.4	6.5	.1218	.3696	.1626
66.6	2.4	.3	63.8	.07	.03	4	6.3	6.4	.1637	.3351	.1644
66.7	1.3	1.0	64.4	.03	.03	4	6.2	6.3	.1491	.3343	.1654
59.2	1.2	.3	57.6	.03	.03	3	6.4	6.5	.7351	.3532	.1679
57.0	1.4	.3	55.2	.03	.03	3	6.4	--	.1567	.3477	.1629
57.1	1.8	.4	54.8	.04	.07	4	6.3	6.4	.1897	.3210	.1614
67.6	2.4	.4	64.7	.04	.04	4	6.3	6.3	.1937	.3257	.1713

*Exchange acidity. **Analyses by Univ. Hawaii Dept. Agron. and Soil Sci., Hawaii Agr. Expt. Sta., Honolulu.

Profile No. 54

Area: Barrow, Alaska.

Vegetation: Nearly bare soil is partly covered by lichen and partly by prostrate willow about 3 or 4 inches high, sedges, and other arctic plants.

Parent material: Unconsolidated mixtures of sand, silt, and clay.

Topography: Gently sloping; microrelief is flattened, puffed spots or raised polygons, about 20 feet wide, separated by shallow troughs about 2 feet lower; profile is from a raised polygon.

O1 1 to 0 inch, intermittent mat of roots and stems.

A11 0 to 3 inches, dark reddish-brown (5YR 3/3) coarse sandy loam, rich in humus; abundant, fine roots.

A12 3 to 11 inches, dark reddish-brown (5YR 3/3) loam or sandy clay loam, rich in humus; cold and viscous on July 12; only a few living roots.

A13f 11 to 12 inches, very dark-brown to black coarse sandy loam, rich in humus; mottled and streaked with nearly white ice; upper part of solidly frozen layer.

Climatic data (Barrow, Alaska)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	-15	-18	-15	0	19	34	40	38	31	17	1	-10	10
Mean precipitation, 1921-50 (inches)	0.2	0.2	0.1	0.1	0.1	0.3	0.8	0.8	0.6	0.5	0.3	0.2	4.1

Annual precipitation more than 1.2 and less than 7.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate										B.D. (gm. per cc.)	Organic matter by H_2O_2 %	C/N
		Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2			
0-3	A11	17.1	15.4	12.8	15.5	9.9	17.6	11.7		4.6	1		16.9	
3-11	A12	.9	1.6	1.9	22.3	22.2	27.0	24.1		12.2	1		14.0	
11-12	A13f	15.4	17.4	12.1	5.3	14.4	20.8	14.6		9.3	3		30.0	

Cation exch. cap.	Extractable cations, meq./100 gm.					Base sat. s	pH 1:1
	Ca	Mg	H*	Na	K		
31.3	4.5	4.6	22.0		0.2	30	5.4
36.7	4.8	5.1	26.4		.4	28	5.2
53.9	11.9	10.8	29.7		1.3	45	5.4

*Exchange acidity.

Profile No. 55
Area: Blount County, Tennessee.
Vegetation: Grass, chiefly mountain oatgrass, scattered hardwoods, and old dead chestnut trees.
Parent material: Residuum from slate or shale.
Topography: Gently sloping ridge between a knoll and deeply dissected area.

A11 0 to 3 inches, black (10YR 2/1) to very dark brown (10YR 2/2) loam; fine, granular structure; very friable; abundant, fibrous, grass roots; very porous; abrupt, smooth boundary.
A12 3 to 8 inches, black (10YR 2/1) to very dark brown (10YR 2/2) loam; moderate, medium and coarse, granular structure; very friable; plentiful fine roots; porous; abrupt, smooth boundary.
A3 8 to 13 inches, dark-brown (7.5YR 3/2), heavy loam or clay loam; weak, medium, subangular blocky structure; friable; plentiful fine roots; porous; clear, smooth boundary.
B2 13 to 21 inches, brown (10YR 4/3) silt loam; weak, medium, subangular blocky structure; friable; plentiful fine roots; gradual, smooth boundary.
B3 21 to 32 inches, brown (10YR 4/3) fine loam or silt loam; weak, medium, granular structure; friable; a few, fine, dark-brown lines along small root channels; few, fine roots; gradual, smooth boundary.
C 32 to 38 inches +, grayish-brown (10YR 5/2) to brown (10YR 5/3) silt loam; has slight olive cast; structureless; friable; a few fragments of black shale or slate.

Climatic data (Gatlinburg, Tenn.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1933-52 (deg. F.)	40	40	48	57	65	73	74	73	68	58	46	39	57
Mean precipitation, 1933-52 (inches)	4.9	4.7	5.7	4.1	4.2	4.9	6.8	5.8	2.9	2.9	3.3	4.1	54.2

Annual precipitation more than 42.2 and less than 66.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N	Free iron Fe_2O_3 %
0-8	A11 and A12	10.3	7.9	5.2	8.4	5.9	38.9	23.4	22.2	27.4	<1		9.47		3.84
8-13	A3	3.2	9.7	5.7	8.1	6.2	39.2	27.9	20.7	29.2	<1		4.73		3.68
13-21	B2	2.2	9.1	5.7	8.4	7.2	52.4	15.0	26.2	38.2	<1		1.68		3.68
21-32	B3	2.0	9.0	5.4	8.6	7.4	48.0	19.6	25.2	35.1	<1		1.03		3.12
32+	C	2.2	3.9	2.6	6.7	14.5	60.8	9.3	50.4	29.4	14.0		.30		2.40

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. %	pH 1:1
38.3	0.1	0.3	37.7	<0.1	0.2	2	4.4
30.2	.2	.3	29.6	<.1	.1	2	4.6
21.4	.2	.2	20.9	<.1	.1	2	4.6
17.9	.2	.3	17.4	<.1	<.1	3	4.8
8.9	.3	.0	8.6	<.1	<.1	3	4.8

*Exchange acidity.

Profile No. 56

Area: Multonomah County, Oregon.
Vegetation: Cutover land covered by second-growth alder and Douglas-fir.
Parent material: Somewhat micaceous loess.
Topography: High, gently sloping upland that has micro-undulating relief; elevation 420 feet.

A1 0 to 5 inches, very dark grayish-brown (10YR 3/2) silt loam, dark grayish brown (10YR 5/2) when dry; few, fine, distinct, threadlike mottles of brownish yellow (10YR 5/6); moderate, medium, granular structure; hard, friable, slightly plastic; many, prominent, dark wormcasts; gradual boundary.

B21 5 to 12 inches, brown (10YR 4/3) silt loam, pale brown (10YR 6/3) when dry; few, fine, distinct, threadlike mottles of brownish yellow (10YR 5/6); moderate, coarse, granular structure; hard, friable, slightly plastic; common, iron and manganese concretions 2 to 5 millimeters in diameter.

B22 12 to 20 inches, brown (10YR 5/3) silt loam, very pale brown (10YR 7/3) when dry; many, coarse mottles of strong brown (7.5YR 5/6); weak, fine, subangular blocky structure; hard, firm, plastic; splotches and nearly black concretions of iron and manganese.

C1x 20 to 33 inches, yellowish-brown (10YR 5/4) silt loam, very pale brown (10YR 7/4) when dry; many, coarse mottles of strong brown (7.5YR 5/6) and nearly black; streaks of very pale brown (10YR 7/3); brittle when moist; gradual boundary.

C2x 33 to 45 inches, similar to the C1x horizon but is slightly lighter in color; medium, subangular blocky structure, and somewhat less brittle when moist.

C3 45 to 60 inches +, strong-brown (7.5YR 5/6) silt loam; white (10YR 8/2) mottles; massive; firm, nonplastic; micaceous.

Climatic data (Headworks, Oregon*)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	37	40	44	50	56	60	65	64	61	53	44	40	51
Mean precipitation, 1931-52 (inches)	11.2	9.5	9.9	5.6	5.2	4.5	1.1	1.4	3.9	8.1	12.0	13.4	85.7

Annual precipitation more than 49.1 and less than 122.3 inches during 9 years out of 10.

*8 miles NE of town of Sandy

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C %	Organic matter C/N	Free iron oxides Fe_2O_3 %
0-5	A1	1.7	2.0	1.0	2.4	14.4	64.2	14.3							1.92
5-12	B21	.8	1.1	.8	2.0	14.3	65.4	15.6							1.60
12-20	B22	1.2	2.3	1.1	2.2	14.4	64.0	14.8							2.32
20-33	C1x	.9	2.0	1.0	1.9	16.0	65.0	13.2							2.72
33-45	C2x	.2	1.0	.7	1.8	19.8	62.3	14.2							2.00
45-60+	C3	.1	.7	.7	2.0	16.4	59.1	21.0							2.16

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Clay minerals: Mi %	K %	Vm	Q
14.3	6.5	1.4	5.3	0.8	0.3	63	5.2	2	18	xx	x
18.5	3.4	.8	13.4	.5	.4	28	5.4	1	20	xx	x
14.0	2.4	.9	10.2	.2	.3	27	5.4	<	22	xx	x
17.9	3.8	1.8	11.5	.5	.3	36	5.3	<	22	xxx	x
19.0	5.0	3.0	10.7	.1	.2	44	5.4	<	25	xx	-
20.5	7.0	4.5	8.4	.3	.3	59	5.6	8	25	xxxx	-

*Exchange acidity.

Chapter 11. Aridisols

The Aridisols are primarily soils of dry places. They have an ochric epipedon and one or more additional diagnostic horizons. These are cambic, argillic, natric, calcic, gypsic, and salic horizons and duripans. The Aridisols do not have a spodic or oxic horizon, nor do they have a mollic or umbric epipedon.

Included in Aridisols are most soils that have been called Desert soils and Red Desert soils, Sierozems, and Reddish Brown soils, and Solonchak. Some of the Regosols, and Lithosols of dry climates, and some Brown soils and Solonetz are also included.

The Aridisols include soils having one of the following combinations of properties.

1. Soils that are usually dry when not frozen and not irrigated and that have a calcic horizon that immediately underlies a calcareous ochric epipedon.
2. Soils that are usually dry when not frozen and not irrigated and that have an ochric epipedon and an argillic horizon.
3. Soils that are usually dry when not frozen and not irrigated, that have both an ochric epipedon and conductivity of the saturation extract greater than 1 millimho per cm. at 25° C. at some depth, and in addition, have one or more of the following: a cambic, calcic, gypsic or salic horizon, or a duripan that can be softened by a single treatment with acid followed by a single treatment with concentrated alkali.
4. Soils that are usually moist, and have no argillic or spodic horizon, but that have a calcic, gypsic, or salic horizon and, in addition, have conductivity of the saturation extract greater than 1 millimho per cm. at 25° C. at some depth.

The first three of the above combinations of properties are found in positions where there is normally no ground water. The fourth combination is normally found in positions that receive runoff or seepage. No hydromorphic suborder has been defined, because those Aridisols that show mottling with low chromas, or that have blue hues, also show, as a rule, a salic horizon, duripan, or other distinctive horizon.

ORTHIDS (4.1)

The Orthids have no argillic, spodic, oxic, or natric horizon. Rather, they have an ochric epipedon and a cambic horizon, a duripan, or an illuvial horizon of water soluble material; namely, a calcic, gypsic, or salic horizon. The duripan, if present, can be softened by a single treatment with acid followed by a single treatment with concentrated alkali.

The definitions of the great groups and subgroups and the key that follow are presented tentatively, as they have not been tested. It should be noted that there are a number of Orthids formed from ash and pumice. These have many of the properties of the Andepts. Mechanical analyses have no meaning, as the clays do not disperse. Duripans may be present or absent. The classification of these soils is not being attempted at this writing, and the reader should bear in mind that the key and discussion that follow assume that allophane, ash, and pumice are minor in amount. It should also be noted that the name "Orthid" can combine improperly in some classes to give the name "orthic" to an intergrade subgroup. Hence, one of the names will probably be changed.

Key to Orthids

4.11 Orthids with a cambic horizon that has less than 5 percent carbonates if underlain by a calcic horizon, and with no duripan that has its upper boundary within 50 cm. (20 inches) of the surface.

Camborthid, p. 157

4.110 Camborthids with no calcic or gypsic horizon having an upper boundary within 50 cm. (20 inches) of the surface, and having no duripan.

Orthic Camborthid, p. 157

4.11-4.13 Other Camborthids with a calcic or gypsic horizon, and lacking a duripan.

Calcic Camborthid, p. 157

4.11-4.12 Other Camborthids with a duripan.

Duric Camborthid, p. 157

4.12 Other Orthids that have a duripan.

Durorthid, p. 157

4.120 Durorthids with no mottles with chromas of 2 or less within 1 meter of the surface.

Orthic Durorthid, p. 157

4.12 Other Durorthids with mottles that have chromas of 2 or less within 1 meter of the surface.

Aquic Durorthid, p. 157

4.13 Other Orthids with a calcic or gypsic horizon, or both, but no overlying salic horizon.

Calcorthid, p. 157

4.130 Calcorthids that are calcareous to the surface and have no mottles with chromas of 2 or less within 1 meter of the surface.

Orthic Calcorthid, p. 158

4.13 Other Calcorthids that have mottles with chromas of 2 or less within 1 meter of the surface.

Aquic Calcorthid, p. 158

4.14 Other Orthids with salic horizon.

Salorthid, p. 158

Camborthids (4.11)

The Camborthids are soils that are usually dry, and that have an ochric epipedon and a cambic horizon. They may have, below the cambic horizon, a calcic or gypsic horizon, or a duripan. They include many soils that have been called Desert soils, Reddish Desert soils, and Sierozems in the United States.

There has been little discussion of the properties expected in a cambic horizon in soils of arid regions. Attention has so far been concentrated on more obvious horizons--the calcic, gypsic, salic, natric, and argillic horizons.

It was pointed out in the discussion of cambic horizons in Chapter 5, that rock structure should be absent, that peds should be present if structure is suitable, and that other evidences of alteration should be present in cambic horizons. The latter evidences included formation of clay, redistribution of carbonates, and chemical weathering to liberate iron from combined forms.

In Aridisols the cambic horizon should lack rock structure, including fine stratifications, and should have peds, normally prisms or blocks. Calcareous parent materials should show evidences of at least partial leaching, but there has been no discussion of how much redistribution should be expected. If carbonates are present, amounts should be small. The figure of 5 percent is used very tentatively for soils that have an underlying calcic horizon. Ten percent perhaps could be used, but the limit probably should not be much larger than 10 percent, and probably should not be that high if there is an underlying calcic horizon at a shallow depth.

There has been a strong tendency for soil morphologists in the United States to consider the cambic horizon a part of an A horizon, perhaps because it commonly occurs at depths where an A2 horizon is expected in soils of humid regions. Consequently, it is possible that the cambic horizons have been generally overlooked in a search for the more obvious argillic, natric, and calcic horizons. A cambic horizon must extend below 17.5 cm. (7 inches) to be diagnostic, for those horizons apt to be obliterated by plowing are not used for classification in this system.

Orthic Camborthids (4.110)

This subgroup includes Camborthids that have no calcic or gypsic horizon with an upper boundary within 50 cm. (20 inches) of the surface. It is possible that 40 cm. (16 inches) or some other limit will be better than 50 cm. No duripans are present unless they are in buried soils.

Profile 57, page 160, is used here for lack of a better example of the Orthic Camborthid. This soil is being cultivated and irrigated, and the upper part of the cambic horizon has been mixed in the plow layer. Normally, the upper boundary of the cambic horizon is at depths of 1 to 3 inches. In profile 57, the cambic horizon lies below the plow layer, from 13 to 20 inches. The ca horizon, sampled from 20 to 52 inches, may include a calcic horizon, but the presence or absence of a calcic horizon at this depth is not considered to have significance, even at the series level. The presence or absence of the ca horizon is much more significant than the absolute amount of calcium carbonate. Profile 57 has an ochric epipedon, but the color is darker than normal, and it would have a mollic epipedon if it had more organic carbon. Possibly, profile 57 should represent a Mollic Camborthid, a subgroup not yet defined.

Calcic Camborthids (4.11-4.13)

This subgroup includes Camborthids that have a calcic horizon with an upper boundary within 50 cm. (20 inches) of the surface. No duripan is present at any depth within the soil.

Duric Camborthids (4.11-4.12)

This subgroup includes Camborthids that have a duripan with its upper boundary deeper than 50 cm. (20 inches).

Durorthids (4.12)

The Durothids are usually dry when not frozen, unless they are being irrigated. They may have a cambic horizon if the top of the duripan is less than 50 cm (20 inches) from the surface. The duripan may begin at depths greater than 50 cm. if no cambic horizon is present. Such situations occur in highly calcareous alluvium.

The Durorthids are normally found on fans, or river terraces, under a sparse xerophytic vegetation. Some are salty and have an occasional high water table. Others have no ground water at present, although it is possible that ground water was present in Pleistocene time. All that have been studied contain volcanic ash or glass.

Orthic Durorthids (4.120)

This subgroup includes the Durorthids that have no evidences of ground water in the form of mottles with chromas of 2 or less above a depth of 1 meter.

Profile 58, page 161, is an example of this subgroup. A duripan in this soil occurs between 14 and 16 inches. A second indurated horizon occurs between 21 and 30 inches. It is common to find such multiple pans. It is possible but not certain that the lower pans are buried horizons. The horizons from a depth of 8 to 14 inches, and the horizons between the pans, show weak cementation. The large amounts of extractable sodium are normal. The low carbonate content is accidental—the result of a lack of lime in the rocks from which the fan sediments were derived. Other soils with duripans may have large amounts of calcium carbonate.

Aquic Durorthids (4.12-   )

This subgroup is provided for Durorthids that have mottles with chromas of 2 or less within a depth of 1 meter.

Calcorthids (4.13)

The soils of this great group may be considered the arid equivalents of the Rendzinas (Rendolls). They have formed in parent materials that apparently have so much calcium carbonate or gypsum that the rainfall is unable to remove it, even from the surface horizon. The soils have no duripan but have an ochric epipedon that contains calcium carbonate, gypsum, or both. In addition, they have a calcic or gypsic horizon that begins at a shallow depth. The soils may be either usually dry or usually moist. If the latter, they must have a horizon at some depth in which the conductivity of the saturation extract is more than 1 millimho per cm. at 25° C. There may be a salic horizon at depth, but not overlying the calcic or gypsic horizons.

The calcic horizon may be soft, or indurated. In this approximation, it is proposed that the distinction between indurated and soft calcic horizons be a basis for distinguishing families rather than subgroups or great groups. Opinions on the wisdom of this are not unanimous.

Orthic Calcorthids (4.130)

The Orthic Calcorthids have a calcic or gypsic horizon with an upper boundary within 50 cm. (20 inches) of the surface, and have no mottles with chromas of 2 or less, and no unmottled horizons with chromas of less than 1, or with hues bluer than 10Y within a depth of 1 meter. Profile 59, page 162, is an example of an Orthic Calcorthid with a calcic horizon. Profile 60, page 163, is an example with a gypsic horizon.

Aquic Calcorthid (4.13-   )

This subgroup is provided tentatively for Calcorthids that have mottles with chromas of 2 or less within a depth of 1 meter, or that have unmottled horizons with chromas of less than 1, or that have horizons with hues bluer than 10Y within a depth of 1 meter.

Salorthids (4.14)

The Salorthids are the Orthids that have a salic horizon at a depth of less than 50 cm. (20 inches). No subgroups are proposed. The Salorthids have been called Solonchaks. When dry at the surface they usually have a thin or thick salt crust. Vegetation is sparse, and salt loving. Salorthids are commonly found in playas (intermittent lakes) but are also found on terraces, fans, and deltas. Where salts have come to the surface by capillary rise, the soil just below the surface is very fluffy, and there is a microrelief of 15 to 30 cm. (6 to 12 inches). These have been called "Puff Solonchaks."

Profile 61, page 164, is an example of a Salorthid.

ARGIDS (4.2)

The Argids are Aridisols that have an argillic horizon. They must be dry most of the time that they are not frozen, unless they are being irrigated. It perhaps needs emphasis here that the soil, and not just the solum, must be dry. For the most part, the substratum below the soil is also dry. Argids must have an ochric epipedon and an argillic or natric horizon. They may also have a calcic, gypsic, or salic horizon or a duripan.

Most commonly, the native vegetation consists of scattered, xerophytic, woody or succulent plants, and annual grasses and forbs. Toward the margin of the desert, grasses become dominant but as a rule do not form a sod. Rather they seem to have been scattered perennial or annual plants.

Some of the Argids are on old land surfaces, perhaps early Pleistocene. Others, particularly those with a natric horizon, are found on much younger surfaces.

Bedrock (R) may be deep or shallow. Where shallow, ruptic intergrades with Entisols or even with "not-soil" are common. No subgroup definitions are attempted at this time.

Key to Argids

4.21 Argids that have an argillic horizon but do not have a natric horizon or duripan.

Haplargid, p.

4.22 Other Argids with an argillic horizon and a duripan, but with no natric horizon.

Durargid, p.

4.23 Other Argids that have a natric horizon but do not have a duripan.

Natrargid, p.

4.24 Other Argids with a natric horizon and a duripan.

Nadurargid, p.

Haplargids (4.21)

The Haplargids have an ochric epipedon and an argillic horizon, but no natric horizon or duripan. Unless irrigated, they are usually dry throughout the soil, and the layers immediately below the soil are normally dry at all times. Usually, but not always, the Haplargids have a ca horizon below or in the base of the argillic horizon. Haplargids have been called Desert soils, Red Desert soils, Sierozems, and Brown soils, but not all soils called by these names are Haplargids.

The Haplargids are not uncommon on the rocky slopes above the desert fans, and on the oldest parts of the fans. So far as is known, the land surfaces on which Haplargids are found are older than the last glacial substage. They have presumably had, at some time, a more humid climate than the present. The evidence, however, is scattered and incomplete.

Profile 62, page 165, is an example of a Haplargid that should be considered orthic. The thin A horizon, the reddish hues of the argillic horizon, and the deep ca horizon are typical. The high content of exchangeable sodium below the ca horizon is also characteristic. It means only that the more soluble salts and the more easily exchangeable ions have been carried to the greatest depths.

The reader should beware of attaching high significance to the climatic data. Rainfall is erratic and often comes in heavy showers with much runoff. The Haplargids on the fans may receive far more moisture in some years than the climatic record would suggest.

As effective moisture increases, the upper horizons become darker. The content of organic matter typically increases faster in the argillic horizon than in the A, which accentuates the slight increase of organic carbon in the argillic horizon (see profile 62). With increasing moisture, the Haplargids grade to either Typustalfs or Argustolls. Definitions of these subgroups have not been written.

Durargids (4.22)

The Durargids are Argids that have an argillic horizon and an underlying duripan. The duripan seems the same as that in profile 58, page 161, but it underlies an argillic horizon.

Natrargids (4.23)

The Natrargids have an ochric epipedon and a natric horizon. Unlike the Haplargids they may be usually moist, but conductivity of the saturation extract must be 1 millimho or more at some depth. The Natrargids are often found on the lower slopes of fans, where they receive runoff from higher areas. The age of the fans may be late Wisconsin, or possibly even more recent.

Profile 63, page 166, is an example of an Orthic Natrargid. Mechanical analyses and organic carbon values are not available for this profile, but a profile collected a few feet away has been analyzed, and the data are included to document the description. Horizon depths vary slightly, but the samples came from adjacent pedons. Profile 63 was collected between creosotebushes (Larrea sp.). Salts and exchangeable sodium between the bushes and 2 feet from the nearest creosotebush are lower than they are under the bushes. To a depth of 2 feet, the salt content under the creosotebush was about twice that of the profile between the bushes. Exchangeable sodium to a depth of 18 inches was about 50 percent higher under the creosotebush than between the bushes.

The carbonates in the A and in the natric horizon are typical, as is the increase in organic matter in the natric horizon. Because the Natragids are most often low on the fans, high content of silt and clay is very common but is not essential to the orthic subgroup.

Nadurargids (4.24)

The Nadurargids have an ochric epipedon, and have a natric horizon and a duripan, in that sequence. The duripan is similar to that in profile 58; it does not soften in acid, though it is usually partially cemented with calcium carbonate.

Profile 64, page 167, is given as an example of the Nadurargids, for lack of a better one. The massive, hard, A horizon is not at all typical of this class, and it is not certain that the profile is orthic. The natric horizon and the duripan are representative. The distribution of carbonates is also representative.

The reader is again cautioned that the climatic data must be interpreted with caution. The rainfall is highly variable from year to year, and these soils receive additional water from higher land.

Profile Descriptions for Chapter 11

(Colors are for moist soil unless indicated otherwise)

Profile No. 57

Area: Luna County, New Mexico.
Vegetation: Cotton.
Parent material: Mixed acid, igneous alluvium.
Topography: Less than 1 percent slope; alluvial fan or plain; elevation 4,300 feet.

Ap 0 to 13 inches, dark yellowish-brown (10YR 3/4) clay loam, light brownish gray (10YR 6/2) when dry; weak, coarse, blocky structure; hard, friable; plentiful roots; a 4-inch tillage pan is about 7 inches below the surface in the bottom of furrow; calcareous; clear boundary.

B 13 to 20 inches, dark yellowish-brown (10YR 4/4) silty clay loam, brown (10YR 5/3) when dry; weak, fine blocky structure; firm; plentiful roots; calcareous; abrupt boundary.

C1ca 20 to 52 inches, dark-brown (7.5YR 3/2) silty clay loam, pinkish-gray (7.5YR 7/2) when dry; weak to moderate, fine, blocky structure; firm; plentiful roots; calcareous; clear, smooth boundary.

C2ca 52 to 62 inches, dark-brown (7.5YR 3/2) silty loam; pinkish-gray (7.5YR 7/2) when dry; moderate, fine, blocky structure; firm; calcareous; abrupt boundary.

IIC3 62 to 70 inches, dark-grayish brown (10YR 4/2) sandy loam, white (10YR 8/2) when dry; weak, coarse, blocky structure; very few pores; calcareous; abrupt boundary.

IIIC4 70 to 98 inches, light brownish-gray (10YR 6/2) gravelly sandy clay loam, light gray (10YR 7/2) when dry; massive; thin, cemented layers; lime-coated gravel fragments from quartz, and from gray, acid, igneous and metamorphosed rocks; quartz dominant some of which is pink; calcareous; abrupt boundary.

IVC5 98 inches +, dark reddish-gray (5YR 4/2) loam; pinkish gray (5YR 6/2) when dry; abrupt boundary.

Climatic data (Deming, New Mexico)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	40	45	51	59	68	77	80	79	73	62	49	43	60
Mean precipitation, 1931-52 (inches)	0.5	0.6	0.3	0.3	0.3	0.6	1.5	1.6	1.6	0.9	0.4	0.7	9.2

Annual precipitation more than 5.0 and less than 13.4 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-13	Ap	0.1	0.7	2.3	11.5	9.7	36.8	38.9	27.9	26.9	----		0.47	9	Tr.
13-20	B	.0	.3	1.2	8.1	6.1	48.5	35.8	20.4	40.2	----		.43	9	3.1
20-52	C1ca	.1	.4	.5	1.6	2.3	66.2	28.9	11.6	58.0	----		.31	9	4.9
52-62	C2ca	.8	3.8	6.0	9.2	4.8	52.7	22.7	19.1	43.3	----		.16	5	11.4
62-70	IIC3	3.1	11.6	16.6	21.7	9.3	23.9	13.8	31.5	11.0	----		.08	4	7.6
70-98	IIIC4	15.6	35.8	23.1	15.4	2.6	3.9	3.6	9.3	3.3	32.6		.08	5	6.3
98+	IVC5	3.2	4.9	4.6	10.4	13.3	39.1	24.5	36.9	22.3	----		.16	6	.8

Cation exch. cap. h	Ca	Mg	H	Na	K	pH Sat. paste	pH 1:10	Exch. Na %	E. C. mmhos. per cm. 25°C.	Gypsum %	Saturation ext., soluble (meq./l.) Na	K	H_2O at sat. %
	Extractable cations, meq./100 gm.												
30.9	19.3	7.2		1.3	3.1	7.9	9.0	4.2	0.98	0.2	6.5	0.2	48
30.8	19.6	7.0		2.2	2.0	8.1	9.5	7.1	.95	.1	7.5	.2	50
32.8	18.7	5.7		5.6	2.2	8.5	9.9	17.4	1.37	.2	15.5	.7	46
31.3	17.5	6.0		6.5	1.6	8.6	9.9	20.8	1.11	.1	8.2	.5	42
13.7	5.6	2.2		5.0	1.0	8.6	9.9	36.5	1.38	.1	14.5	.2	31
4.8	2.6	.2		1.5	.4	8.9	9.8	31.2	1.08	.1	11.2	.5	29
28.7	18.0	7.2		2.6	.9	7.6	9.0	9.1	2.22	.2	22.5	.5	65

Profile No. 58

Area: Pershing County, Nevada.
Vegetation: Sparse cover of shadscale, budsage, and cheatgrass.
Parent material: Alluvium from mixed rocks.
Topography: 2 percent slope, facing northwest; alluvial fan; elevation 4,550 feet.

A11 0 to 3 inches, dark grayish-brown (10YR 4/2) silt loam, light brownish gray (10YR 6/2) when dry; weak, coarse, vesicular, platy structure; slightly hard, very friable, slightly sticky, slightly plastic; abrupt, smooth boundary.

A12 3 to 8 inches, brown (10YR 5/3) silt loam, very pale brown (10YR 7/3 when dry; strong, fine, platy structure; soft, very friable, nonsticky, nonplastic; abundant, fine, fibrous roots; many, fine pores; abrupt, smooth boundary.

?B 8 to 14 inches, grayish-brown (10YR 5/2) silt loam, very pale brown (10YR 7/3) when dry; massive, breaking to weak, medium and fine, granular structure; slightly hard, friable, nonsticky, nonplastic; many vesicles; many fine roots; very few, hard, cemented fragments that are as much as 1/32 of an inch in diameter; abrupt, smooth boundary.

C1m 14 to 16 inches, banded, very dark grayish-brown (2.5Y 3/2) and dark grayish-brown (10YR 4/2) silt loam, dark grayish brown (2.5Y 4/2) and light brownish gray (10YR 6/2) when dry; very hard, very firm, slightly sticky, slightly plastic; many vesicles; few, fine pores; abrupt, smooth boundary.

C2 16 to 18 inches, brown (10YR 4/3) loam, pale brown (10YR 6/3) when dry; very weak, coarse to medium, platy, breaking to weak, medium and fine, granular structure; soft, very friable, nonsticky, nonplastic; fine roots; many, small subangular concretions; clear, wavy boundary.

IIC3 18 to 21 inches, dark grayish-brown (2.5Y 4/2) coarse sandy loam; weak, medium, platy structure in the lower part; massive, breaking to weak, very fine, subangular blocky structure in the upper part; soft, very friable, nonsticky, nonplastic; fine roots; many, small, cemented fragments; few, white threads of lime; abrupt, smooth boundary.

IIC4m 21 to 25 inches, olive-brown (2.5Y 4/3) fine sandy loam, brown (10YR 5/3) to light olive brown (2.5Y 5/4) when dry; moderate, thick, platy, breaking to moderate, medium, subangular blocky structure; extremely hard, extremely firm, nonsticky, nonplastic; fine, horizontal roots between plates; few, fine pores some of which have lime coating; many, fine, threads of lime; abrupt, smooth boundary.

IIC5m 25 to 28 inches, olive-brown (2.5Y 4/3) fine sandy loam, brown (10YR 5/3) to light olive brown (2.5Y 5/4) wnen dry; moderate, medium and thick, platy, breaking to moderate medium, subangular blocky structure; extremely hard, extremely firm, nonsticky, nonplastic; fine roots between plates; common, fine pores; many, thin, horizontal, lime threads; abrupt, smooth boundary.

IIC6m 28 to 30 inches, like IIC5m horizon but has weak structure; vertical and horizontal threads of lime.

Climatic data (Winnemucca, Nev.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	28	35	39	47	56	64	74	70	60	49	38	30	49
Mean precipitation, 1921-50 (inches)	1.0	1.0	0.9	0.8	0.8	0.8	0.3	0.2	0.3	0.8	0.8	1.0	8.8

Annual precipitation more than 4.7 and less than 12.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Organic matter C % w	C/N k
0-3	A11	3.0	2.3	1.3	7.6	22.0	54.3	9.5	59.1	23.1	1	0.73	--	0.83	10
3-8	A12	2.7	2.0	.9	6.2	20.1	59.4	8.7	57.2	27.3	1	.67	--	.41	10
8-14	B	5.1	4.3	1.8	8.1	19.9	53.4	7.4	58.3	21.2	3	.83	--	.29	13
14-16	C1m	4.7	4.8	2.1	6.3	15.1	56.6	10.4	50.3	26.0	4	1.15	--	.23	--
16-18	C2	9.1	7.8	3.1	8.3	17.5	46.1	8.1	51.1	18.3	3	1.34	--	.34	--
18-21	IIC3	13.4	11.9	4.8	11.0	17.0	37.6	4.3	45.5	16.5	3	2.6	<1	.38	--
21-25	IIC4m	9.8	7.1	3.3	11.7	22.4	41.5	4.2	47.4	17.9	3	9.2	2	.33	--
25-28	IIC5m	13.2	8.8	3.6	11.1	20.2	38.7	4.4	50.6	16.5	5	12.9	3	.31	--
28-30	IIC6m	13.8	11.6	4.6	11.6	19.6	35.4	3.4	49.5	13.7	9	15.1	2	.26	--

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	pH 1:10	Exch. Na %	Sat. ext., soluble (meq./l.) Na	Ca+Mg	Moisture tensions 1/3 atmos. %	15 atmos. %	H_2O at sat. %
18.9	11.6	3.0		0.8	3.2	7.9	8.2	4	2.7	3.7	20.6	6.3	35.0
20.4	10.9	2.7		2.8	4.5	8.5	9.0	14	7.3	.9	19.0	6.6	24.7
16.5	6.9	2.1		4.7	1.9	8.7	8.9	28	8.3	1.2	15.8	5.6	22.6
18.2	6.4	2.2		7.5	.8	8.8	8.7	41	14.4	.6	13.8	6.8	17.7
20.3	5.7	1.8		9.7	.4	8.8	8.7	48	13.6	.5	13.5	6.3	39.1
22.6	14.1	2.2		14.2	.3	9.0	9.4	63	24.5	1.1	15.3	6.9	28.4
21.3	17.9	2.4		13.6	.3	8.7	9.6	64	89.0	3.6	15.8	6.7	31.4
20.3	16.9	2.4		13.2	.3	8.6	9.5	65	124.0	4.6	15.3	6.4	29.9
19.2	15.8	2.8		13.5	.3	8.6	9.3	70	147.0	5.7	14.7	6.0	30.0

Profile No. 59

Area: Beryl-Enterprise, Utah.
Vegetation: Sparse cover of sagebrush (*Artemesia tridentata*), galleta grass (*Hilaria jamesii*), and shadscale (*Atriplex confertifolia*).
Parent material: Alluvium originating mainly from rhyolite and partly from latite, andesite, and obsidian.
Topography: Gently sloping; alluvial fan; elevation 5,000 to 5,500 feet.

A11 0 to 1 inch, brown (7.5YR 5/4) loam, pink (7.5YR 7/4) when dry; very weak, thin, platy structure; soft, very friable, very firm; vesicular pores; calcareous.
A12 1 to 12 inches, brown (7.5YR 5/4) loam, pink (7.5YR 7/4) when dry; very weak, very fine, granular structure to massive; soft, very friable; calcareous.
C1ca 12 to 27 inches, pink (7.5YR 7/4) loam, pinkish white (7.5YR 8/2) when dry; massive; weakly cemented; calcareous.
C2 27 to 39 inches, brown (7.5YR 5/4) fine sandy loam; pink (7.5YR 7/4) when dry; massive; slightly hard, very friable; a moderate amount of gravel; calcareous.
IIC3 39 to 112 inches +, unconforming beds of sand and gravel of variable size and composition but all highly siliceous; single grained; very weakly calcareous; moderately alkaline.

Climatic data (Modena, Utah)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1930-52 (deg. F.)	25	31	38	47	55	63	72	70	62	50	37	29	48
Mean precipitation, 1930-52 (inches)	0.8	0.8	1.0	0.8	0.7	0.5	0.9	1.3	0.7	1.1	0.6	1.0	10.1

Annual precipitation more than 4.9 and less than 15.3 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
0-1	A11	---	---	---	---	---	---	---		---	0.0		1.04	9
1-12	A12	5.4	5.0	6.6	13.6	16.7	41.7	11.0		36.0	6.0		.71	9
12-27	C1ca	1.6	4.9	3.9	10.2	22.7	46.7	10.0		24.2	6.6		.37	11
27-39	C2	5.2	12.0	8.2	13.8	18.7	37.6	4.5		12.7	10.9		.13	---

Particle size distribution (mm.) (%) Pipette and hexametaphosphate

Cation exch. cap.	Extractable cations, meq./100 gm. Ca	Mg	H	Na	K	pH sat. paste	pH 1:5	$CaCO_3$ equiv. % v
						8.2	9.2	9.5
						8.3	9.5	10.8
						8.5	9.8	22.9
						8.3	9.7	2.0

Profile No. 60

Area: Clark County, Nevada

Vegetation: Very sparse cover (about 2 percent) of shrubs, consisting of creosotebush, 45 percent; shadscale, 40 percent; white bur-sage (Franseria sp.), 10 percent; catclaw, 5 percent; and a trace of jointfir.

Parent material: Medium-textured alluvium.

Topography: Approximately 1 percent slope, slightly convex, facing east; old terrace; elevation about 2,200 feet.

A1 0 to ½ inch, brown (7.5YR 5/4) fine sandy loam, pink (7.5YR 8/4) when dry; weak, medium, platy structure; soft, very friable; few roots; very few vesicular pores; calcareous, abrupt, smooth boundary.

C1cs ½ to 14 inches, pink (7.5YR 8/4) fine sandy loam, pinkish white (7.5YR 8/2) when dry; massive; soft, very friable; plentiful roots; large amount of gypsum; calcareous, abrupt, wavy boundary.

C2cs 14 to 27 inches, pink (7.5YR 8/4) loam, white (7.5YR 8/0) when dry; massive; hard, firm; large amount of gypsum; calcareous; clear, wavy boundary.

C3 27 to 36 inches, pink (7.5YR 8/4), light clay loam; massive; hard, firm; many, medium, gypsum crystals; few, fine, distinct, white segregations of lime; calcareous; clear, wavy boundary.

C4 36 to 47 inches, pink (7.5YR 8/4) loam; massive; hard, firm; many, medium, gypsum crystals; few, fine, faint, pinkish white segregations of lime; calcareous; clear, wavy boundary.

C5 47 to 57 inches, pinkish-white (7.5YR 8/2) loam; massive; slightly hard, firm, slightly sticky; calcareous.

Climatic data (Las Vegas, Nev.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	44	50	57	66	74	84	91	88	81	67	54	47	67
Mean precipitation, 1921-50 (inches)	0.4	0.6	0.4	0.2	0.2	0.1	0.5	0.5	0.3	0.3	0.2	0.6	4.4

Annual precipitation more than 0.1 and less than 8.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-1/2	A1												0.52	9	19
1/2-14	C1cs												.10	4	< .5
14-27	C2cs												.17		5
27-36	C3												.18		26
36-47	C4												.28		38
47-57	C5												.23		68

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. Paste	E. C. mmhos per cm. 25° C.	Gypsum %	Exch. Na %	Sat. Ext. Soluble (meq./l.): Na	K	Ca+Mg	H_2O at sat. %
9.4				0.5	0.4	7.9	3.3	5.0	5	3.6	0.9	40.0	36.4
10.0				.1	.1	8.0	2.9	36.5	1	1.0	.4	36.7	78.2
10.5				1.1	.3	8.1	11.3	34.8	10	63.0	2.7	46.8	65.7
20.9				3.6	.9	8.3	20.6	6.4	17	180.0	7.4	66.3	78.4
17.6				3.4	1.2	8.3	28.4	6.4	19	254.0	9.1	80.6	83.2
10.4				2.1	.7	8.4	24.0	2.7	20	212.0	8.5	71.5	85.3

Profile No. 61

Area: Davis County, Utah.
Vegetation: A scattered stand of glosswort (Salacarnia sp.).
Parent material: Mixed lacustrine.
Topography: Less than 1 percent slope; nearly flat lake plain.

A1sa 0 to 1 inch, dark grayish-brown (2.5Y 4/2) silt loam, gray (5Y 6/1) when dry; weak, thick, platy structure; slightly hard, friable, slightly sticky, slightly plastic; calcareous; abrupt, smooth boundary.

C1sa 1 to 4 inches, light brownish-gray (2.5Y 6/2) loam, light gray (2.5Y 7/2) when dry; weak, thick, platy structure; slightly hard, friable, slightly sticky, slightly plastic; common, fine and medium pores; calcareous; clear, smooth boundary.

C2sa 4 to 9 inches, light olive-gray (5Y 6/2) silt loam, light gray (5Y 7/2) when dry; few, medium, distinct, brown mottles; massive; hard, firm, sticky, plastic; common, fine and medium pores; calcareous, clear, wavy boundary.

C3sa 9 to 20 inches, light olive-gray (5Y 6/2) silty clay loam, white (5Y 8/2) when dry; common, fine, distinct, brown mottles; massive; hard, firm, sticky, plastic; common, medium and fine pores; calcareous; gradual, wavy boundary.

C4sa 20 to 32 inches, light olive-gray (5Y 6/2) silt loam, light gray (5Y 7/2) when dry; few, fine, distinct, brown mottles; massive (laminated); hard, firm, sticky, plastic; common, fine and medium pores; calcareous; abrupt, smooth boundary.

IIC5sa 32 to 44 inches, pinkish-gray (7.5YR 6/2) silty clay loam, pinkish gray (7.5YR 7/2) when dry; massive (laminated); hard, firm, sticky, very plastic; common, medium and fine pores; calcareous; abrupt, smooth boundary.

IIC6sa 44 to 60 inches, light brownish-gray (2.5Y 6/2) silty clay loam, light gray (2.5Y 7/2) when dry; many, coarse, prominent mottles of reddish yellow; massive; hard, firm, very sticky, very plastic; common, medium and fine pores; calcareous.

Climatic data (Farmington, Utah)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	28	34	41	51	59	67	76	74	65	54	39	32	52
Mean precipitation, 1931-52 (inches)	2.1	1.9	2.2	2.2	1.8	1.4	0.5	1.0	0.7	1.8	1.9	2.1	19.5

Annual precipitation more than 13.8 and less than 25.2 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	H_2O at saturation %
0-1	A1sa	0.2	0.2	0.2	5.5	26.6	56.3	11.0	63.9	24.2			0.65	31	29.1
1-4	C1sa	.0	.1	.1	6.4	22.7	48.9	21.8	54.2	23.5			.36	16	46.3
4-9	C2sa	.1	.1	.1	3.0	18.8	57.0	20.9	49.0	29.5			.21	11	46.0
9-20	C3sa	.0	.1	.1	3.0	11.5	57.0	28.3	32.0	39.2			.21	11	51.3
20-32	C4sa	.0	.1	.1	6.5	17.6	54.0	21.7	48.6	29.2			.22	--	47.6
32-44	IIC5sa	.0	.0	.1	.9	5.1	63.9	30.0	24.9	44.9			.25	--	54.8
44-60	IIC6sa	.1	.1	.1	.6	2.4	64.2	32.5	20.9	46.2			.28	--	60.2

(Particle size distribution (mm.) (%) Pipette and hexametaphosphate)

Cation exch. cap. f	Extractable cations, meq./100 gm. Ca	Mg	H	Na	K	pH saturated paste	pH 1:10	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	HCO_3	Salt %	Saturation extract, soluble (meq./l.) Na	K	Ca	Cl
7.8	--	--	--	11.9	0.8	8.2	9.3	203	16	2.4	6.4	3785	25.0	22.6	3390
15.9	--	--	--	5.2	1.4	8.6	9.7	93	21	5.2	3.2	1175	12.5	2.0	1040
15.9	--	--	--	9.9	1.4	9.0	9.9	66	22	5.0	2.0	750	7.5	1.4	670
18.6	--	--	--	10.9	1.3	8.9	9.8	70	27	3.8	2.5	825	6.9	1.2	740
15.9	--	--	--	3.3	1.1	8.8	9.8	82	28	4.2	2.8	1025	7.7	1.2	960
16.2	--	--	--	4.1	1.2	8.7	9.7	76	30	3.6	2.8	888	6.6	1.2	805
17.6	--	--	--	5.9	1.2	8.8	9.7	74	22	3.8	3.1	881	6.3	1.4	808

Profile No. 62

Area: Maricopa County, Arizona.

Vegetation: Sparse cover of galleta and other grasses, creosotebush, paloverde, cane cholla, and annual weeds.

Parent material: Alluvium washed from materials that weathered from granite, schist, and rhyolite.

Topography: Less than 1 percent slope, convex; near the low end of a large fan; elevation about 1,690 feet.

A1 — 0 to 4 inches, brown (7.5YR 4/4) coarse sandy loam, reddish yellow (7.5YR 6/6) when dry; on surface is a thin veneer of coarse sand about 1/8 inch thick; weak, medium and thick, platy breaking to weak, fine, granular structure; slightly hard, very friable, sticky, plastic; common, fine and medium roots; many, fine pores; abrupt, wavy boundary.

B1 — 4 to 10 inches, dark-brown (7.5YR 4/4) coarse sandy loam, strong brown (7.5YR 5/6) when dry; massive, breaking to weak, medium, subangular blocky structure; slightly hard, very friable, sticky, plastic; a few, thin patchy, clay skins on peds; common, fine roots follow ped faces; common, fine and medium, continuous, tubular pores in peds; clear, wavy boundary.

B21t — 10 to 19 inches, reddish-brown (5YR 4/4) sandy clay loam, brown (7.5YR 5/4) when dry; moderate, medium and coarse, prismatic, breaking to moderate, medium and coarse, angular blocky structure; very hard, friable, very sticky, very plastic; thin, continuous, clay skins; common, fine roots follow ped faces; few, fine pores; clear, wavy boundary.

B22t — 19 to 27 inches, reddish-brown (5YR 4/4) clay loam or sandy clay loam, brown (7.5YR 5/4) when dry; moderate, medium and coarse, subangular blocky structure; very hard, friable, very sticky, very plastic; thin, continuous, clay skins; common, fine roots follow ped faces; numerous, fine mycelia of lime; calcareous; clear, wavy boundary.

B3tca — 27 to 37 inches, brown (7.5YR 4/4) loam, strong brown (7.5YR 5/6) when dry; common, medium and distinct, pinkish-white (7.5YR 8/2) mottles; massive, breaking to weak, fine and medium, subangular blocky structure; slightly hard, very friable, sticky, plastic; thin, patchy, clay skins on ped faces; common, fine and medium, continuous pores in peds; pink (7.5YR 7/4) segregations of lime; calcareous; clear, wavy boundary.

IIC1ca — 37 to 54 inches, pinkish-gray (7.5YR 7/2) gravelly coarse sandy loam, pinkish white (7.5YR 8/2) when dry; mottled with pinkish gray (7.5YR 6/2) and reddish yellow (7.5YR 8/6) when dry; massive; extremely hard, firm, nonsticky, nonplastic; few, fine, continuous pores; calcareous.

IIC2ca — 54 to 76 inches, same description as for IIC1ca horizon except color is pink (7.5YR 7/4) when moist; gradual, wavy boundary.

IIC3 — 76 to 98 inches +, light-brown (7.5YR 6/4) gravelly coarse sand, pinkish gray (7.5YR 7/2) when dry; massive; soft, loose, slightly sticky, nonplastic; few carbonate concretions; calcareous.

Climatic data (Wittman, Ariz.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperature, 1931-47 (deg. F.)	49	53	58	66	75	84	91	89	83	71	58	52	69
Mean precipitation, 1931-47 (inches)	0.9	1.3	0.9	0.6	0.2	0	1.0	1.8	1.0	0.4	0.7	1.3	10.0

Annual precipitation more than 2.9 and less than 17.1 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-4	A1	17.4	19.9	5.8	6.8	8.9	30.6	10.6	32.5	10.7	5		0.16	6	--
4-10	B1	12.8	18.0	6.4	7.8	10.1	31.1	13.8	35.1	10.3	8		.12	6	--
10-19	B21t	11.7	17.9	6.6	7.4	8.3	26.5	21.6	29.8	8.9	9		.14	6	--
19-27	B22t	9.6	15.7	5.7	5.7	7.7	27.7	27.9	28.8	9.7	10		.16	7	2
27-37	B3tca	12.3	15.1	5.4	5.8	6.7	33.2	21.5	29.9	13.1	9		.16	8	10
37-54	IIC1ca	19.1	18.1	6.5	5.9	4.1	29.7	16.6	20.8	15.9	26		.05	-	22
54-76	IIC2ca	15.8	20.8	9.5	8.3	4.3	26.4	14.9	21.9	12.7	21		.02	-	15
76-98+	IIC3	24.6	33.7	15.1	8.9	2.0	10.0	5.7	11.4	4.0	20		.01	-	6

Cation exch. cap. f.	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	pH 1:10	E. C. mmhos. per cm. 25°C.	HCO_3	Exch. Na %	Saturation extract soluble (meq./l.): Na	K	Ca	Mg	Cl	H_2O at sat. %
8.5	7.7	8.0		0.1	0.9	7.2	7.8	0.3	1.0	1.2	0.4		1.8	0.8	0.5	28.6
14.7	9.6	8.7		.3	.6	7.5	7.4	.4	1.6	2.0	.6		2.1	.9	.5	23.3
20.7	13.9	10.8		.5	.4	7.6	8.2	.6	.6	2.4	1.8		2.7	.9	2.2	32.6
23.3	29.1	13.5		.6	.4	8.1	8.9	.9	.6	2.6	3.1		3.7	1.3	4.5	41.2
17.1	27.9	9.6		.7	.3	8.1	8.9	.9	.4	4.1	3.7		3.0	1.1	5.0	44.2
6.3	21.6	8.0		.8	.2	8.6	9.2	.9	2.4	12.7	13.5		1.0	.6	5.7	40.3
6.1	24.5	11.4		1.2	.2	8.8	9.6	1.2	1.8	19.7	18.9		.5	.6	5.1	37.7
4.0	19.5	9.1		1.2	.2	9.0	9.7	1.2	2.6	30.0	20.0		.4	.5	3.4	30.8

Profile No. 63

Area: Beryl-Enterprise, Utah.

Vegetation: Bare spot 2 feet from nearest creosotebush (*Larrea* sp.); sparse cover of creosotebush, sagebrush (*Artemesia tridentata*) galleta grass (*Hilaria jamesii*), and shadscale (*Atriplex confertifolia*).

Parent material: Alluvium originating mainly from rhyolite with some latite, andesite, and obsidian.

Topography: Gently sloping; alluvial fan; elevation 5,000 to 5,500 feet.

A1 0 to 5 inches, brown (10YR 5/3) fine sandy loam, very pale-brown (10YR 7/3) when dry; very strong, platy structure with many vesicles in the upper 1 1/2 to 2 inches; crumbles readily to a structureless mass.

B2t 5 to 13 inches, reddish-brown (5YR 4/4) silty clay; strong, medium and coarse, columnar, breaking to very fine, blocky structure in upper part, moderate, columnar, breaking to strong, blocky structure in the lower part; most columns are flat topped, but a few have gray caps as much as 1/4 inch thick; hard; columns have a thin colloidal coating; core of columns is pale brown to pinkish white because of accumulations of lime; calcareous.

B3t 13 to 19 inches, light-brown (7.5YR 6/4) clay loam, massive; soft; calcareous, lime well disseminated.

Cca 19 to 36 inches, pink (7.5YR 8/4) sandy clay loam; massive; a few slightly to moderately cemented lenses; calcareous.

The laboratory data in the top part of the table are from a profile similar to the one described but removed from it by a few feet. Depths in inches of the horizons in the bottom part of the table are: 0 to 2, 2 to 5, 5 to 13, 13 to 19, and 19 to 36.

Climatic data (Modena, Utah)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1930-52 (deg. F.)	25	31	38	47	55	63	72	70	62	50	37	29	48
Mean precipitation, 1930-52 (inches)	0.8	0.8	1.0	0.8	0.7	0.5	0.9	1.3	0.7	1.1	0.6	1.0	10.1

Annual precipitation more than 4.9 and less than 15.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C w	CaCO3 equiv. % v
0-1	A11	0.8	1.8	2.0	4.1	31.8	53.8	5.7		27.1			0.69	3.4
1-5	A12	0.1	1.0	1.6	12.6	18.6	55.2	10.9		32.4			.41	3.4
5-10	B2t	0.1	0.3	0.5	4.1	6.4	48.8	39.8		35.2			.56	9.5
10-18	B3t	0.1	0.7	0.7	2.7	7.5	50.0	38.3		32.8			.38	14.3
18-48	Cca	0.9	4.5	4.2	10.0	10.2	33.4	36.8		33.5			.24	28.4

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH: saturated paste	1:5	Exch. Na %	Saturation extract soluble (milliequivalents per liter): Na	K	Ca	Mg	HCO3	H2O at sat. %
13.4				3.35		8.6	9.9	24.9	10.85	1.00	1.19	1.25	10.35	20.9
16.1				5.02		8.5	9.0	31.3	9.85		1.49	1.18	9.27	22.6
30.0				18.39		8.8	10.0	61.3	18.20		.18	.32	11.86	70.0
19.3				14.56		9.0	10.1	75.6	97.5	2.70	.53	.60	8.94	57.4
12.5				8.78		8.5	9.5	70.0	264.0	1.56	3.06	--	4.31	49.1

Profile No. 64

Area: Fresno County, California

Vegetation: Saltgrass, spikeweed, pickleweed, soft chess, jackass clover.

Parent material: Alluvium from granitic material.

Topography: Less than 1 percent slope; minor microrelief including some low mounds; basin; elevation 220 feet.

A1 — 0 to 6 inches, grayish-brown (2.5Y 5/2) silt loam, light gray (2.5Y 7/2) when dry; very weak, very fine, granular structure when moist, massive on drying with some coarse prismatic cracks appearing late in the dry season; hard, friable, nonsticky, very slightly plastic; few, fine roots in soil mass; roots are concentrated along the prismatic cracks, with root mats in places; many very fine, interstitial pores and common very fine, tubular pores; calcareous; abrupt, wavy boundary.

B2t — 6 to 12 inches, dark grayish-brown (2.5Y 4/2), light clay loam, grayish brown (2.5Y 5/2) when dry; weak, coarse, prismatic and moderate, medium structure; very hard, very firm, slightly sticky, plastic; dark, organic films on many ped faces;patchy, clay films; few, fine roots; common, very fine, tubular pores; calcareous; clear, wavy boundary.

B3t — 12 to 21 inches, grayish-brown (2.5Y 5/2) loam, light brownish gray (2.5Y 6/2) when dry; weak, medium, subangular blocky structure; very hard, very firm, nonsticky, very slightly plastic; dark, organic films on some ped faces; thin, patchy, clay films; few, fine roots; common, very fine, tubular pores; calcareous; abrupt, wavy boundary.

C1mca — 21 to 28 inches, grayish-brown (2.5Y 5/2) sandy loam, light brownish gray (2.5Y 6/2) when dry; dark grayish brown (2.5Y 4/2) in upper part; indurated, some soft, fragmental material in lower part; very few roots; calcareous; abrupt, wavy boundary.

C2ca — 28 to 39 inches, light brownish-gray (2.5Y 6/2), stratified fine sandy loam and loam with some thin lenses of silt, light gray (2.5Y 7/2) when dry; few, fine mottles of yellowish brown (10YR 5/6 and 5/8); massive; hard, firm, nonsticky, very slightly plastic; common, very fine, interstitial pores and a few, very fine, tubular pores; many segregations of lime; calcareous; clear, smooth boundary.

C3ca — 39 to 63 inches, light brownish-gray (2.5Y 6/2) stratified sand and silt, light gray (2.5Y 7/2) when dry; common, fine mottles of yellowish brown (10YR 5/6-5/8) and strong brown (7.5YR 5/6-5/8); hard, firm, nonsticky, very slightly plastic; common, very fine, interstitial pores; very thin segregations of lime; calcareous; clear, smooth boundary.

C4 — 63 inches +, similar to C3ca horizon but less calcareous.

Climatic data (Fresno, Calif.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	45	51	56	62	69	76	82	80	74	64	54	46	63
Mean precipitation, 1921-50 (inches)	1.6	1.7	1.6	1.0	0.3	0.1	®	0	0.1	0.7	0.8	1.6	9.3

Annual precipitation more than 4.6 and less than 14.0 inches during 9 years out of ten.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-6	A1	0.3	2.9	3.7	13.2	17.4	53.4	9.1	57.5	22.5	0		0.45	9	3
6-12	B2t	.2	2.0	2.4	9.5	12.2	48.3	25.4	41.2	26.3	0		.21	7	5
12-21	B3t	7.6	23.5	3.2	6.9	2.3	45.1	11.4	27.8	24.5	0		.13	7	8
21-28	C1mca	9.7	13.6	6.3	12.1	14.8	37.3	6.2	41.6	18.1	4		.09	-	15
28-39	C2ca	8.2	10.8	5.7	15.2	15.2	39.0	5.9	46.6	17.3	1		.56	-	14
39-63	C3ca	2.1	3.0	2.3	9.9	18.1	60.4	4.2	55.9	30.1	1		.02	-	7

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	Exch. Na %	pH sat. paste	E. C mmhos. per cm. 25° C.	Moisture tensions: 1/3 atmos.	15. atmos.	Sat. ext. soluble (meq./l.): Na	Ca	CO_3	HCO_3	H_2O at sat. %
11.7	16.9	1.8	--	3.7	1.3	32	8.1	11.4	16.6	4.2	6.4	4.0	2.8	7.5	24.4
22.1	15.9	1.6	--	14.8	1.4	67	8.9	23.0	21.3	9.4	21.8	.7	5.2	8.3	27.4
17.5	17.1	1.5	--	11.3	1.0	65	9.3	23.0	17.6	7.4	22.6	.5	5.2	9.1	31.0
17.3	17.1	1.0	--	9.6	.3	56	9.1	17.0	19.1	9.5	16.3	.4	5.2	5.0	34.5
12.4	15.5	.9	--	6.4	.1	52	9.3	9.1	18.4	6.9	9.0	.3	2.4	4.4	36.8
10.1	17.3	.8	--	2.8	.1	28	8.9	6.9	17.0	4.2	6.2	.4	.0	9.3	36.9

Chapter 12. Mollisols

The Mollisols include most soils that have been called Chernozem, Brunizem (Prairie), Chestnut, and Reddish Prairie, and the associated Humic Gley soils and Planosols. They also include those Rendzinas, Brown soils, Reddish Chestnut soils, and Brown Forest soils that have a mollic epipedon.

The Mollisols must have a mollic epipedon, but not all soils that have this epipedon are Mollisols. Those soils with a mollic epipedon that has a clay fraction dominated by allophane or a silt and sand fraction dominated by volcanic ash are excluded. So are the soils with an argillic horizon that has a base saturation of less than 35 percent, or a base saturation that decreases with depth from the argillic horizon to the C. And, the Mollisols may not have an oxic or spodic horizon, nor may they have the diagnostic properties of Vertisols. These are the exclusions.

In addition to the mollic epipedon, the Mollisols may have an albic horizon, cambic horizon, argillic horizon, natric horizon, duripan, or ca, cs, or sa horizon.

The vast majority of the Mollisols have developed under a grass vegetation, either tall or short, but closely enough spaced to form a sod. A few have had mostly sedges and water-loving plants, and a few others have developed under deciduous hardwood forest. Those under hardwood forest are only known on basic and calcareous parent materials and have had a large earthworm population. The worms pull the leaves underground, where they decay and produce conditions similar to those produced by underground decomposition of grass roots.

The climatic range of Mollisols is from boreal or alpine to tropical. Rainfall may be sufficient to provide some annual leaching through the soil in most years, or it may only moisten the solum. Dry seasons are normal.

Six suborders are recognized. These are discussed in the following pages.

RENDOLLS (5.1)

The Rendolls have been generally called Rendzinas. The name Rendoll takes its prior formative element from the word Rendzina.

The Rendolls have developed in humid climates from parent materials with high calcium carbonate content. They include those soils with a mollic epipedon of limited thickness that is on parent materials having more than 40 percent calcium carbonate equivalent. The mollic epipedon can be no more than 30 cm. (12 inches) thick if it contains less than 20 percent gravel, and no more than 50 cm. (20 inches) thick if it contains more than 40 percent gravel. A cambic horizon is permitted in Rendolls, but an argillic or calcic horizon is not.

No subdivisions of Rendolls are made in the Great Group category. Since the suborder and great groups are equivalent, no specific great group name is needed, and the suborder name is used. Definitions for subgroups are not proposed at this time. The Orthic Rendoll should not have a cambic horizon, and the mollic epipedon should be free of mottles of brown, strong brown or reddish brown. There often are spots of gray color that are actually bits of parent material voided in the mollic epipedon by earthworms, but these are not considered mottles. The presence of mottles should be a basis for an aquic subgroup. A cambic horizon should be a basis for udollic or eutrochreptic subgroups, depending on the nature of the epipedon.

ALBOLLS (5.2)

The Albolls are the Mollisols that have an albic horizon immediately below the mollic epipedon. Below the albic horizon there is an argillic horizon of slow or very slow permeability. Both the albic and argillic horizons show, as evidence of periodic saturation with water, mottles with chromas of 2 or less, or iron-manganese concretions, or both.

The Albolls have been called Soloths, solodized Solonetz, and Planosols, but they do not include all of these. The albic horizon is thought to be caused by a perched water table, which is held up by the slowly permeable argillic horizon. During spring, the albic horizon, and usually the mollic epipedon, is saturated with water. During summer both are nearly always dry at some period of drought. The base saturation in the profile normally reaches a minimum in the albic horizon.

Key to Albolls

5.21 Albolls with an argillic horizon but without a natric horizon.

Argalboll, p. 169

5.210 Argalbolls with less than 7 percent exchangeable sodium in all parts of the argillic horizon, or with less exchangeable sodium than hydrogen, and with an abrupt textural change from the albic to the argillic horizon.

Orthic Argalboll, p. 169

5.21-5.22 Other Argalbolls with more than 7 percent exchangeable sodium and more exchangeable sodium than hydrogen in some part of the argillic horizon.

Natric Argalboll, p. 169

5.21-5.3 Other Argalbolls without an abrupt textural change from the albic to the argillic horizon.

Aquollic Argalboll, p. 169

5.22 Other Albolls with a natric horizon.

Natralboll, p. 169

5.220 Natralbolls with an albic horizon continuous throughout each pedon.

Orthic Natralboll, p. 169

5.22-5.35 Other Natralbolls.

Ruptic Natraquollic Natralboll, p. 169

Argalbolls (5.21)

The Argalbolls have been called Planosols and Soloths. They have a mollic epipedon, an albic horizon, and an argillic horizon, in that sequence. The albic horizon and the argillic horizon show evidence of periodic wetness. The albic horizon has mottles with chromas of 2 or less, or has low chromas throughout and has conspicuous iron-manganese concretions. The argillic horizon has mottles with chromas of 2 or less in the upper part or throughout.

The natural vegetation on Argalbolls is tall grass, with scattered trees in some instances.

Orthic Argalbolls (5.210)

This subgroup includes the Argalbolls that have an abrupt textural change between the albic horizon and the argillic horizon, and that have less than 7 percent exchangeable sodium in the argillic horizon, or more exchangeable hydrogen than sodium in the argillic horizon.

Profile 65, page 180, illustrates the concept of the Orthic Argalboll. Dry colors were not recorded, but the albic horizon of this soil normally has about a 10YR 6/1 color when dry, so the mollic epipedon is something like 13 inches thick. The transition from the A to the B horizon in this soil usually consists of very fine nodular remnants of B surrounded by A2 material from which a large part of the clay has been stripped. Iron-manganese concretions are abundant, though not mentioned in the available description. The dark colors of the upper part of the argillic horizon, darker than those of the overlying horizons, are typical.

Repeated permeability measurements show that the argillic horizon is very slowly permeable to saturated flow of water.

Natric Argalbolls (5.21-5.22)

This subgroup includes the Argalbolls that have more than 7 percent exchangeable sodium and more exchangeable sodium than hydrogen in the argillic horizon.

Aquollic Argalbolls (5.21-5.3)

This subgroup includes the Argalbolls that lack an abrupt textural change between the albic horizon and the argillic horizon.

Profile 66, page 181, illustrates this subgroup. This profile is not orthic because it lacks the abrupt textural change between the albic horizon (A2) and the argillic horizon.

Natralbolls (5.22)

The Natralbolls are soils that have been called solodized Solonetz. They have a mollic epipedon, an albic horizon, and a natric horizon, in that sequence. Ruptic intergrades are probable in this great group, because the albic horizon tends to be discontinuous.

These soils are in climates as humid as those of the Argalbolls, but they also extend into drier climates and grade into the Natrargids of the desertic regions.

It should be remembered that exchangeable sodium may be low in the natric horizon if exchangeable magnesium and sodium exceed calcium and hydrogen. The soils with large amounts of magnesium in the natric horizon must have more than 15 percent saturation with sodium in some horizon or layer below the natric horizon.

The subgroups for Natralbolls are incompletely developed. The orthic subgroup should have a continuous albic horizon. If the albic horizon is discontinuous within each pedon, a ruptic intergrade to the Natraqualls is indicated.

Bisequum profiles with a cambic horizon above the albic horizon are not included with the Natralbolls even though the lower sequum includes a natric horizon. They are classified in the great group category on the properties of the upper sequum.

AQUOLLS (5.3)

The Aquolls are the Mollisols that have no albic horizon but that are strongly hydromorphic. They include soils that have been called Humic Gley (Wiesenboden), calcium carbonate Solonchak, and Solonetz; they also include a number of the hydromorphic Alluvial soils of grassland areas.

The common features of the Aquolls, in addition to those definitive for all Mollisols, are the absence of an albic horizon or of parent material having more than 40 percent calcium carbonate equivalent.

The Aquolls are saturated with water at some season, or are artificially drained, and have one or more of the following characteristics that are associated with wetness:

1. A histic epipedon.
2. Sodium saturation of more than 15 percent in the upper part of the mollic epipedon and decreasing saturation with increase in depth below 50 cm. (20 inches).
3. Colors, as follows, immediately below the mollic epipedon:
   a. If hues are 10YR or redder and are accompanied by mottling, chromas are 2 or less on ped surfaces or in matrix; and if hues of 10YR or redder are not mottled, chromas are less than 1.
   b. If hues are between 10YR and 10Y and are accompanied by distinct or prominent mottles, chromas are 3 or less on ped surfaces or in matrix; and if hues between 10YR and 10Y are not mottled, chromas are 1 or less.
   c. Hues bluer than 10Y.
   d. Any color if due to uncoated grains of sand.

The Aquolls have developed under the influence of permanent or fluctuating ground water that is at or near the surface part of each year. The natural vegetation is normally grasses and sedges, although some Aquolls have been under deciduous forest during at least part of their genesis. It should be noted that the classification that follows makes no provision for cold soils, comparable in temperatures to the other cryic great groups. If these soils exist, provision will need to be made for them.

Key to Aquolls

5.31 Aquolls with no argillic horizon and no calcic horizon immediately below the mollic epipedon, and with no duripan.

Haplaquoll, p. 170

5.310 Haplaquolls with a mollic epipedon that is between 15 and 60 cm. thick (6 and 24 inches) and that has a gradual or diffuse lower boundary, with no histic epipedon.

Orthic Haplaquoll, p. 170

5.31-1 Other Haplaquolls with a mollic epipedon that is less than 15 cm. (6 inches) thick or that has an abrupt lower boundary at the base of an Ap less than 25 cm. (10 inches) thick, and that has a mean annual temperature of more than 8.3° C. (47° F.).

Entic Haplaquoll, p. 170

5.31-10 Other Haplaquolls with a histic epipedon.

Histic Haplaquoll, p. 171

5.31-3.14 Other Haplaquolls that have a mollic epipedon less than 15 cm. thick with a clear or abrupt lower boundary, and that have a mean annual temperature less than 8.3° C. (47° F.).

Cryaqueptic Haplaquoll, p. 171

5.31-Cumulic Other Haplaquolls that have a mollic epipedon that is more than 60 cm. (24 inches) thick and has a gradual or diffuse lower boundary.

Cumulic Haplaquoll, p. 171

5.32 Other Aquolls that have an argillic horizon but no natric horizon or duripan.

Argaquoll, p. 171

5.320 Argaquolls that have no carbonates in the matrix of the mollic epipedon and in at least the upper part of the argillic horizon; that have a chroma of less than 1.5 in all parts of the mollic epipedon; that have less than 7 percent exchangeable sodium in all parts of the argillic horizon; that have a gradual or clear upper boundary of the argillic horizon, if this horizon is not the base of an Ap.

Orthic Argaquoll, p. 171

5.32-533 Other Argaquolls that have carbonates in the matrix of the mollic epipedon or the upper part of the argillic horizon and that have a calcic horizon.

Calcic Argaquoll, p. 171

5.32-5.5 Other Argaquolls that have chromas of 1.5 or more in the mollic epipedon, and that are never dry in all parts of the solum for periods longer than 30 days.

Udollic Argaquoll, p. 171

5.32-5.6 Other Argaquolls that have chromas of 1.5 or more in the mollic epipedon and that are dry in the solum for periods of longer than 30 days.

Ustollic Argaquoll, p. 171

5.32-5.35 Other Argaquolls that have more than 7 percent exchangeable sodium in some part of the argillic horizon.

Natric Argaquoll, p. 171

5.32-5.2 Other Argaquolls having an argillic horizon with an abrupt upper boundary that is not the base of an Ap.

Albollic Argaquoll, p. 171

5.33 Other Aquolls that have a calcic horizon.

Calcaquoll, p. 171

5.330 Calcaquolls that have a calcic horizon in or immediately below the mollic epipedon.

Orthic Calcaquoll, p. 172

5.33-5.31 Other Calcaquolls.

Haplic Calcaquoll, p. 172

5.34 Other Aquolls with a duripan.

Duraquoll, p. 172

5.35 Other Aquolls with a natric horizon.

Natraquoll, p. 172

Haplaquolls (5.31)

The Haplaquolls have been called Humic Gley soils for the most part, although those on flood plains have been called Alluvial soils by some. They have a mollic epipedon on a cambic horizon or on the C. Chromas of the epipedon are generally 1 or less, and the cambic horizon is normally gray or olive gray, mottled with shades of brown. Some Haplaquolls with near neutral colors or blue hues have no mottles.

The Haplaquolls are found in closed depressions, drainageways kept wet by seepage, or the low parts of the flood plains. The native vegetation on most has been grasses, sedges, and other water-loving plants, A few have had a deciduous hardwood vegetation during at least a part of their genesis.

The central concept of the group is reflected in the orthic subgroup. Other subgroups indicate the permissible variations.

Orthic Haplaquolls (5.310)

This subgroup includes Haplaquolls that have a mollic epidedon between 15 and 60 cm. (6 and 24 inches) thick. The lower boundary of the epipedon is gradual or diffuse. No histic epipedon is present.

Profile 67, page 182, is an example of the Orthic Haplaquolls. The mollic epipedon is 17 inches thick. The cambic horizon, from 17 to 26 inches, has lost its carbonates and has developed structure. Other evidences of alteration are lacking in the available data.

Entic Haplaquolls (5.31-1)

This subgroup includes Haplaquolls with a thin epipedon that has a mean annual temperature of 8.3° C.

(47° F.) or more. If the soil has not been plowed, the epipedon is less than 15 cm. (6 inches) thick and has a gradual lower boundary. If the soil has been plowed, some of the underlying horizon is apt to have been mixed with the mollic epipedon and given the epipedon an abrupt lower boundary. Consequently, an Ap that is 25 cm. (10 inches) thick and that constitutes a mollic epipedon is the upper limit of thickness for the mollic epipedon in the subgroup.

Histic Haplaquolls (5.31-10)

This subgroup is provided for Haplaquolls that have a histic epipedon above the mollic epipedon. These soils were once common in parts of the United States, but they have largely disappeared as a result of drainage and cultivation.

Cryaqueptic Haplaquolls (5.31-3.14)

This subgroup includes the Haplaquolls that have a thin mollic epipedon and low temperatures. The mean annual temperature is less than 8.3° C. (47° F.). The epipedon is less than 15 cm. thick. In the virgin soil it has a clear or abrupt lower boundary. If cultivated, the mollic epipedon is no thicker, as a rule, than the Ap, but in any case the lower boundary is clear or abrupt.

Cumulic Haplaquolls (5.31-Cumulic)

This subgroup includes the Haplaquolls with a mollic epipedon that is thicker than 60 cm. (24 inches) and that has a gradual or diffuse lower boundary. The soils are chiefly on flood plains or in positions that have received slow deposition of sediments.

Argaquolls (5.32)

The Argaquolls are Aquolls that have been called Humic Gley soils. They have an argillic horizon but have no natric horizon or duripan. They are found chiefly on land surfaces where there has been little or no erosion or deposition since Wisconsin time. So far as is known, the ground water has fluctuated with the season, being high in the winter and low in the summer. The vegetation has been grass, grass and sedges, or deciduous hardwood forest.

The central concept is reflected by the orthic subgroup. Other subgroups reflect permissible variations.

Orthic Argaquolls (5.320)

This subgroup includes Argaquolls that do not have carbonates in the matrix of the mollic epipedon or in the upper part of the argillic horizon. The epipedon has chromas of less than 1.5. The argillic horizon, often largely in the mollic epipedon, has less than 7 percent exchangeable sodium in all parts, and it has a gradual or clear upper boundary unless this boundary coincides with the base of the Ap.

Profile 14, page 79, is used here as an example of the Orthic Argaquolls. The colors of the mollic epipedon in this profile are lighter than in many of the subgroup. The most common color is 10YR 2/1 when moist. Profile 14 had a deciduous forest vegetation for at least the later part of its genesis. Those Argaquolls that never had a forest vegetation usually have a darker colored epipedon. It is possible that the soils with a profile like profile 14 will eventually be considered as intergrades to the Ochraqualfs.

Calcic Argaquolls (5.32-5.33)

This subgroup is provided for Argaquolls that have a calcic horizon and have carbonates in the mollic epipedon or in the upper part of the argillic horizon. It seems likely that these soils are being recalcified as a result of an environmental change.

Udollic Argaquolls (5.32-5.5)

This subgroup includes the Argaquolls that have chromas of 1.5 or more in the mollic epipedon. They have no carbonates in the mollic epipedon, or the upper part of the argillic horizon; they may have periods of less than 30 days when the solum is dry. They are in humid regions that have considerable summer rainfall. Carbonates are often present in the C, but ca horizons are uncommon.

Ustollic Argaquolls (5.32-5.6)

This subgroup includes Argaquolls that have chromas of 1.5 or more in the mollic epipedon, and that are dry in the solum for periods longer than 30 days. These soils are in the drier part of the climatic range of the Mollisols, or possibly in Mediterannean climates. If in the former, increasing saturation with sodium can be expected below the solum. Carbonates are absent in the mollic epipedon and in the upper part of the argillic horizon. It is normal to have ca horizons below the argillic horizon.

Natric Argaquolls (5.32-5.35)

This subgroup includes Argaquolls that have chromas less than 1.5 in the mollic epipedon, and that have more than 7 percent exchangeable sodium in some part of the argillic horizon. An abrupt upper boundary is common in the argillic horizon.

Albollic Argaquolls (5.32-5.2)

This subgroup includes Argaquolls that have chromas less than 1.5 in the mollic epipedon. They lack carbonates in the mollic epipedon and in the upper part of the argillic horizon, and have less than 7 percent exchangeable sodium in the argillic horizon. They have an argillic horizon with an abrupt upper boundary. They normally have a sprinkling of uncoated sand or silt particles just above the argillic horizon that gives the appearance of an albic horizon when the soil is dry. When moist, this horizon is not apparent except under a hand lens.

Calcaquolls (5.33)

The Calcaquolls have been called calcium carbonate Solonchaks in recent years. They include the Aquolls that have calcic horizons, but that have no argillic horizon, natric horizon, or duripan. The carbonates have been precipitated from ground water, from shallow standing water, or from both. The precipitation in some if not all of these soils is largely biotic, by plants and snails. In the most humid regions, the soils have been under shallow temporary lakes. In the drier regions, precipitation seems to have been from the ground water at the capillary fringe.

Orthic Calcaquolls (5.330)

This subgroup includes the Calcaquolls that have the calcic horizon in or immediately below the mollic epipedon. Profile 1, page 66, is an example of an Orthic Calcaquoll.

Haplic Calcaquolls (5.33-5.31)

This subgroup is provided tentatively for Calcaquolls in which the calcic horizon is separated from the mollic epipedon by a cambic horizon or by C material.

Duraquolls (5.34)

This great group is included very tentatively. Soils earlier thought to fit this class are now placed with the other allophanic soils in the order Inceptisol.

Natraquolls (5.35)

This is another tentative great group. At this writing little more can be said beyond the statement that it includes Aquolls with a natric horizon. It is probable that most of the soils will be ruptic intergrades with Natralbolls.

ALTOLLS (5.4)

The Altolls include principally soils that have been called Chernozems. They are found chiefly under cool continental climates where summers are hot and winters are cold. The native vegetation was grass, chiefly tall grass.

The Altolls have a mollic epipedon that, to depths of 15 cm. (6 inches) or more, has chromas of less than 1.5 when moist, and that has common bleached silt and sand grains. Below this depth, the chromas increase, or there are no mottles. The mean annual temperature is less than 8.5° C. (47° F.). The mollic epipedon may rest on an argillic or cambic horison, or on C. Below a cambic horizon there may be a sequum consisting of an albic horizon and a natric horizon or possibly an argillic horizon. Much more commonly there is a ca horizon below the cambic horizon.

Key to Altolls

5.41 Altolls without an argillic or cambic horizon but with a mollic epipedon that is more than 50 cm. (20 inches) thick, and this epipedon has common or abundant worm holes and worm casts and a transition to the C in which more than 25 percent of the material is discrete worm casts or krotovinas of Al and C material.

Vermaltoll, p. 173

5.410 Vermaltolls with a mollic epipedon more than 75 cm. (30 inches) thick.

Orthic Vermaltoll, p. 173

5.41-5.42 Other Vermaltolls.

Haplic Vermaltoll, p. 173

5.42 Other Altolls with the mollic epipedon resting on C or on a cambic horizon, but with no argillic horizon, and no calcic horizon if there is no cambic horizon.

Haplatoll, p. 173

5.420 Haplaltolls having a mollic epipedon less than 50 cm. (20 inches) thick, and a cambic horizon; but no albic horizon and natric horizon below the cambic horizon, and no mottles with chromas of 2 or less within 1 meter of the surface.

Orthic Haplaltoll, p. 173

5.42-1 Other Haplaltolls that have no cambic horizon and have no mottles with chromas of 2 or less within 1 meter of the surface, but do have a mollic epipedon less than 50 cm. (20 inches) thick.

Entic Haplaltoll, p. 173

5.42-5.45 Other Haplaltolls with an albic horizon and a natric horizon underlying a cambic horizon.

Natric Haplaltoll, p. 173

5.42-5.3 Other Haplaltolls with mottles having chromas of 2 or less within 1 meter of the surface and having a mollic epipedon less than 50 cm. (20 inches) thick.

Aquic Haplaltoll, p. 173

5.42-Cumulic Other Haplaltolls with a mollic epipedon more than 50 cm. (20 inches) thick.

Cumulic Haplaltoll, p. 173

5.43 Other Altolls with an argillic horizon but with no natric horizon.

Argaltoll, p. 173

5.430 Argaltolls with less than 7 percent exchangeable sodium in the argillic horizon, without an albic horizon, and without carbonates in the matrix of the mollic epipedon or in the upper part of the argillic horizon.

Orthic Argaltoll, p. 173

5.43-5.44 Other Argaltolls with carbonates in the matrix of the epipedon or in the upper part of the argillic horizon and with a calcic horizon.

Calcic Argaltoll, p. 174

5.43-5.45 Other Argaltolls with more than 7 percent exchangeable sodium in some part of the argillic horizon, and with no albic horizon.

Natric Argaltoll, p. 174

5.43-7.2 Other Argaltolls with an albic horizon between the mollic epipedon and the argillic horizon.

Altalfic Argaltoll, p. 174

5.44 Other Altolls with a calcic horizon but no natric horizon.

Calcaltoll, p. 174

5.440 Calcaltolls with the calcic horizon in or immediately below the mollic epipedon.

Orthic Calcaltoll, p. 174

5.44-5.42 Other Calcaltolls with a calcic horizon in the C.

Haplic Calcaltoll, p. 174

5.45 Other Altolls with a natric horizon.

Natraltoll, p. 174

Vermaltolls (5.41)

This great group is provided for Altolls having a mollic epipedon that is more than 50 cm. (20 inches) thick and that shows evidences of intensive mixing by worms or burrowing mammals. The evidence of mixing consists of common or abundant worm holes and worm casts in the epipedon, and 25 percent or more of the transitional material between the epipedon and the C is discrete worm casts or krotovinas of A1 and C materials. Both worms and mammals probably contribute to the thick epipedon.

It is believed that the Orthic Vermaltoll should have a mollic epipedon 75 cm. (30 inches) or more thick, and that those with a thinner epipedon are intergrades to the Haplaltolls or to Haplic Vermaltolls.

Haplaltolls (5.42)

The Haplaltolls have been called Chernozems. They are those Altolls that have no cambic horizon and no calcic horizon, and Altolls that have a cambic horizon. If a cambic horizon is present, they may also have a calcic horizon, or have an albic and natric horizon underlying the cambic horizon. They have a ca horizon if there are carbonates in the parent material.

In the United States, the Hapaltolls are found chiefly on land surfaces of late Wisconsin age or on younger surfaces. The native vegetation was chiefly tall grass.

The central concept is that of the orthic subgroup. Other subgroups reflect permissible variations.

Orthic Haplatolls (5.420)

The Orthic Haplaltolls have a mollic epipedon that has chromas of less than 1.5 in the upper 15 cm., that is less than 50 cm. (20 inches) thick, and that rests on a cambic horizon. They have no mottles with chromas of 2 or less within 1 meter of the surface, and no albic or natric horizon underlying the cambic horizon.

Profile 68, page 183, is an example of the Orthic Haplaltoll. The tonguing of the surface horizons is a common feature; it is attributed to frost action. The cambic horizon, between 14 and 17 inches, shows structure, and partial but not complete leaching of the carbonates. The calcic horizon, between 26 and 37 inches, is normal in these soils if the parent materials contain carbonates.

Entic Haplaltolls (5.42-1)

This subgroup includes Haplaltolls that have no cambic horizon and no calcic horizon. They have no mottles with chromas of 2 or less within 1 meter of the surface. The mollic epipedon is less than 50 cm. (20 inches) thick. If the parent material is calcareous, the mollic epipedon is also normally calcareous.

Natric Haplaltolls (5.42-5.45)

This subgroup is provided for the Haplaltols that have an albic and a natric horizon underlying the cambic horizons. The soils have not been identified in the United States but do occur elsewhere.

Aquic Haplaltolls (5.42-5.3)

This subgroup includes Haplaltolls that differ from the orthic subgroup only in having mottles with chromas of 2 or less, or in having the colors diagnostic for Aquolls, within 1 meter of the surface.

Cumulic Haplaltolls (5.42-Cumulic)

This subgroup includes Haplaltolls that have a mollic epipedon that is more than 50 cm. (20 inches) thick and that has a gradual or diffuse lower boundary. Normally, there is a thick cambic horizon with dark colors below the mollic epipedon, but this is not required. The transition between the mollic epipedon and the underlying horizon does not show, in the form of worm casts or Krotovinas, as much as 25 percent mixing of recognizable bits of the epipedon with the underlying horizon.

Argaltolls (5.43)

The Argaltolls are the Altolls that have an argillic but not a natric horizon. The argillic horizon may reflect the presence of sodium during some earlier stage in the history of the soil. The Argaltolls may be on older surfaces than the Haplaltolls, or they may have been forested at some stage of their development. These are three possible explanations of the presence of the argillic horizons, and there may be others.

The Argaltolls have mostly been called Chernozems in the United States.

Orthic Argaltolls (5.430)

This subgroup includes the Argaltolls that have less than 7 percent exchangeable sodium in the argillic horizon, that have no albic horizon, and that have no carbonates in the matrix of the mollic epipedon or in the upper part of the argillic horizon.

Profile 69, page 184, is an example of the Orthic Argaltolls. The explanation of the genesis of the argillic horizon is debatable, but its presence seems established.

Calcic Argaltolls (5.43-5.44)

This subgroup includes the Argaltolls that have a calcic horizon and have carbonates in the epipedon or in the upper part of the argillic horizon.

Natric Argaltolls (5.43-5.45)

This subgroup includes Argaltolls that have more than 7 percent exchangeable sodium in some part of the argillic horizon and that have no albic horizon. In this subgroup it seems probable that sodium has played a part in the development of the argillic horizon.

Altalfic Argaltolls (5.43-7.2)

This subgroup includes the Argaltolls that have an albic horizon above the argillic horizon. They are intergrades between what have been called Chernozem and Gray Wooded soils.

Calcaltolls (5.44)

The Calcaltolls have been called Chernozems. The group is provided for Altolls that have a mollic epipedon and a calcic horizon, but that have no cambic, argillic, or natric horizon.

Orthic Calcaltolls (5.440)

The Orthic Calcaltolls should have the calcic horizon in or immediately below the mollic epipedon. At least some part of the epipedon should be calcareous.

Profile 70, page 185, is an example of the Orthic Calcaltoll. The mottled colors shown by the description are not the result of gleying, but are the result of accumulations of secondary lime in spots. The lime itself is white, and it imparts low chromas and high values to the spots where it has accumulated in large quantities. The clay of the ca horizon is largely calcite.

Haplic Calcaltolls (5.44-5.42)

These soils have a calcic horizon separated from the epipedon by a calcareous horizon that is massive and lacks evidence of alteration sufficient to qualify it as a cambic horizon.

Natraltolls (5.45)

This group includes Altolls that have a natric horizon in or below the epipedon but have no intervening cambic horizon. There may be, particularly in virgin profiles, a thin albic horizon.

Profiles 4 and 18, pages 69 and 83, represent the Orthic Natraltolls. At this writing, no other subgroups are being proposed. It is possible that at a later date profile 4 will be retained as orthic, and profile 18 classified in another subgroup because its argillic horizon has only a little exchangeable sodium, but large amounts of exchangeable magnesium.

UDOLLS (5.5)

The Udolls include the soils that have been called Brunizems (Prairie soils) and some Reddish Prairie soils, Alluvial soils, and Regosols. They have developed in climates humid enough that, in most years, there is some movement of water through the soil and down to the ground water. There is also, as a rule, a summer deficit of rainfall so that in most years there are horizons that are dry for short periods. The native vegetation was dominantly tall grass, although a few soils of this suborder have had forest vegetation for a part if not for all of their history. These soils, so far as is known, are always in calcareous or highly basic parent materials.

The Udolls are those Mollisols that have chromas higher than those of the Aquolls or that lack mottles if chromas are between 1 and 2. The parent materials contain less than 40 percent calcium carbonate equivalent unless there is an argillic horizon, or unless the epipedon is thicker than 30 to 50 cm. (12 to 20 inches), depending on the gravel content. (See Rendoll definition.) They have a mean annual temperature higher than 8.3° C. (47° F.) if the chromas of the epipedon are less than 1.5 to depths of 15 cm. or more. Ca horizons may be present or absent. In addition, the Udolls have one of the following combinations of properties associated with their humid climate.

1. If an argillic or cambic horizon is present they have either (a) base saturation (by NH_4OAC) of less than 80 percent in the argillic or cambic horizon; or (b) base saturation that is more than 80 percent if there is no increase in saturation with sodium and potassium with depth below the argillic or cambic horizon, or if the exchange acidity exceeds the sum of exchangeable sodium and potassium below the argillic or cambic horizon. The conductivity of the saturation extract is less than 1 millimho per cm. at 25° C. to whichever of these depths is shallower: the depth at which the total water-holding capacity (1/3 bar tension) equals 30 cm. (12 inches) of water, or the depth to rock (R).

2. If no argillic or cambic horizon is present, they have either (a) base saturation of less than 80 percent in the mollic epipedon and in at least part of the next underlying horizon; or (b) if base saturation is more than 80 percent in all parts of the mollic epipedon or in all parts of the next underlying horizon, which is the C, then there must be either no increase with depth in the C of saturation with sodium and potassium, or the exchange acidity must exceed the sum of the exchangeable sodium and potassium. In addition, the conductivity of the saturation extract must be less than 1 millimho per cm. at 25° C. below any ca horizon that may be present. And, if there is no ca horizon, conductivity must be less than 1 millimho to a depth at which the total water-holding capacity (1/3 bar tension) equals 30 cm. (12 inches) of water or to rock, whichever depth is shallower.

Key to Udolls

5.51 Udolls that do not have an argillic or a cambic horizon but do have a mollic epipedon that is more than 50 cm. (20 inches) thick that has common or abundant worm holes and worm casts and that has a transition to the C in which more than 25 percent of the material is discrete worm casts or krotovinas from the A1 and C.

Vermudoll, p. 175

5.510 Vermudolls with a mollic epipedon more than 75 cm. (30 inches) thick.

Orthic Vermudoll, p. 175

5.51-5.52 Other Vermudolls.

Haplic Vermudoll, p. 176

5.52 Other Udolls with a cambic horizon or C underlying the mollic epipedon.

Hapludoll, p. 176

5.520 Hapludolls with a mollic epipedon less than 50 cm. (20 inches) thick; with a cambic horizon free of carbonates in some part; with no albic horizon and argillic horizon underlying the cambic horizon; with no detectable allophane, and less than 20 percent volcanic ash and pumice, and with color as follows:
(a) If faint mottles are present within 50 cm. (20 inches) of the surface, and hues are as red or redder than 10YR, color values within a depth of 50 cm., are more than 2.5 if the chromas are 2 or less.
(b) If faint mottles are present within 50 cm. (20 inches) of the surface, and hues are 2.5Y or yellower, color values within a depth of 50 cm., are more than 4 if chromas are 3 or less.
(c) No mottles with chromas of 2 or less are present within 40 cm. (16 inches).

Orthic Hapludoll, p. 176

5.52-3.2 Other Hapludolls with detectable allophane or with more than 20 percent volcanic ash and pumice.

Andeptic Hapludoll, p. 176

5.52-1 Other Hapludolls with no cambic horizon or with carbonates in all parts of the cambic horizon, and with other properties of the Orthic Hapludolls.

Entic Hapludoll, p. 176

5.52-1.1 Other Hapludolls with no cambic horizon that is free of carbonates in some part, and with mottling shallower or values darker than those of Orthic Hapludolls.

Aquentic Hapludoll, p. 176

5.52-5.3 Other Hapludolls with cambic horizon free of carbonates in some part, and with mottling shallower or values darker than those of Orthic Hapludolls.

Aquic Hapludoll, p. 176

5.52-5.21 Other Hapludolls with an albic horizon and an argillic horizon underlying the cambic horizon.

Albollic Hapludoll, p. 176

5.52-Cumulic Other Hapludolls with an epipedon that is thicker than 50 cm. (20 inches) and that has a diffuse or gradual lower boundary.

Cumulic Hapludoll, p. 176

5.53 Other Udolls with an argillic horizon.

Argudoll, p. 176

5.530 Argudolls that have a mean annual temperature of 8.3° C. (47° F.) or more; that have no detectable allophane, and less than 20 percent ash or pumice; that have no argillic horizon that has mottles of 2 or less and that has a clay increase of as much as 20 percent within a 3-inch vertical distance from its top; that have no albic horizon, and no duripan; and that have colors as follows:
(a) If hues are 10YR or redder, and there are faint mottles within 50 cm. (20 inches) there are colors within a depth of 50 cm. with values of more than 2.5 if chromas are 2 or less.
(b) If hues are 2.5Y or yellower, and there are faint mottles within 50 cm. (20 inches), there are colors within a depth of 50 cm. with values of 4 or more if chromas are 3 or less.
(c) There are mottles with chromas of 2 or less within 40 cm. (16 inches) of the surface.

Orthic Argudoll, p. 176

5.53-5.2 Other Argudolls that have an argillic horizon in which there are mottles with chromas of 2 or less and in which clay increases 20 percent or more within 3 inches of the top.

Albollic Argudoll, p. 177

5.53-5.3 Other Argudolls that have the dark, mottled colors which are excluded from the orthic subgroup.

Aquic Argudoll, p. 177

5.53-5.4 Other Argudolls with mean annual temperature of 8.3° C. (47° F.) or less.

Altollic Argudoll, p. 177

Vermudolls (5.51)

The Vermudolls are the Udolls that have been mixed by worms and burrowing mammals. If A and C are mixed regularly, the mollic epipedon is thickened, and normally no horizons can be formed except the mollic epipedon. The Vermudolls have a mollic epipedon that is thicker than 50 cm. (20 inches), that shows many worm holes and worm casts, and that has a transition to the C in which more than 25 of the matrix consists of identifiable worm casts and krotovinas of A1 and C materials. The Vermudolls are unknown in the United States, and the subgroup definitions are given very tentatively.

Orthic Vermudolls (5.510)

This subgroup includes those Vermudolls with a mollic epipedon more than 75 cm. (30 inches) thick.

Profile 71, p. 186, is an example of the Orthic Vermudoll. Mixing by animals has apparently been so intensive that the rainfall has been unable to remove the carbonates completely from the surface horizon. The nearly level slope of the soil has precluded significant erosion since the loess was deposited, presumably in Wisconsin time. The high lime content of the loess is in accord with the abundance of limestone in the Alps, the probable source of glacial meltwaters.

Haplic Vermudolls (5.51-5.52)

This subgroup includes Vermudolls with a mollic epipedon between 50 and 75 cm. (20 and 30 inches) thick.

Hapludolls (5.52)

The Hapludolls have been called Brunizems (Prairie soils) for the most part. A few have been called Brown Forest soils, Alluvial soils, and Regosols. They are found in humid climates, and primarily on land surfaces of Late Wisconsin or younger age. The native vegetation has been mostly tall grass. Some have had a forest vegetation, and these have either calcareous or highly basic parent material.

The Hapludolls have a mollic epipedon resting on a cambic horizon or on C. If a cambic horizon is present, there may be an underlying sequum that has an albic horizon and an argillic horizon.

The central concept of the great group is that of the orthic subgroup. Other subgroups include the permissible variations.

Orthic Hapludolls (5.520)

This subgroup includes the Hapludolls that have a cambic horizon that is free of carbonates in some part and that has no underlying sequum. Allophane can not be detected, and volcanic ash and pumice constitute less than 20 percent of the soil. The mollic epipedon is less than 50 cm. (20 inches) thick. Deeper penetrations of dark colors, combined with low chromas and mottles within the upper 50 cm., than listed in the key, exclude soils from this subgroup.

Profile 33, page 98, is an example of the Orthic Hapludoll. Chemical data for this profile are given in table 14. The mollic epipedon is about 15 inches thick. The cambic horizon, between 15 and 34 inches, has lost its carbonates and acquired structure, but there is little other evidence of alteration.

Andeptic Hapludolls (5.52-3.2)

This subgroup is provided tentatively for Hapludolls that have detectable amounts of allophane, or that have more than 20 percent of volcanic ash and pumice. The definition of this subgroup has received no discussion, and it likely will be modified to permit intergrades to specific great groups in the Andept suborder.

Entic Hapludolls (5.52-1)

This subgroup includes the Hapludolls that have no cambic horizon, or that have carbonates in all parts of the cambic horizon. They have the combinations of colors of the orthic subgroup. And they have no detectable allophane and less than 20 percent volcanic ash and pumice.

Aquentic Hapludolls (5.52-1.1)

This subgroup includes the Hapludolls that have no detectable allophane and less than 20 percent of ash; that have no cambic horizon that lacks carbonates in any part; and that have one or more of the combinations of Mottles, low chromas, and dark colors listed below:

1. With mottles that have chromas of 2 or less within 40 cm. (16 inches) of the surface.
2. With faint mottles of medium or high chromas within 50 cm. (20 inches) in a matrix color that extends to 50 cm. and is either
   a. in hues of 10YR or redder, with chromas of 2 or less and with values as dark or darker than 2.5; or
   b. in hues of 2.5Y or yellower, with chromas of 3 and values of 4 or less.

Aquic Hapludolls (5.53-5.3)

This subgroup includes soils similar to the Aquentic Hapludolls in color but that have a cambic horizon that, in at least its upper part, contains no carbonates.

Albollic Hapludolls (5.52-5.21)

The subgroup includes Hapludolls that have, below the cambic horizon, a sequum of an albic horizon and an argillic horizon.

Cumulic Hapludolls (5.52-Cumulic)

This subgroup includes Hapludolls that have a mollic epipedon more than 50 cm. (20 inches) thick, with a gradual or diffuse lower boundary, and with no evidence of mixing by burrowing animals, such as is required of the Vermudolls. The soils of this subgroup are normally found on flood plains or on concave slopes where sedimentation can be expected.

Argudolls (5.53)

This great group includes the Udolls that have an argillic horizon, but that have no cambic horizon and albic horizon above the argillic horizon.

The soils of this group have been called Brunizems (Prairie soils) and Reddish Prairie soils. They are normally on land surfaces older than those of the Hapludolls, and they are considered to represent a more advanced stage of development than any but the Albollic Hapludolls. The native vegetation of the Argudolls was primarily tall grass. A few have had scattered trees with a grass understory. A very few have had forest with a complete canopy, but available evidence indicates an earlier grass vegetation on these soils.

The central concept of the Argudolls is that of the orthic subgroup; other subgroups represent the permissible variations.

Orthic Argudolls (5.530)

This subgroup was the central concept of the Brunizems (Prairie soils), now subdivided into Hapludolls and Argudolls. It includes the Argudolls that, if there are mottles with chromas of 2 or less in the argillic horizon, have no increase of as much as 20 percent clay in a 3-inch vertical distance in that horizon. No albic horizon may be present. There is no detectable allophane, and less than 20 percent volcanic ash and pumice. The mean annual temperature is more than 8.3° C. (47° F.). And, colors in the argillic horizon are brownish. Soils are excluded if they have one of the following:

1. Mottles with chromas of 2 or less within 40 cm. (16 inches) of the surface.

2. Colors in hues of 10YR or redder, with chromas of 2 or less and values of 2.5 or less extending to a depth of 50 cm. if accompanied by faint mottles within 50 cm.

3. Colors in hues of 2.5Y or yellower, with chromas of 3 or less and values of 4 or less extending to a depth of 50 cm. if accompanied by faint mottling within 50 cm.

Profile 72, page 187, represents the Orthic Argudoll. This soil developed in glacial till of Kansan age but is on a much younger land surface. The mollic epipedon is 17 inches thick. The argillic horizon begins in the lower part of the epipedon and fades out at a depth between 3 and 4 feet. Some soils of this subgroup lack the mottles in the lower part of the argillic horizon that are present in this profile. Many others have eroded under cultivation and have a thinner epipedon.

Albollic Argudolls (5.53-5.2)

This subgroup includes Argudolls that have at the top of the argillic horizon an increase in clay content of 20 percent (for example, from 20 to 40 percent) within a vertical distance of 3 inches or less, and that have mottles with chromas of 2 or less in the argillic horizon. Commonly, there is a thin horizon, above the argillic horizon that contains many bleached silt or sand grains. When dry, this horizon appears to be an albic horizon. When moist, it can be recognized only by using a hand lens.

Aquic Argudolls (5.53-5.3)

This subgroup includes the Argudolls with the dark mottled colors that are excluded from the orthic subgroup. They are otherwise comparable to the Orthic Argudolls.

Altollic Argudoll (5.53-5.4)

This subgroup includes the Argudolls that have mean annual temperature of 8.3° C. (47° F.) or less. So far as is now known, they occur in the United States chiefly at high elevations in areas that escaped the effects of the last glaciation or its closing stages.

USTOLLS (5.6)

The Ustolls include the Mollisols that lie, with respect to climate, between the Udolls and the Aridisols. They include many soils called Chernozems, Chestnut soils, Reddish Chestnut soils, and some that have been called Brown soils.

They have a mollic epipedon, usually with a chroma of 2 or more. If the mean annual temperature is less than 8.3° C. (47° F.) the chroma must be more than 1.5 in at least part of the upper 15 cm. (6 inches). This is the limit between Ustolls and Altolls. The soils may have only a mollic epipedon resting on C or R. They may have an argillic, natric, cambic, calcic, or gypsic horizon.

If there is a cambic or argillic horizon, base saturation (by NH_4OAc) is more than 80 percent in this horizon; below it there is less exchangeable hydrogen than sodium and potassium, and the percentage of exchangeable sodium and potassium increases with depth. If a ca horizon is present, the increase in sodium and potassium normally occurs in or below the ca horizon. Or, if the percentage of exchangeable sodium and potassium do not increase, the conductivity of the saturation extract exceeds 1 millimho per cm. at 25° C. in some horizon at depth in the soil.

If there is no cambic or argillic horizon, either the exchangeable sodium and potassium exceed hydrogen and the percentage saturation with sodium and potassium increase with depth, or the conductivity of the saturation extract exceeds 1 millimho per cm. at 25° C. at some depth. This unspecified depth is below any ca horizon that may be present. If no ca horizon is present, the depth is whichever of these two is shallower; the depth at which the total water-holding capacity at 1/3 bar exceeds 12 inches of water, or the depth to bedrock.

Key to Ustolls

5.61 Ustolls with no argillic or cambic horizon and with a mollic epipedon that is more than 50 cm. (20 inches) thick and that has common or abundant worm holes and worm casts, and a transition to the C in which more than 25 percent of the material is discrete worm casts or krotovinas of Al and C material.

Vermustoll, p. 178

5.610 Vermustolls with a mollic epipedon more than 75 cm. (30 inches) thick.

Orthic Vermustoll, p. 178

5.61-5.62 Other Vermustolls.

Haplic Vermustoll, p. 178

5.62 Other Ustolls in which the mollic epipedon rests on C or on a cambic horizon; if there is no cambic horizon, there is no calcic horizon within 30 cm. (12 inches) below the epipedon.

Haplustoll, p. 178

5.620 Haplustols with a mollic epipedon between 15 and 50 cm. (6 and 20 inches) thick; with a cambic horizon; with no mottles that have chromas of 2 or less within 1 meter of the surface; with the mollic epipedon darkest at the surface and becoming lighter colored with depth.

Orthic Haplustoll, p. 178

5.62-1 Other Haplustolls with no cambic horizon.

Entic Haplustoll, p. 178

5.62-5.3 Other Haplustolls with mottles that, within 1 meter of the surface, have chromas of 2 or less.

Aquic Haplustoll, p. 179

5.62-4.1 Other Haplustolls with a mollic epipedon in which the lower part is as dark or darker than the upper part.

Orthidic Haplustoll, p. 179

5.63 Other Ustolls with an argillic horizon, but with no calcic horizon in the upper part of the argillic horizon, and with no natric horizon and no duripan.

Argustoll, p. 179

5.630 Argustolls that, within a 3-inch vertical distance from the top of the argillic horizon, do not have a clay increase of as much as 20 percent (for example, from 20 to 40 percent); and that are as dark or darker in color in the upper part of the mollic epipedon than in the upper part of the argillic horizon.

Orthic Argustoll, p. 179

5.63-5.2 Other Argustolls that, within a 3-inch vertical distance from the top of the argillic horizon, have an increase of 20 percent or more clay.

Albollic Argustoll, p. 179

5.63-4.2 Other Argustolls with colors darker in the upper part of the argillic horizon than in the upper part of the mollic epipedon.

Argidic Argustoll, p. 179

5.64 Other Ustolls with a duripan but without a natric horizon.

Durustoll, p. 179

5.640 Durustolls having an argillic horizon above the duripan, and colors at least 1/2 unit darker in the upper part of the mollic epipedon than in the upper part of the argillic horizon.

Orthic Durustoll, p. 179

5.64-4.2 Other Durustolls having an argillic horizon in which color is as dark or darker in its upper part than in the upper part of the mollic epipedon.

Argidic Durustoll, p. 179

5.64-5.62 Other Durustolls with no argillic horizon.

Haplic Durustoll, p. 179

5.65 Other Ustolls with a calcic horizon and no natric horizon.

Calcustoll, p. 179

5.650 Calcustolls having the calcic horizon directly under the epipedon, having no argillic horizon, and having no mottles with chromas of 2 or less within 75 cm. (30 inches) of the surface.

Orthic Calcustoll, p. 179

5.65-5.3 Other Calcustolls having mottles with chromas of 2 or less within 75 cm. (30 inches) of the surface.

Aquic Calcustoll, p. 179

5.66 Other Ustolls with a natric horizon.

Natrustoll, p. 179

Vermustolls (5.61)

The Vermustolls are the Ustolls that have a mollic epipedon more than 50 cm. (20 inches) thick that shows evidence of intensive mixing by burrowing animals, chiefly mammals and earthworms. The epipedon rests on the C, and in the transition to the C, more than 25 percent of the matrix consists of recognizable bits of A1 and C in the form of worm casts and krotovinas.

Vermustolls are rare or absent in the United States. The subgroup definitions are therefore very tentative. The orthic subgroup should have an epipedon more than 75 cm. (30 inches) thick. It is possible that 1 meter for the epipedon would make a better division. The Vermustolls with an epipedon thinner than that of the orthic subgroup would constitute a haplic subgroup.

Haplustolls (5.62)

The Haplustolls include many soils that have been called Chernozems, Chestnut soils, and Reddish Chestnut soils. Some Brown soils are also included if they have a mollic epipedon. A few Regosols and Alluvial soils in subhumid climates are also included.

The Haplustolls include the Ustolls that have a mollic epipedon on a cambic horizon or on C or R. They have no argillic horizon, or natric horizon, or duripan. They usually have ca horizons, but they may have a calcic horizon only if there is a cambic horizon and the upper boundary of the calcic horizon is more than 30 cm. (12 inches) below the epipedon.

Haplustolls are generally found on land surfaces no older than the middle or closing stages of the Wisconsin glaciation.

Orthic Haplustolls (5.620)

This subgroup is the central concept of the Haplustolls. It includes Haplustolls that have a mollic epipedon 15 to 50 cm. (6 to 20 inches) thick; that have a cambic horizon; that have no mottles with chromas of 2 or less within 1 meter (40 inches) of the surface; and that have the darkest colors in the upper part of the mollic epipedon.

It is typical, as the Haplustolls grade into the Aridisols, that the darkest colors are not at the surface but are 10 to 20 cm. (4 to 8 inches) below the surface. The color differences are most obvious when the soil is dry. The soils with this color pattern are excluded from the Orthic subgroup.

Profile 73, page 188, is an example of the Orthic Haplustolls. The mollic epipedon is only 5 inches thick, but the solum is less than 15 inches thick. The cambic horizon, between 5 and 14 inches, shows almost complete leaching of carbonates and the formation of prismatic structure. The increase in content of clay in the ca horizon is due to clay-size carbonates, not to silicate clays. Sodium saturation increases markedly below the ca horizon.

Entic Haplustolls (5.62-1)

This subgroup includes Haplustolls that have no cambic horizon. These soils were formerly considered Regosols or Alluvial soils. No mottles with chromas of 2 or less should be present within 1 meter of the surface.

Aquic Haplustolls (5.62-5.3)

This subgroup includes Haplustolls that have mottles with chromas of 2 or less within 1 meter of the surface.

Orthidic Haplustolls (5.62-4.1)

This subgroup includes the Haplustolls that are excluded from the orthic subgroup by having lighter or no darker colors in the surface few inches of the mollic epipedon than in some lower parts.

Argustolls (5.63)

The Argustolls are primarily soils that have been called Chernozems, Chestnut soils, and Reddish Chestnut soils. A few Brown soils and Reddish Brown soils may be included.

The Argustolls have a mollic epipedon and an argillic horizon, but no natric horizon or duripan. Nor, do they have a calcic horizon in the upper part of the argillic horizon.

The Argustolls are primarily on land surfaces older than those of the Haplustolls, though few of the surfaces have been dated. It seems possible that at least some of the surfaces are older than the Wisconsin glaciation, and they may be appreciably older.

Orthic Argustolls (5.63)

This subgroup includes the Argustolls that have no clay increase of as much as 20 percent (for example, from 20 to 40 percent) within a vertical distance of less than 3 inches. And, the upper part of the mollic epipedon is as dark or darker than the upper part of the argillic horizon.

The soils of this subgroup have been mostly called Chernozems, Chestnut soils, and Reddish Chestnut soils.

Profile 74, page 189, is an example of the Orthic Argustoll. The plow layer has the same colors as the upper part of the argillic horizon; that is, the part of the argillic horizon between depths of 8 and 11 inches. Both are part of the mollic epipedon. The argillic horizon extends from 8 to 20 inches. Below the ca horizon, saturation with exchangeable sodium increases.

Profile 3, page 68, is another example of this subgroup. In this soil, the argillic horizon is entirely within the mollic epipedon. It is characteristic that the soils of this subgroup have a thin solum unless they have coarse textures.

Albollic Argustolls (5.63-5.2)

This subgroup includes the Argustolls that have, within a 3-inch vertical distance from the top of the argillic horizon, an increase of 20 percent or more in clay; a very thin albic horizon may be present, or frequently, bleached sand and silt grains just above the argillic horizon may give the appearance of an albic horizon when they are dry. Mottles may be present in the argillic horizon but are not necessary to the classification.

Argidic Argustolls (5.63-4.2)

This subgroup includes soils that have been called Brown soils, and possibly Reddish Brown soils. In the upper part of the argillic horizon they have darker colors than in the upper part of the mollic epipedon.

Durustolls (5.64)

This group is provided tentatively for Ustolls with duripans. At this writing, it seems probable that all duripans found in Mollisols are associated with volcanic ash. There is need for further discussion on the classification of these soils.

Calcustolls (5.65)

This great group includes soils recently called Calcisols. It includes Ustolls that have a calcic horizon within 30 cm. (12 inches) below the base of the epipedon. They may have an argillic horizon in the calcic horizon, but they have no duripans.

Orthic Calcustolls (5.650)

This subgroup represents the central concept of the Calcustolls. The soils have a calcareous epipedon, and a calcic horizon immediately below the epipedon. There are no mottles with chromas of 2 or less within 75 cm. (30 inches) of the surface.

Profile 75, page 190, illustrates this subgroup. The mollic epipedon is 6 inches thick and calcareous. It rests directly on a cambic horizon that extends to 44 inches. Below 44 inches, exchangeable sodium and potassium increase. This profile possibly contains a buried soil, beginning at about 30 inches.

Aquic Calcustclls (5.65-5.3)

This subgroup includes the Calcustolls that have mottles with chromas of 2 or less within 75 cm. (30 inches) of the surface.

Natrustolls (5.66)

The Natrustolls have been called Solonetz and solodized Solonetz. They include the Ustolls that have a natric horizon. The mollic epipedon often includes a thin albic horizon that lies entirely within the upper 17.5 cm. (7 inches). The albic horizon is permitted if a mixture of the surface 7 inches has the properties of a mollic epipedon.

No subgroups have been defined.

Profile 76, page 191, is an example of the Orthic Natrustolls. It has a mollic epipedon that is 10 inches thick. There is a thin albic horizon, from 10 to 13 inches, and a natric horizon from 13 to 21 inches.

The exchangeable magnesium is high in the natric horizon, and sodium is low. In other profiles the reverse is true. Whether there should be separate subgroups is undecided. If two subgroups are recognized on the basis of the relative dominance of sodium and magnesium in the exchange complex, profile 76 presumably would be placed in an Argic Natrustoll subgroup (5.66-5.63).

Profile Descriptions for Chapter 12

(Colors for moist soil unless otherwise stated)

Profile No. 65

Area: Wayne County, Iowa.
Vegetation: Bluegrass.
Parent Material: Loess.
Topography: Flat or nearly level.

A1 0 to 9 inches, black (10YR 2/1) silt loam, dark grayish brown (10YR 4/2) when dry; very fine, granular structure.

A2 9 to 15 inches, very dark gray (10YR 3/1) silt loam that has numerous, fine, very light colored mottles; very thin, platy structure.

B&A 15 to 19 inches, very dark gray (10YR 3/1) silty clay; numerous, fine, white mottles; fine, subangular blocky structure.

B21t 19 to 28 inches, very dark brown (10YR 2/2) to very dark gray (10YR 3/1) silty clay; dark reddish-brown (5YR 3/3-3/4) mottles; fine, angular, blocky structure; dark reddish-brown (5YR 3/3-3/4) concretions.

B22t 28 to 36 inches, dark grayish-brown (2.5Y 4/2) to grayish-brown (2.5Y 5/2) silty clay; dark reddish-brown (5YR 3/3) to reddish-brown (5YR 4/4) mottles; medium, subangular blocky structure.

B3t 36 to 45 inches, grayish-brown (2.5Y 5/2), light silty clay; yellowish-brown (10YR 5/6-5/8) mottles; numerous, black (10YR 2/1) ferromanganese concretions.

C 45 to 60 inches, grayish-brown (2.5Y 5/2) silty clay loam; yellowish-brown (10YR 5/6-5/8) mottles; massive; numerous, dark concretions.

Remarks: Horizon thickness as described do not exactly correspond to the horizons sampled for laboratory study. The data and description are taken from papers by: Ulrich, Rudolph, Soil Sci. Soc. Amer. Proc. 14: 287-295 and Soil Sci. Soc. Amer. Proc. 15: 324-329.

Climatic data (Millerton, Iowa)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-50 (deg. F.)	24	27	38	51	61	71	76	74	67	56	40	28	51
Mean precipitation, 1931-50 (inches)	1.4	1.0	2.1	2.9	4.1	5.3	3.2	4.0	3.7	2.2	2.2	1.5	33.4

Annual precipitation more than 22.6 and less than 44.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Total sand	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Fine clay <0.0006	>2	B.D. (gm. per cc.) u	Organic matter C % d	C/N k
0-5	A1				4.8		74.2	21.0	3.7		1.16	2.20	12
9-13	A2				5.4		71.2	23.4	9.9		1.31	1.05	11
13-17	B&A				4.4		64.7	30.9					
20-24	B21t				2.6		45.0	52.4	32.8		1.24	.91	10
24-29	B21t				2.3		45.4	52.3					
29-35	B22t				2.4		48.7	48.9	28.2		1.28	.54	10
35-41	B3t				2.2		54.8	43.0					
41-47	C1				1.8		56.2	42.0	19.7			.23	
47-53	C2				2.4		59.3	38.3			1.40		

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH sat. paste 2½:1	Base sat. % s
20.6	13.4	2.9	4.0	0.07	0.27	5.9	80.6
18.5	9.1	3.2	5.8	.24	.15	5.0	68 6
---	11.7	5.4	5.8	---	.12	5.2	---
43.5	22.0	12.1	7.4	1.69	.32	5.6	83.0
---	23.3	12.3	6.5	---	.45	5.8	---
41.8	22.4	12.2	4.7	2.03	.46	6.1	88.8
---	19.3	10.5	1.3	---	.38	6.1	---
33.4	18.4	10.0	2.8	1.8	.38	6.6	91.6
---	18.2	10.2	1.7	---	.30		---

*Exchange acidity.

Profile No. 66

Area: Sargent County, North Dakota.
Vegetation: Coarse grasses; (natural) sedges, rushes, reeds, and broad-leaf, water-loving plants.
Parent material: Glacial drift.
Topography: Less than 1 percent slope, slightly concave; small, closed depression in upland.

A11 — 0 to 3 inches, black (10YR 2/1) silty clay loam, very dark gray (10YR 3/1) when dry; weak, fine, granular structure; slightly hard, friable, slightly sticky, slightly plastic; abundant roots; many, fine, sand grains of clear quartz.

A12 — 3 to 10 inches, black (10YR 2/1) silty clay loam, dark gray (10YR 4/1) when dry; strong, fine and medium, platy structure; slightly hard, very friable, slightly sticky, slightly plastic; upper sides of peds coated with bleached silt and very fine sand; abundant roots; clear, wavy boundary.

A2 — 10 to 13 inches, very dark gray (10YR 3/1) loam, gray (10YR 5/1) when dry; very dark grayish-brown (10YR 3/2) mottles, light gray (10YR 6/1) and brownish yellow (10YR 6/8) when dry; moderate, medium, platy structure; very hard, friable, sticky, plastic; peds coated with bleached grains of sand; plentiful roots; clear, wavy boundary.

B21t — 13 to 16 inches, very dark gray (10YR 3/1) clay loam, dark gray (10YR 4/1) when dry; common, dark-brown (10YR 4/3) mottles; moderate, very fine, blocky structure; very hard, firm, very sticky, very plastic; peds coated with gray (10YR 5/1) silt; plentiful roots; clear, wavy boundary.

B22t — 16 to 25 inches, black (10YR 2/1) clay, very dark gray (10YR 3/1) when dry; weak, coarse, prismatic, breaking to strong, medium, blocky structure; extremely hard, very firm, very sticky, very plastic; clear, smooth boundary.

B23g — 25 to 31 inches, dark olive-gray (5Y 3/2) sandy clay loam, dark gray (5Y 4/1) when dry; common, olive (5Y 5/3) mottles; weak, coarse, prismatic, breaking to moderate, fine, blocky structure; extremely hard, very firm, very sticky, very plastic; clear, wavy boundary.

B3g — 31 to 36 inches, olive-gray (5Y 4/2) loam, gray (5Y 6/1) when dry; common, fine, distinct mottles of dark yellowish brown (10YR 4/4), light olive brown (2.5Y 5/4) when dry; weak, coarse, prismatic, breaking to moderate, fine, blocky structure; extremely hard, very firm, very sticky, very plastic; few roots; common, fine and medium-sized gravel; calcareous; clear, smooth boundary.

C1g — 36 to 48 inches, dark-gray (5Y 4/1) loam, light gray (5Y 6/1) when dry; many, fine, distinct white (5Y 8/1) and many large, prominent, dark-brown (7.5YR 4/4) mottles; weak, medium, blocky structure; very hard, firm, sticky, plastic; few roots; many, small, soft segregations of lime and soft thin crusts of lime on gravel; calcareous; clear, smooth boundary.

C2g — 48 to 60 inches, mottled olive-brown (2.5Y 4/4) and gray (5Y 5/1) loam; light olive brown (2.5Y 5/4) and light gray (5Y 6/1) when dry; common, fine, white (10YR 8/1) mottles; hard, firm, slightly sticky, slightly plastic; few roots; small amount of soft, segregated lime; calcareous.

Climatic data (Forman, N. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1937-52 (deg. F.)	9	11	27	43	56	65	72	70	60	48	29	16	42
Mean precipitation, 1931-52 (inches)	0.5	0.6	0.9	1.9	2.4	4.0	3.1	2.2	1.4	1.2	0.7	0.5	19.5

Annual precipitation more than 12.0 and less than 27.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Organic matter C % w	C/N k
0-3	A11	--	0.7	1.6	8.3	9.2	46.4	33.8	31.5	29.2	--	1.2	--	6.87	12
3-10	A12	0.3	1.0	1.4	4.0	5.5	55.6	32.2	25.7	38.0	--	.6	--	6.29	11
10-13	A2	3.8	4.3	4.3	9.0	8.6	45.4	24.6	33.2	26.2	2.9	.5	--	1.26	9
13-16	B21t	2.5	3.5	3.7	7.9	7.8	39.6	35.0	29.7	22.6	1.8	.5	--	.87	8
16-25	B22t	2.8	4.5	5.0	9.6	7.9	29.2	41.0	26.2	16.6	2.9	.4	4	.53	8
25-31	B23g	8.5	10.7	8.8	13.5	8.3	20.4	29.8	24.3	11.8	6.0	.5	2	.41	--
31-36	B3g	5.9	8.4	7.7	14.3	9.8	29.0	24.9	30.0	17.1	10.5	.7	16	.33	--
36-48	C1g	10.8	10.3	7.2	11.5	8.5	31.0	20.7	26.8	19.6	15.2	.7	26	.24	--
48-60	C2g	8.4	9.5	7.5	13.1	9.6	31.5	20.4	29.6	19.0	11.0	.7	23	.18	--

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	Saturation Extract Soluble (meq./l.): Na	K	Ca	Mg	Moisture tensions 1/3 atmos. %	15 atmos. %	H_2O at sat. %
37.3	25.6	7.9		--	3.1	6.4	0.5	2.3	7.1	4.1	37.3	21.9	88.8
35.0	19.6	6.3		--	2.1	5.7	.3	1.0	3.3	2.1	42.4	20.8	87.2
15.9	8.2	3.7		--	1.1	5.6	.3	.6	1.8	1.5	21.4	9.8	43.6
22.2	12.1	5.9		--	1.2	5.4	.3	.5	2.2	1.3	23.2	13.0	47.5
25.9	15.7	7.9		--	1.1	5.5	.3	.4	1.9	1.2	24.8	14.8	59.8
18.8	12.1	5.7		--	.6	6.2	.4	.3	2.2	1.7	20.0	11.0	47.2
13.2				--	.4	7.6	.6	.4	4.4	2.1	16.7	8.8	41.7
9.3				--	.3	7.6	.5	.4	4.1	2.2	14.6	6.5	36.1
9.3				--	.3	7.7	.4	.4	4.2	2.0	14.2	6.6	30.6

Profile No. 67

Area: Waseca County, Minnesota.
Vegetation: Corn; (natural) tall grasses and marsh grasses.
Parent material: Glacial till.
Topography: Shallow depression in nearly level, ground moraine on upland.

Ap 0 to 7 inches, black (10YR 2/1) clay loam; breaks out into weak clods, which crush readily into weak, very fine, blocky structure; plastic.

A12 7 to 13 inches, black (10YR 2/1) clay loam; weak, very fine, blocky structure; firm, sticky; clear, smooth boundary.

A13 13 to 17 inches, very dark-gray (10YR 3/1) clay loam, weak, very fine, blocky structure; friable, sticky; smooth boundary.

B21g 17 to 23 inches, dark-gray (5Y 4/1) mixed with olive-gray (5Y 5/2) clay loam; massive clods, breaking to weak, very fine, blocky structure; friable; tongues of this material extend into the B22 horizon.

B22g 23 to 26 inches, olive-gray (5Y 5/2) to olive (5Y 5/3) clay loam; few, medium, distinct mottles of yellowish brown; massive clods breaking to very, fine, blocky structure; friable, sticky; numerous worm holes, which are filled with very dark gray (10YR 3/1) material.

C1 26 to 33 inches, olive (5Y 5/3) clay loam; few, medium, distinct mottles of yellowish brown; massive clods, which break into weak, very fine, blocky structure; friable, sticky; calcareous.

C2 33 to 46 inches, olive (5Y 5/3) clay loam; massive; friable, slightly sticky; a few fragments of shale.

C3 46 inches +, gray (5Y 5/1) to olive (5Y 5/3) loam; many, medium, distinct mottles of yellowish brown (10YR 5/8); friable; ground water at depth of 48 inches.

Climatic data (Waseca, Minn.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	15	18	30	46	59	68	73	71	62	51	33	20	45
Mean precipitation, 1931-52 (inches)	1.0	1.0	1.9	2.3	3.6	4.5	3.2	3.5	3.0	1.6	1.7	1.0	28.3

Annual precipitation more than 19.1 and less than 37.5 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	$CaCO_3$ equiv. % n
0-7	Ap	1.0	2.8	4.5	12.9	8.7	37.2	32.9	31.2	22.1	0		4.8	13	--
7-13	A12	1.0	2.8	4.3	13.3	8.6	37.0	33.0	31.9	21.5	0		4.4	13	--
13-17	A13	1.0	3.3	5.1	16.0	9.0	33.5	32.1	31.4	20.2	<1		1.90	12	--
17-23	B21g	1.2	3.3	5.4	18.2	9.6	32.3	30.0	33.1	18.9	<1		.76	15	--
23-26	B22g	1.8	3.8	6.0	19.0	10.1	29.8	29.5	31.8	18.5	<1		.46	12	2
26-33	C1	2.6	4.0	5.1	14.8	10.3	34.6	28.6	31.7	21.9	<1		.30	--	12
33-46	C2	2.0	4.1	4.8	13.6	10.2	38.8	26.5	31.6	25.5	<1		.22	--	15
46+	C3	2.5	4.6	5.9	16.0	11.3	36.7	23.0	34.3	23.1	8		.19	--	12

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
49.9	36.7	8.3	4.0	0.3	0.6	92	7.2
46.9	35.1	8.3	2.8	.2	.5	94	7.2
37.8	27.2	7.6	2.1	.3	.6	94	7.2
32.6	23.5	6.7	1.7	.3	.4	95	7.5
Calcareous, not run----------------------------							7.7
Calcareous, not run----------------------------							7.8
Calcareous, not run----------------------------							7.9
Calcareous, not run----------------------------							7.9

*Exchange acidity.

Profile No. 68

Area: Sargent County, North Dakota.
Vegetation: Plowed field; (natural) tall grass.
Parent material: Glacial till.
Topography: 1 to 3 percent slopes; top of a low ridge that has a 3 percent slope to the east and a 1 percent slope to the west.

Ap 0 to 8 inches, black (10YR 2/1) clay loam; very dark gray when dry; weak, fine, granular structure; slightly hard, very friable; abundant, clear, very fine and fine grains of quartz sand; abrupt, smooth boundary resulting from tillage; tongues of this horizon extend through the A12 horizon.

A12 8 to 14 inches, very dark grayish-brown (10YR 3/2) clay loam, dark grayish brown (10YR 4/2) when dry; moderate, medium, prismatic and blocky structure; very hard, friable, sticky, plastic; diffuse, smooth boundary.

B2 14 to 17 inches, dark grayish-brown (2.5Y 4/2) clay loam, grayish brown (2.5Y 5/2) when dry; moderate, coarse, prismatic and blocky structure; very hard, firm, sticky, plastic; peds coated with very dark grayish brown (10YR 3/2), dark grayish brown (10YR 4/2) when dry; many, patchy clay skins on vertical faces of peds; inside of peds are calcareous.

C1 17 to 26 inches, light olive-brown (2.5Y 5/4) clay loam, light yellowish brown (2.5Y 6/4) when dry; weak, coarse, prismatic structure; hard, friable, sticky, plastic; patchy clay skins on vertical faces of peds; white (10YR 8/2) lime segregations; calcareous; diffuse boundary.

C2ca 26 to 37 inches, same color, texture, and structure as the C1 horizon but more calcareous; friable, slightly sticky, slightly plastic; diffuse boundary.

C3 37 to 44 inches, similar to C2ca horizon but less calcareous.

C4 44 to 60 inches, light olive-brown (2.5Y 5/4) clay loam, light yellowish-brown (2.5Y 6/3) when dry; common, fine, white (10YR 8/2) mottles; weak, coarse, prismatic, breaking to weak, fine, blocky structure; hard and friable; common, fine, soft, lime segregations; many, small nests of gypsum crystals; calcareous.

Climatic data (Forman, N. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperature, 1937-52 (deg. F.)	9	11	27	43	56	65	72	70	60	48	29	16	42
Mean precipitation, 1931-52 (inches)	0.5	0.6	0.9	1.9	2.4	4.0	3.1	2.2	1.4	1.2	0.7	0.5	19.5

Annual precipitation more than 12.0 and less than 27.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) u	Organic matter C % w	C/N k	E. C. mmhos. per cm. 25° C.
0-8	Ap	3.0	5.6	4.2	10.3	9.5	35.5	31.9	31.4	19.3	3.2	---	3.47	11	1.6
8-14	A12	2.3	6.2	5.9	11.5	10.1	31.7	32.3	30.5	17.4	2.6	1.24	2.30	12	1.1
14-17	B2	3.2	5.4	5.2	11.5	10.6	36.1	28.0	30.2	22.8	6.4	---	.94	9	.9
17-26	C1	4.2	5.9	5.7	11.3	10.2	35.1	27.6	28.5	23.1	7.8	1.35	.51	9	.8
26-37	C2ca	4.7	6.8	6.0	10.9	9.7	33.4	28.5	27.8	21.4	7.3	---	.18	---	2.8
37-44	C3	3.5	6.4	6.3	11.4	9.8	33.6	29.0	28.6	21.1	6.2	---	.16	---	3.5
44-60	C4	4.2	6.7	6.2	11.8	10.1	33.8	27.2	29.9	20.6	9.8	---	.16	---	4.5
60+	---	---	---	---	---	---	---	---	---	---	---	1.84	---	---	---

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	Exch. Na %	pH Sat. paste	$CaCO_3$ equiv. % v	Gypsum %	Sat. ext., soluble (meq./l.): Na	K	Ca	Mg	H_2O at sat. %
29.4	24.3	8.0		--	2.3	-	7.0	--	--	0.6	1.8	8.8	5.0	58.9
25.5	20.8	7.8		--	1.0	-	7.0	--	--	.5	.5	5.8	4.0	54.0
16.2	---	---		--	.4	-	7.6	17	--	.5	.3	4.4	3.1	46.9
12.9	---	---		0.1	.3	1	7.8	22	--	.6	.2	3.5	3.8	41.4
12.2	---	---		0.1	.3	1	7.9	28	--	3.6	.3	12.1	24.0	46.3
13.3	---	---		0.4	.3	3	7.8	23	--	7.5	.3	16.8	25.9	45.8
11.4	---	---		0.4	.3	4	7.7	23	2.50	11.1	.4	23.3	34.5	44.4
---	---	---		--	---	-	---	--	--	---	---	---	---	---

Profile No. 69

Area: Spink County, South Dakota.
Vegetation: (natural) mixed tall and mid grasses.
Parent material: Firm, glacial till.
Topography: Nearly level; on upland ground moraine.

A11 0 to 2½ inches, black (10YR 2/1) silt loam, very dark gray (10YR 3/1) when dry; weak, fine, platy, breaking to moderate, fine, granular structure; very friable.

A12 2½ to 7 inches, black (10YR 2/1) clay loam, very dark gray (10YR 3/1) when dry; moderate, medium, prismatic, breaking to moderate, fine, granular structure; very friable.

B21 7 to 12 inches, very dark grayish-brown (10YR 3/2) clay loam, dark grayish brown (10YR 4/2) when dry; very strong, medium, prismatic, breaking to moderate, medium, blocky structure; friable; clay skins evident.

B22t 12 to 22 inches, very dark grayish-brown (10YR 3/2) clay loam, dark grayish brown (10YR 4/2) to olive brown (2.5Y 4/4) when dry; very strong, medium, prismatic, breaking to moderate, medium, blocky structure; firm; clay skins evident.

B3 22 to 28 inches, grayish-brown (10YR 5/2) to light olive-brown (2.5Y 5/4) clay loam, light brownish gray (10YR 6/2) to light yellowish brown (2.5Y 6/4) when dry; numerous, white (10YR 8/1) mottles; strong, medium, prismatic, breaking to moderate, medium and coarse, blocky structure; friable.

C1 28 to 48 inches, mottled light olive-brown (2.5Y 5/4) and white (2.5Y 8/1) clay loam, light yellowish brown (2.5Y 6/4) and white (2.5Y 8/1) when dry; disseminated lime.

C2 48 to 60 inches, like the C1 horizon but no disseminated lime.

Climatic data (LaDelle, S. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	13	17	30	46	58	67	74	72	62	49	31	19	45
Mean precipitation, 1931-52 (inches)	0.5	0.4	1.1	1.8	2.3	3.8	2.5	2.2	1.7	1.2	0.6	0.5	18.5

Annual precipitation more than 10.3 and less than 26.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N	$CaCO_3$ equiv. % v
0-2½	A11	1.6	4.3	3.7	8.2	6.0	50.8	25.4		27.4	-		4.33		--
2½-7	A12	2.4	5.9	4.4	8.8	5.8	45.5	27.2		24.3	1		3.12		--
7-12	B21	4.0	7.8	7.0	12.3	5.8	29.7	33.4		15.3	2		1.37		--
12-22	B22t	4.7	9.5	7.9	13.5	7.2	24.0	33.2		14.8	2		.64		--
22-28	B3	6.5	8.9	6.8	12.7	6.8	28.2	30.1		18.1	9		.54		11
28-48	C1	6.2	9.6	7.0	12.5	7.1	28.4	29.2		18.2	6		.36		11
48-60	C2	5.4	8.7	6.5	12.4	7.4	29.2	30.4		18.7	6		.31		10

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	pH 1:10	Est. salt %	E. C. mmhos. per cm. 25° C.	Exch. sodium %	Sat. Ex. (meq./l.) Na	K	H_2O at sat. %	Gypsum me./100g soil
27.0				0.1	2.6	6.0	6.5	-	0.8	-	0.4	2.7	57.9	--
26.0				.1	1.4	6.1	6.7	-	.8	-	.4	.8	54.5	--
24.6				.1	.7	6.4	7.0	-	1.0	-	.4	.4	44.4	--
24.1				.1	.6	7.0	7.8	-	1.0	-	.4	.4	49.1	--
19.7				.1	.5	7.6	8.5	-	1.0	-	.4	.4	46.7	--
18.4				.3	.3	7.7	8.7	-	1.0	2	.9	.4	45.3	--
19.7				.7	.4	7.8	8.8	-	1.2	4	2.8	.4	50.4	--

Profile No. 70

Area: Renville County, North Dakota.
Vegetation: Summer fallow; (natural) tall grasses and mid grasses.
Parent material: Glacial till.
Topography: 3 percent slope; crest of short rise between wet depressions; till plain.

Ap 0 to 5 inches, very dark gray (10YR 3/1) loam, dark gray (10YR 4/1) when dry; moderate, fine, granular structure; soft, very friable; calcareous; gradual boundary.

A12 5 to 10 inches, very dark grayish-brown (2.5Y 3/2) loam, grayish brown (2.5Y 5/2) when **dry; numerous, medium mottles of grayish brown (2.5Y 5/2) and very dark gray (N 3/), light gray (2.5Y 7/2) and gray (N 5/) when dry,** which are mainly segregations of lime; very weak, medium, prismatic, breaking readily to moderate, medium, granular structure; slightly hard, very friable; calcareous; clear boundary.

C1ca 10 to 28 inches, mottled light olive-brown (2.5Y 5/4) or grayish-brown (2.5Y 5/2) and light-gray (2.5Y 7/2) clay loam, light brownish gray (2.5Y 6/2) and white(2.5Y 8/2) when dry; weak, medium, granular structure; hard, friable; calcareous; numerous lime segregations.

C2 28 to 36 inches, olive-brown (2.5Y 4/4) to dark grayish brown (2.5Y 4/2) clay loam; when dry, light brownish gray (2.5Y 6/2) with a few, fine mottles of light yellowish brown (2.5Y 6/4) and white (2.5Y 8/2); hard, friable; few lime segregations; calcareous.

C3 36 to 40 inches, light olive-brown (2.5Y 5/4) loam, light gray (2.5Y 7/2) when dry; few, fine mottles of yellowish red (5YR 4/6); moderate, thick, platy structure; very hard, firm; calcareous.

C4 40 to 48 inches, faintly mottled light olive-brown (2.5Y 5/4) and grayish-brown (2.5Y 5/2) loam, mottled light gray (2.5Y 7/2) and pale yellow (2.5Y 7/4) when dry; moderate, thick, platy structure; very hard, firm; nests of gypsum crystals; calcareous.

C5 48 to 60 inches, faintly mottled olive-brown (2.5Y 4/4) and dark grayish-brown (2.5Y 4/2) loam, light brownish gray (2.5Y 6/2) and white (2.5Y 8/2) when dry; very few, verv fine mottles of dark reddish brown (2.5YR 3/4), reddish brown (5YR 4/4) when dry; moderate, thick, platy structure; very hard, firm; nests of gypsum crystals; calcareous.

Climatic data (Mohall, N. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	6	8	21	41	54	62	69	67	57	44	25	12	39
Mean precipitation, 1931-52 (inches)	0.5	0.5	0.9	1.3	1.9	4.1	2.7	2.2	1.3	0.8	0.6	0.5	17.1

Annual precipitation more than 9.3 and less than 24.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % v
0-5	Ap	5.1	6.3	7.0	13.4	12.0	32.5	23.6	36.0	16.0			2.96	10	6.2
5-10	A12	4.2	7.0	7.2	12.5	11.0	31.2	26.9	35.0	14.2			1.75	9	8.9
10-28	C1ca	3.8	6.1	6.4	11.5	9.3	30.8	32.3	28.9	17.6			.46	8	28.2
28-36	C2	3.8	6.2	6.7	13.0	9.9	33.3	27.2	31.6	19.1			.24	8	16.6
36-40	C3	4.8	7.8	7.8	13.1	9.4	32.9	24.1	30.5	19.2			.12	6	17.2
40-48	C4	5.0	7.5	7.4	13.5	10.0	33.2	23.4	31.4	19.2			.10	6	16.8
48-60	C5	4.6	7.2	7.3	13.4	10.5	42.4	14.6	31.6	29.0			.13	7	14.5

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH Sat. paste	pH 1:5	E. C. mmhos. per cm. 25° C.	Gypsum %	Exch. Na %	Saturation extract soluble (meq./l.) Na	K	SO_4
22.8				0	1.6	7.8	8.5	0.6	----	0	Tr.	Tr.	
19.9				0	.8	7.9	8.5	.7	----	0	Tr.	Tr.	
11.8				.2	.5	8.1	8.9	1.4	----	1.7	.2	Tr.	
13.7				2.3	.8	8.5	8.9	15.0	0.51	16.8	4.4	.1	58.6
12.2				2.1	.7	8.2	8.7	14.0	.45	17.2	3.9	.1	
12.0				2.0	.7	8.1	8.5	13.5	1.60	16.7	4.0	.1	51.6
12.0				2.2	.6	8.0	8.4	13.5	3.68	18.3	3.9	.1	

Profile No. 71

Area: Novi Sad, Yugoslavia.
Vegetation: Cultivated field.
Parent material: Loess.
Topography: Nearly level.

Ap — 0 to 8 inches, very dark grayish-brown (10YR 3/2), light silty clay loam, dark grayish brown (10YR 4/2) when dry; almost entirely wormcasts but strong, very fine, granular structure in upper 1½ inches (self mulching) and weak, very fine to coarse, granular structure below; hard, friable, sticky, plastic; abrupt; wavy lower boundary.

A12-A13 — 8 to 20 inches, very dark grayish-brown (10YR 3/2, rubbed and 10YR 2.5/2, not rubbed), light silty clay loam; almost entirely wormcasts but moderate, fine, granular structure; hard, friable, sticky, plastic; a few small spots of secondary lime; calcareous; gradual, wavy boundary.

A13 — 20 to 34 inches, very dark grayish-brown (10YR 3.5/1.5, rubbed and 10YR 3/2, not rubbed), heavy silt loam or light silty clay loam; mixture of wormcasts from horizons above and below; firm, slightly sticky, slightly plastic; common, very fine, psuedo mycelia; gradual, wavy boundary.

C1 — 34 to 44 inches, dark-brown (10YR 4/3) to dark grayish-brown (2.5Y 4/2) silty clay loam; firm, slightly sticky, slightly plastic; common to many, very fine, white pseudo mycelia; krotovinas, 3 to 8 inches in diameter, spaced at 3- to 12-inch intervals; many, dark wormcasts; calcareous; wavy boundary.

C2 — 44 to 48 inches, light olive-brown (2.5Y 5/4) silt loam; few, very fine, distinct mottles and iron-manganese concretions; firm, slightly plastic; krotovinas as in C1 horizon; common, dark wormcasts from above; calcareous; gradual, smooth boundary.

C3 — 48 to 72 inches +, light olive-brown (2.5Y 5/4) silt loam; similar to C2 horizon except for a few, large snail shells as much as 1¼ inch in diameter; krotovinas to a depth of 5½ feet.

Remarks: The soil was moist to the base of the pit, except for the surface mulch. Rainworm holes ¼ inch in diameter are at intervals of 1 to 2 inches in all horizons.

Climatic data (Novi Sad, Yugoslavia)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1925-40 (deg. F.)	32	34	43	54	62	69	73	71	65	55	46	34	53
Mean precipitation, 1925-40 (inches)	1.4	1.2	1.9	2.0	2.7	2.4	1.8	2.4	1.9	2.8	1.9	1.7	24.1

Annual precipitation more than 14.2 and less than 34.0 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	CaCO$_3$ equiv. % n
0-8	Ap	0.1	0.2	0.2	1.9	7.1	64.2	26.3	41.1	31.5			1.70	11	15.4
8-16	A12	.1	.2	.2	1.8	7.0	64.5	26.2	41.3	31.5			1.68	11	16.1
16-20	A13	.0	.1	.2	1.3	6.0	63.2	29.2	37.8	32.3			1.46	11	23.9
20-34	A13	.1	.1	.1	1.0	5.7	62.2	30.8	36.2	32.3			1.22	12	37.6
34-44	C1	.0	.2	.2	.9	5.6	61.8	31.3	34.4	33.6			.90	12	51.1
44-48	C2	.0	.2	.3	1.0	5.5	65.9	27.1	35.6	36.4			.46	9	51.2
48-72	C3	.0	.3	.4	1.2	4.9	67.8	25.4	33.7	39.7			.36	9	50.8

(Particle size distribution (mm.) (%) Pipette and hexametaphosphate)

Cation exch. cap. e	Ca	Mg	H*	Na	K	pH 1:1	Moisture tensions 1/3 atmos. %	15 atmos. %
17.3	23.3	1.2	<0.1	0.1	0.9	7.9	27.8	11.0
17.8	34.6	2.6	.2	.2	.9	7.7	30.5	11.6
16.7	32.4	2.2	<.1	.2	.6	7.9	31.6	12.9
14.5	33.0	2.8	<.1	.1	.4	7.9	32.7	13.6
11.7	30.4	3.2	<.1	.1	.3	8.0	32.2	13.0
9.2	29.1	3.2	<.1	.2	.3	7.8	30.0	9.9
8.2	26.4	5.2	<.1	.2	.3	8.0	30.0	8.7

(Extractable cations, meq./100 gm.: Ca, Mg, H*, Na, K)

*Exchange acidity.

Profile No. 72
Area: Adair County, Iowa.
Vegetation: Cultivated field.
Parent material: Glacial till.
Topography: 15 percent slope; convex.

Ap 0 to 7 inches, very dark brown (10YR 2/2), light clay loam; crushed colors are black (10YR 2/1) to very dark brown (10YR 2/2), dark gray (10YR 4/1) when dry; weak, fine, granular structure; friable; clear boundary.

A3 7 to 11 inches, very dark grayish-brown (10YR 3/2), light clay loam somewhat mixed with very dark brown (10YR 2/2) and dark brown (10YR 3/3); crushed colors are very dark grayish brown (10YR 3/2) and dark gray (10YR 4/1), dark grayish brown (10YR 4/2) when dry; moderate, fine, subangular blocky structure; firm; clear boundary.

B21t 11 to 17 inches, dark-brown (10YR 3.5/3) clay loam somewhat mixed with very dark brown (10YR 2/2) along channels; moderate, fine and very fine, subangular blocky structure; firm; thin, continuous clay skins; clear boundary.

B22t 17 to 23 inches, dark yellowish-brown (10YR 4/4) clay loam somewhat mixed with very dark brown (10YR 2/2) along channels in the upper part; moderate, fine, subangular blocky structure; firm; medium, continuous clay skins; clear boundary.

B23t 23 to 34 inches, dark brown (10YR 4/3) clay loam; few, fine, faint, mottles of grayish-brown and a few, coarse mottles of strong brown (7.5YR 5/6) and reddish-yellow (7.5YR 6/8); weak, fine and medium, blocky structure; very firm; medium, continuous clay skins; gradual boundary.

B3 34 to 48 inches, dark brown (10YR 4/3), light clay loam; common, medium mottles of grayish brown (2.5Y 5/2) and a few, fine mottles of strong brown (7.5YR 5/6); weak, medium and coarse, blocky structure; very firm; medium, clay skins on vertical surfaces of weak, medium prisms and thin, continuous clay skins on the blocky peds that become discontinuous in the lower part; clear boundary.

C1 48 to 60 inches, mottled grayish-brown (2.5Y 5/2) and dark yellowish-brown (10YR 4/4) loam or clay loam; massive; firm; thin, discontinuous clay skins on vertical surfaces; common white, soft to very hard, carbonate nodules less than 1/4 inch in diameter; gradual boundary.

C2 60 to 72 inches, mottled grayish-brown (2.5Y 5/2) and yellowish-brown (10YR 5/6) loam or clay loam; massive; friable; calcareous; gradual boundary.

C3 72 inches +, yellowish-brown (10YR 5/4), light clay loam; common, medium mottles of grayish brown (2.5Y 5/2) and a few, fine mottles of strong brown (7.5YR 5/6); massive; firm; calcareous.

Climatic data (Greenfield, Iowa)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1938-52 (deg. F.)	22	26	35	50	61	70	75	73	65	56	38	26	50
Mean precipitation, 1931-52 (inches)	1.1	1.0	2.2	2.6	4.2	5.4	3.6	4.3	3.4	2.3	1.7	1.2	33.0

Annual precipitation more than 22.5 and less than 43.5 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	$CaCO_3$ equiv. % n
0-7	Ap	1.2	4.0	6.6	15.0	10.0	34.8	28.4	36.0	17.3	4		2.56	12	
7-11	A3	1.4	3.9	6.0	13.7	9.7	32.6	32.7	33.4	16.6	1		1.65	11	
11-17	B21t	1.5	4.6	6.0	12.0	8.0	32.7	35.2	30.1	17.4	1		1.02	10	
17-23	B22t	1.7	3.9	5.1	10.9	8.7	33.7	36.0	29.4	19.3	2		.49	9	
23-34	B23t	1.2	4.2	5.7	11.9	9.2	33.9	33.9	31.0	18.9	2		.25	10	
34-48	B3	2.0	4.3	5.6	11.3	8.3	36.4	32.1	31.0	20.0	1		.16		
48-60	C1	2.2	4.3	5.6	13.0	11.0	36.5	27.4	34.6	20.8	2		.09		6
72+	C3	1.8	4.4	5.4	10.9	9.1	38.2	30.2	31.2	22.5	3		.08		9

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	Base sat. % s
26.1	13.1	3.4	9.1	0.1	0.4	5.6	65
26.0	13.6	4.0	8.0	.1	.3	5.5	69
25.5	14.1	4.0	7.0	.1	.3	5.4	73
29.4	14.4	4.1	10.4	.1	.4	5.7	65
21.5	14.5	3.5	3.1	.1	.3	5.6	86
26.3	16.0	2.6	7.3	.1	.3	6.4	72
Calcareous						7.8	
Calcareous						7.7	

*Exchange acidity.

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Profile No. 73

Area: Golden Valley County, North Dakota.
Vegetation: Cropland; (natural) mid grasses and short grasses.
Parent material: Clay, silt, and fine sand of Cretaceous age.
Topography: 3 percent slope, facing northeast; upland.

Ap 0 to 5 inches, very dark brown (10YR 2/2) loam, grayish brown (10YR 5/2) when dry; fine, granular structure; soft, friable, slightly sticky, slightly plastic; abrupt boundary.

B 5 to 14 inches, dark-brown (10YR 3/3) loam, pale brown (10YR 6/3) when dry; weak, coarse, prismatic, breaking to coarse, weak, blocky structure; soft, friable, slightly sticky, slightly plastic; patches of very dark grayish-brown (10YR 3/2) clay on vertical faces; abrupt boundary.

C1 14 to 17 inches, olive-brown (2.5Y 4/3) loam, pale yellow (2.5Y 7/3) when dry; weak, coarse, prismatic, breaking to weak, coarse, blocky structure; slightly hard, friable, slightly sticky, slightly plastic; calcareous; clear boundary.

C2ca 17 to 22 inches, light olive-brown (2.5Y 5/3) clay loam, white (2.5Y 8/2) when dry; weak, medium, platy, breaking to weak, fine, blocky structure; slightly hard, friable, slightly sticky, slightly plastic; calcareous; clear boundary.

C3 22 to 28 inches, light yellowish-brown (2.5Y 6/4) loam, pale yellow (2.5Y 7/3) when dry; massive and weak, medium, platy structure; loose, friable, sticky, plastic; calcareous; abrupt boundary.

IIC4 28 to 37 inches, olive (5Y 5/3) very fine sandy loam, pale yellow (5Y 8/3) when dry; massive; soft, very friable, nonsticky, nonplastic; calcareous; abrupt boundary.

IIC5 37 to 50 inches, light olive-gray (5Y 6/2) very fine sandy loam, white (5Y 8/2) when dry; massive; soft, very friable, nonsticky, nonplastic; calcareous; abrupt boundary.

IIIC6 50 to 61 inches, mottled light olive-brown (2.5Y 5/4) and yellowish-brown silty clay loam, pale yellow (2.5Y 8/4) and yellow (10YR 7/8) when dry; moderate, coarse and medium, platy structure; sticky, plastic; stratified; calcareous.

Remarks: Roots extend to the IIIC6 horizon.

Climatic data (Beach, N. D.*)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	13	16	27	43	56	63	71	68	58	46	30	20	43
Mean precipitation, 1931-52 (inches)	0.5	0.4	0.6	1.1	1.8	3.2	1.7	1.4	1.2	0.9	0.4	0.3	13.7

Annual precipitation more than 6.6 and less than 20.8 inches during 9 years out of 10.

*Both temperature and precipitation record missing 1944-48 (5 years)

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate												
0-5	Ap	0.1	0.2	0.2	12.0	22.7	44.3	20.5	58.9	18.5	--		1.73	11
5-14	B	.1	.1	.2	11.8	24.9	42.9	20.0	61.5	16.5	Tr.		.99	10
14-17	C1	.1	.2	.2	8.6	23.7	44.6	22.6	56.0	19.8	Tr.		1.28	10
17-22	C2ca	<.1	.4	.3	7.1	18.0	45.3	28.9	44.6	24.9	--		1.16	10
22-28	C3	.1	.2	.3	8.9	23.4	48.4	18.7	55.9	24.1	--		.42	10
28-37	IIC4	.1	.1	.1	8.0	46.7	35.5	9.5	77.6	12.3	Tr.		.16	
37-50	IIC5	<.1	.1	.1	5.3	47.8	38.6	8.1	79.5	12.0	--		.07	
50-61	IIIC6	<.1	<.1	<.1	.2	1.1	69.5	29.2	14.7	56.1	--		.10	

Cation exch. cap. b	Extractable cations, meq./100 gm. Ca	Mg	H*	Na	K	pH 1:1	pH 1:10	$CaCO_3$ equiv. % v	E. C. mmhos. per cm. 25° C.	Exch. Na %	Saturation extract soluble (meq./l.) Na	K	HCO_3^-	$SO_4^=$	H_2O at sat. %
16.5	13.2	3.2	1.4	< 0.1	0.8	7.5	7.8	< 1	0.6	<1	0.6	0.4			44.7
14.5	11.2	3.2	1.4	<.1	.2	7.3	7.7	< 1	.5	<1	.5	.1			47.4
10.6				<.1	.2	8.1	8.7	16	.7	<1	.6	.1			54.7
6.8				<.1	.1	8.3	9.0	38	.8	<1	1.4	.1			54.1
4.3				.1	.1	8.5	9.2	31	1.4	2	4.6	.1			45.4
3.0				.3	<.1	8.6	9.3	24	3.2	10	14.3	.2			41.9
3.4				.7	.1	8.7	9.4	20	5.2	20	30.2	.2	1.9	54.7	43.1
9.8				1.8	.1	8.3	8.8	32	10.0	18	60.0	.1	2.1	124.4	74.9

*Exchange acidity.

Profile No. 74

Area: Kimball County, Nebraska.
Vegetation: Fallow; (natural) mid grasses and short grasses.
Parent material: Loess.
Topography: About 1 percent slope toward the southwest; upland.

Ap 0 to 6 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; weak, fine, granular structure; very friable; abrupt, smooth boundary.

A12 6 to 8 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; weak, coarse, subangular blocky structure; friable; clear, smooth boundary.

B21t 8 to 11 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; compound, prismatic and weak, medium, subangular blocky structure; firm; discontinuous clay skins on vertical and horizontal faces; krotovinas common; abrupt, smooth boundary.

B22t 11 to 20 inches, dark-brown (10YR 3/3) clay loam, pale brown (10YR 6/3) when dry; compound weak, coarse, prismatic and moderate, fine and medium, subangular blocky structure; firm; continuous clay skins on vertical and horizontal faces; krotovinas common; clear, smooth boundary.

B3t 20 to 23 inches, grayish-brown (10YR 5/2) clay loam, light brownish gray (10YR 6/2) when dry; weak, coarse, subangular blocky structure; friable; krotovinas common; calcareous; clear, smooth boundary.

C1ca 23 to 28 inches, light brownish-gray (10YR 6/2) loam, light gray (10YR 7/2) when dry; weak, medium, subangular blocky structure; friable; lime segregations in root channels and on ped faces; krotovinas common; calcareous; clear, smooth boundary.

IIC2 28 to 34 inches, brown (10YR 5/3) fine sandy loam, light gray (10YR 7/2) when dry; massive; friable; segregated lime in root channels; krotovinas common; calcareous.

IIC3 34 to 45 inches, yellowish-brown (10YR 5/4) coarse sandy loam, pink (7.5YR 7/4) when dry; weathered sand, silt, and clay with a high proportion of granitic gravel and sandy, limestone fragments.

Climatic data (Kimball, Neb.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	27	30	36	46	56	66	73	71	61	50	37	30	48
Mean precipitation, 1931-52 (inches)	0.4	0.4	1.1	2.0	2.8	2.7	2.3	2.0	1.3	0.7	0.6	0.6	16.9

Annual precipitation more than 10.8 and less than 23.0 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k
0-6	Ap	4.5	6.8	4.2	5.6	16.1	43.9	18.9	45.3	17.5	4.6		1.27	12
6-8	A12	5.6	6.9	4.0	5.6	15.0	43.5	19.4	43.9	17.3	4.8		1.20	12
8-11	B21t	4.1	7.1	4.3	5.5	11.0	40.6	26.5	39.2	15.9	2.8		.65	10
11-20	B22t	1.3	2.8	2.4	3.4	12.5	44.4	33.2	42.2	16.4	---	1.40	.52	9
20-23	B3t	.8	2.2	2.4	3.7	15.6	46.7	28.6	46.9	17.7	Tr.		.74	8
23-28	C1ca	1.0	3.6	3.7	5.9	19.3	45.3	21.2	51.2	16.9	3.2	1.34	.35	9
28-34	IIC2	4.9	10.9	9.1	12.1	18.9	29.7	14.4	44.8	10.3	45.7	1.40	.12	
34-45	IIC3	35.7	18.4	8.1	6.7	6.1	8.1	16.9	12.6	4.8	2.6		.05	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	pH 1:10	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Exch. Na %	Sat. ext., soluble (meq./l.): Na	K	H_2O at sat. %
16.8	13.3	2.1	4.7	---	2.1	7.6	8.1	0.8	--	--	0.2	1.5	39.0
16.6	12.1	2.4	4.3	---	1.9	7.3	7.7	.7	--	--	.3	1.0	39.2
19.1	12.9	4.1	3.2	---	2.0	7.3	7.7	.6	--	--	.4	.8	45.0
26.3	17.2	7.2	2.8	0.2	2.8	7.6	8.0	.6	--	1	.5	.8	55.6
23.8				.3	3.0	8.3	9.0	.8	9	1	1.0	1.2	53.8
18.6				.4	2.7	8.5	9.2	.8	12	2	1.5	1.2	44.4
13.3				.5	2.1	8.7	9.4	.9	8	3	2.8	1.2	31.2
13.3				.8	2.0	8.8	9.3	1.0	8	5	4.6	1.1	26.3

*Exchange acidity.

Profile No. 75

Area: Quay County, New Mexico
Vegetation: Blue grama, buffalograss, and cactus.
Parent material: Calcareous alluvium.
Topography: 2 percent slope, toward the southwest; convex; elevation more than 5,000 feet.

A11 — 0 to 1½ inches, dark-brown (7.5YR 3/2) clay loam, brown (7.5YR 5/4) when dry; single grained; loose, slightly sticky; calcareous; abrupt, smooth boundary.

A12 — 1½ to 6 inches, dark-brown (7.5YR 3/2) clay loam, brown (7.5YR 5.5/4) when dry; weak, coarse, prismatic, breaking to weak, fine, subangular blocky structure; slightly hard, friable, sticky; calcareous; clear smooth boundary.

C1ca — 6 to 11 or 13 inches, yellowish-brown (10YR 5/4) clay loam, pale brown (10YR 6/3) when dry; moderate, medium, subangular blocky structure; slightly hard, slightly sticky; calcareous; gradual wavy boundary.

C2ca — 11 or 13 to 13 or 19 inches, brownish-yellow (10YR 6/6) clay, white (10YR 8/2) when dry; massive; hard, friable, sticky; numerous, lime concretions of low contrast; calcareous; clear, wavy boundary.

C3ca — 13 or 19 to 30 or 41 inches, very pale brown (10YR 8/4) clay, white (10YR 8/2) when dry, pinkish gray (7.5YR 6/2) when crushed; massive; hard, sticky; semi-indurated; calcareous; clear, wavy boundary.

B21tbca — 30 or 41 to 44 inches, reddish-yellow (7.5YR 6/6) clay, reddish yellow (7.5YR 7/6) when dry; moderate, fine, subangular blocky structure; very hard, sticky; thin, patchy clay skins; numerous, mottles and lime concretions of very pale brown (10YR 7/4), white (10YR 8/2) when dry; calcareous; gradual, wavy boundary.

B22b — 44 to 54 inches, yellowish-red (5YR 5/6) clay loam, reddish brown (5YR 5/4) when dry; moderate, fine, subangular blocky structure; very hard, sticky; thick patchy, clay skins; numerous, white (10YR 8/2) concretions of lime; calcareous.

B3b — 54 to 73 inches, yellowish-red (5YR 4/6) clay loam, yellowish red (5YR 5/6) when dry; slightly hard, friable, slightly sticky; few clay skins, few concretions of lime; calcareous.

Climatic data (Cameron, N. M.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1950-59 (deg. F.)	37	40	45	54	63	74	76	75	69	58	44	39	56
Mean precipitation, 1941-54 (inches)	0.4	0.4	0.6	1.1	3.1	2.2	3.4	2.7	2.0	1.9	0.4	0.7	19.0

Annual precipitation more than 6.1 and less than 31.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	Gypsum %	Organic matter C % w	C/N k
1½-6	A12	0.4	0.7	1.1	9.4	23.4	34.9	30.1	50.3	15.8		0.1	1.69	10
6-11/13	C1ca	.7	.9	1.1	5.8	19.3	35.4	36.8	41.6	17.0		.1	1.27	9
11/13-13/19	C2ca	.3	.4	.6	4.3	12.3	38.0	44.1	26.8	26.7		.1	.68	9
13/19-30/41	C3ca	.4	.6	.7	3.3	9.3	42.5	43.2	22.7	32.0		.3	.24	7
30/41-44	B21tbca	.2	.3	.4	3.7	13.0	39.5	42.9	29.6	25.7		.1	.11	7
44-54	B22b	.2	1.4	1.1	4.8	16.3	37.4	36.8	35.0	22.2		.2	.06	2
54-73	B3b	.1	.5	.8	5.0	19.6	36.7	37.3	43.7	16.5		.1	.05	2

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H	Na	K	pH sat. paste	pH 1:5	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Moisture tensions 1/3 atmos. %	15 atmos. %	Exch. Na. %	Sat. ext. sol. (meq./l.) Na	K	H_2O at sat. %
18.6	31.0	1.3		.1	0.6		8.2	0.64	15.5	21.5	11.8	0.4	0.9	0.32	39
15.8	26.7	1.4		.1	.3	7.6	8.1	.64	31.3	21.9	14.2	.6	.6	.06	41
12.6	24.5	1.4		.1	.2	7.6	8.4	.55	54.6	25.7	10.3	.6	.5	.04	40
10.6	21.4	1.5		.1	.1	7.9	8.8	.49	57.8	26.2	8.7	.6	1.3	.04	40
14.5	10.0	4.4		.2	.2	8.1	8.8	.51	45.0	24.7	11.0	1.6	2.2	.04	45
15.8	21.2	6.2		.7	.4	8.1	8.8	.67	28.3	24.9	12.8	4.8	3.8	.04	45
17.1	20.6	6.4		.7	.4	8.0	8.7	1.04	20.9	24.8	12.4	4.2	6.0	.04	46

Profile No. 76
Area: Ward County, North Dakota.
Vegetation: Summer fallowed land.
Parent material: Calcareous, glacial till.
Topography: Nearly level till plain; elevation about 1,900 feet.

Ap 0 to 7 inches, very dark brown (10YR 2/2) loam, dark gray (10YR 4/1) when dry; weak, subangular blocky, breaking to moderate, fine and very fine granular structure; soft, very friable, slightly sticky, slightly plastic; abrupt, smooth boundary.

A12 7 to 10 inches, very dark grayish-brown (10YR 3/2) loam, grayish brown (10YR 5/2) when dry; weak, medium, prismatic, breaking to weak, blocky structure; slightly hard, friable, slightly sticky, slightly plastic; clear boundary.

A2 10 to 13 inches, dark grayish-brown (10YR 4/2) loam, gray (10YR 6/1) when dry; caps of columns break to platy and blocky structure; slightly hard, friable, slightly sticky, slightly plastic; abrupt, wavy boundary.

B21t 13 to 18 inches, brown (10YR 4/3) clay loam, light brownish gray (10YR 6/2) when dry; moderate, fine columnar, breaking to strong, medium and fine, blocky structure; very hard, firm, sticky, plastic; outsides of columns are dark brown (10YR 3/3); continuous clay skins; clear boundary.

B22t 18 to 21 inches, light olive-brown (2.5Y 5/4) clay loam, light brownish gray (2.5Y 6/2) when dry; moderate, medium, prismatic, breaking to blocky structure; hard, firm, sticky, plastic; outsides of prisms are olive brown (2.5Y 4/4); continuous clay skins; clear, wavy boundary.

C1cacs 21 to 27 inches, olive (5Y 5/3) clay loam, light olive gray (5Y 6/2) when dry; many nests of $CaSO_4$; weak, subangular blocky structure; hard, friable, very sticky, plastic; calcareous; gradual boundary.

C2 27 to 40 inches, olive (5Y 5/3) loam, light olive gray (5Y 6/2) when dry; weak, subangular blocky structure; hard, friable, sticky, plastic; few, fine nodules of lime; calcareous; gradual boundary.

C3 40 to 50 inches, olive (5Y 4/3) clay loam, light olive gray (5Y 6/2) when dry; weak, blocky structure; hard, firm, sticky, plastic; few nodules of lime; calcareous; gradual boundary.

C4 50 to 61 inches, olive (5Y 4/3) loam, light olive gray (5Y 6/2) when dry; weak, blocky structure; hard, firm, sticky, plastic; calcareous; gradual boundary.

Climatic data (Kenmare, N. D.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1933-52 (deg. F.)	7	9	23	41	54	62	70	67	57	46	27	14	40
Mean precipitation, 1933-52 (inches)	0.5	0.6	0.8	0.9	1.8	3.6	2.3	2.0	1.2	0.8	0.6	0.5	15.4

Annual precipitation more than 8.5 and less than 22.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	H_2O at sat. %
0-7	Ap	1.7	4.5	5.2	13.9	12.7	41.0	21.0	37.4	24.3	Tr.		2.33	11	49.2
7-10	A12	1.4	4.7	5.8	14.1	11.8	40.0	22.2	36.6	23.1	Tr.		1.24	11	43.7
10-13	A2	1.6	5.9	7.7	18.8	15.1	32.4	18.5	40.1	17.5	1.5		.66	10	39.7
13-18	B21t	1.4	4.0	4.9	12.7	10.6	33.3	33.1	29.6	21.2	Tr.		.74	10	59.5
18-21	B22t	1.0	3.5	4.2	11.3	10.1	37.3	32.6	30.0	24.0	Tr.		.59	10	63.5
21-27	C1cacs	.6	2.5	3.1	9.7	10.2	43.1	30.8	29.4	29.6	2.3		.34	11	57.5
27-40	C2	1.7	3.8	4.5	12.7	11.1	41.8	24.4	33.9	26.4	5.8		.20		58.7
40-50	C3	1.6	3.5	3.7	9.4	8.3	44.4	29.1	25.7	32.3	2.0		.21		65.1
50-61	C4	1.2	3.4	4.1	10.8	9.4	44.2	26.9	29.0	30.7	1.9		.19		62.4

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Exch. Na %	pH 1:1	pH 1:10	E.C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Gypsum %	Sat. extract soluble milliequivalents/liter: Na	HCO_3^-	Cl^-	$SO_4^=$
18.4	8.8	5.1	6.4	< 0.1	1.5	<1	5.9	6.4	1.0			1.0			
15.7	6.2	5.9	5.5	0.1	.6	1	5.8	6.3	.7			1.3			
12.5	3.6	5.6	3.2	0.5	.3	4	6.1	6.7	.9			3.6			
23.7	5.2	12.2	1.9	1.8	.4	8	7.1	7.5	3.4	<1	<.1	17.2			
22.4	7.0	21.3	<.1	2.3	.3	10	7.7	8.1	9.0	<1	.1	37.0	1.9	1.2	140.5
14.8				1.5	.2	10	8.2	8.6	9.5	14	2.24	45.2	1.6	2.0	144.4
13.4				2.0	.3	15	8.4	9.0	9.0	11	.1	49.3	2.3	2.0	134.6
16.1				2.3	.4	14	8.4	9.0	8.7	11	.1	49.3	1.4	2.0	123.0
15.8				3.1	.5	20	8.3	9.0	8.0	8	.1	46.0	1.4	2.2	113.6

*Exchange acidity.

Chapter 13. Spodosols

The Spodosols include primarily the soils that have been called Podzols, Brown Podzolic soils, and Ground-Water Podzols. Not all soils called Podzols, however, are in this order.

All mineral soils are included that have a spodic horizon thick enough to be demonstrable after plowing and cultivation for a few years. Those with a very thin spodic horizon that lies entirely within the surface 15 cm. (6 inches) are apt to be excluded. Repeated plowing can mix a thin spodic horizon with an albic horizon so thoroughly that it is impossible to demonstrate that a spodic horizon is included in the plow layer. Such spodic horizons are not diagnostic for this classification, because it is desired to keep virgin soils with their cultivated counterparts until marked changes have occurred. Spodosols are recognized by the spodic horizon, and not by the albic horizon. Soils with thick, white albic (A2) horizons may be placed in several places in this system.

Spodosols are found only in humid regions, but their range is from the boreal forests to the tropics. Most have had a coniferous forest, but those of the warmer regions may be under savannah or under rain forest.

The parent materials are usually siliceous. So far as is known, Spodosols do not form in clayey parent materials. If the crystalline clay content is high, even as high as 30 percent, Spodosols do not seem to form until there has been significant eluviation. In the tropics, the only parent materials of the Spodosols seem to be nearly pure quartz sand. In addition to the spodic horizon, a number of other diagnostic horizons may be present. These include histic, umbric, ochric, and possibly anthropic epipedons. Argillic horizons, duripans, and fragipans may also be found.

For Spodosols, the categoric level at which these horizons are used as differentiae is not the same as the level used for many other orders. This is particularly true of the umbric epipedons, and of the fragipans. Among the Spodosols, these two are considered as family differentiae.

The fragipans are considered family differentiae for Spodosols because the soils that lack a fragipan normally seem to have a horizon that is comparable to it but that is of too coarse a texture to become impermeable to roots and water. The brittle consistence of the fragipan is evident in most of the soils of the great groups in which fragipans occur. The fragipans therefore seem to have no covarying properties but texture. In other orders where fragipans occur, the soils with fragipans differ from those without fragipans in a number of important properties.

Four suborders of Spodosols are recognized. Their definitions, keys, and discussion follow.

AQUODS (6.1)

The Aquods include the soils called Ground-Water Podzols. They are saturated with water at some season, or they have artificial drainage, and they have one or more of the following characteristics associated with wetness:

1. A histic epipedon.
2. Mottles of iron or manganese in the albic horizon or near the top of the spodic horizon, or a duripan in the albic horizon.
3. If free iron and manganese are lacking in the upper part of the spodic horizon, there are mottles in the materials immediately below the spodic horizon, or there are no coatings of iron oxides on the individual grains of silt and sand in those materials immediately below the spodic horizon.

The Aquods may be found in almost any humid climate from the boreal or alpine to the tropical regions. In temperate and tropical regions, the parent materials are mostly very highly siliceous sands.

In cooler climates the parent materials are siliceous, but may be sandy or loamy, and may have many weatherable minerals.

Key to Aquods

6.11 Aquods with mean annual temperature less than 8.3° C. (47° F.), and, if cultivated or without an O horizon, having mean summer temperature in the solum of less than 15.5° C. (60° F.), or if with an O horizon, having summer temperature in the solum of less than 10° C. (50° F.).

Cryaquod, p. 194

6.110 Cryaquods with permafrost at 75 cm. (30 inches) or less; with a continuous spodic horizon that is very firm when moist, or that is 10 cm. (4 inches) or more thick and has at least 2 percent organic matter (1.16 percent organic carbon) in the upper 5 cm.; and with no argillic horizon.

Orthic Cryaquod, p. 194

6.11-1 Other Cryaquods that have no argillic horizon but have a continuous spodic horizon that either is less than 10 cm. (4 inches) thick or has less than 2 percent organic matter in the upper 10 cm.; permafrost at 75 cm. (30 inches) or less.

Entic Cryaquod, p. 194

6.11-1 Other Cryaquods with permafrost at 75 cm. (30 inches) or less; with no argillic horizon; with a discontinuous spodic horizon.

Ruptic Entic Cryaquod, p. 194

6.11-6.13 Other Cryaquods with no argillic horizon and no permafrost within 75 cm. (30 inches) of the surface.

Ferraquodic Cryaquod, p. 194

6.11-7 Other Cryaquods with no permafrost within 75 cm. (30 inches) of the surface and with an argillic horizon underlying the spodic horizon.

Alfic Cryaquod, p. 194

6.16 Other Aquods that have a duripan in the albic horizon.

Duraquod, p. 196

6.12 Other Aquods in which at least the upper 7-1/2 cm. (3 inches) of the spodic horizon is enriched chiefly with humus or aluminum and humus and has essentially no more free iron than the horizons overlying and underlying; and in which the humus in the upper 7-1/2 cm. of the spodic horizon is dispersed humus--coatings and pore fillings--rather than rounded to subangular silt-sized pellets of humus or of humus and iron; soils have mean annual temperature of less than 15.5° C. (60° F.), or mean summer temperature more than 5° C. warmer than mean winter temperature.

Humaquod, p. 194

6.120 Humaquods with a spodic horizon that is hard when dry and very firm when moist, or that is thicker than 10 cm. (4 inches) and contains 2 percent or more of organic matter (1.16 percent organic carbon) in the upper 10 cm.; soils have no argillic horizon and no histic epipedon.

Orthic Humaquod, p. 194

6.12-1 Other Humaquods with spodic horizon that is not hard or very hard when dry and very firm when moist, and that is thinner than 10 cm. (4 inches) or has less than 2 percent organic matter in the upper 10 cm.; soils have no argillic horizon or histic epipedon.

Entic Humaquod, p. 195

6.12-7 Other Humaquods that do not have a histic epipedon but have an argillic horizon underlying the spodic horizon, and this argillic horizon has base saturation of 35 percent or more in some part.

Alfic Humaquod, p. 195

6.12-8.1 Other Humaquods that have no histic epipedon but do have an argillic horizon that underlies the spodic horizon, and this argillic horizon has base saturation throughout of less than 35 percent and dominant chromas of 2 or less on the ped surfaces or in the matrix.

Aquultic Humaquod, p. 195

6.12-8.2 Other Humaquods that do not have a histic epipedon but do have an argillic horizon that underlies the spodic horizon, and this argillic horizon has base saturation throughout of less than 35 percent and dominant chromas of more than 2 on ped faces, if peds are present, and in the matrix, if peds are absent.

Ochrultic Humaquod, p. 195

6.12-10 Other Humaquods with a histic epipedon.

Histic Humaquod, p. 195

6.13 Other Aquods that have a spodic horizon that is more than 5 cm. thick if friable or firm, and more than 2 cm. thick if very firm, and contains more free iron in the upper 7-1/2 cm. (3 inches) than the overlying horizon, and has some rounded to subangular silt-sized pellets of humus or of humus and iron unless very firm; and there are mottles in the albic horizon or in the spodic horizon.

Ferraquod, p. 195

6.130 Ferraquods that have no argillic horizon and no histic epipedon but have a spodic horizon that is very firm when moist or that is thicker than 10 cm. (4 inches) and contains 2 percent or more organic matter (1.16 percent organic carbon) in the upper 10 cm.

Orthic Ferraquod

6.13-1 Other Ferraquods that have no argillic horizon or histic epipedon but have a spodic horizon that is thinner than 10 cm. (4 inches) or that contains less than 2 percent organic matter in the upper 10 cm.

Entic Ferraquod

6.13-7 Other Ferraquods that do not have a histic epipedon but have an argillic horizon that underlies the spodic horizon, and this argillic horizon has base saturation of more than 35 percent in some part.

Alfic Ferraquod

6.13-10 Other Ferraquods that have a histic epipedon but no argillic horizon.

Histic Ferraquod

6.14 Other Aquods with a spodic horizon that is a thin (less than 2 cm.), wavy or involute, hard, continuous ironpan, impervious to roots and water.

Placaquod, p. 195

6.15 Other Aquods that have mean annual temperature of 15.5° C. (60° F.) or more, and mean summer temperature no more than 5° C. warmer than mean winter temperature; that have at least the upper 7-1/2 cm. (3 inches) of the spodic horizon enriched chiefly with humus, or with aluminum and humus, and this humus is primarily in dispersed form, such as coatings and pore fillings.

Thermaquod, p. 195

6.150 Thermaquods with a spodic horizon that is very firm when moist or that is more than 10 cm. (4 inches) thick and contains more than 2 percent organic matter in the upper 10 cm; soils have no argillic horizon underlying the spodic horizon, and no plinthite within 125 cm. (50 inches) of the surface.

Orthic Thermaquod, p. 196

6.15-1 Other Thermaquods with a spodic horizon that is thinner than 10 cm. (4 inches) or has less than 2 percent organic matter in the upper 10 cm.; soils have no argillic horizon underlying the spodic horizon, and no plinthite within 125 cm. (50 inches) of the surface.

Entic Thermaquod, p. 196

6.15-8 Other Thermaquods with an argillic horizon underlying the spodic horizon, and with no plinthite within 125 cm. (50 inches) of the surface.

Ultic Thermaquod, p. 196

6.5-8-11 Other Thermaquods with an argillic horizon containing plinthite within 125 cm. (50 inches) of the surface.

Plintaquultic Thermaquod, p. 196

Cryaquods (6.11)

The Cryaquods are the Aquods of cold places, arctic or alpine regions. They have a mean annual temperature of less than 8.3° C. (47° F.) and if an O horizon is present, a mean summer temperature in the solum of less than 10° C. (50° F.). Few are cultivated, but if they are, and there is no O horizon, the mean summer temperature is less than 15.5° C. (60° F.). They are saturated with water at some season or have artificial drainage, and they have one or more of the following characteristics associated with wetness:

1. A histic epipedon.
2. Mottles in the albic horizon, or in the upper part of the spodic horizon.
3. If free iron and manganese are lacking in the spodic horizon, there are mottles in the first horizon in which there are coatings of free iron on the silt or sand grains, or the coatings are lacking throughout the spodic horizon.

The Cryaquods have been called Ground-Water Podzols. Commonly they have permafrost at shallow depth. The solum is normally thin, compared with that of the other Aquods. A solum 50 cm. (20 inches) or less in thickness is common. Polygonal forms and frost mounds are normal in this great group.

Orthic Cryaquods (6.110)

The Orthic Cryaquods have permafrost at depths of 75 cm. (30 inches) or less. They have a spodic horizon that is very firm when moist. Or, they have a spodic horizon more than 10 cm. (4 inches) thick, and in the upper 5 cm. this horizon has more than 2 percent organic matter; these soils have no argillic horizon underlying the spodic horizon; a histic epipedon may be present or absent.

Entic Cryaquods (6.11-1)

This subgroup includes Cryaquods that have no argillic horizon but have permafrost within 75 cm. (30 inches) of the surface. They have a continuous spodic horizon that is either less than 10 cm. (4 inches) thick or has less than 2 percent organic matter in the upper 10 cm. A histic epipedon may be present or absent.

Ruptic Entic Cryaquods (6.11-1)

This subgroup includes Cryaquods that have a discontinuous spodic horizon that occupies more than half of each pedon. The remainder of the pedon has the profile of the Cryaquents.

Ferraquodic Cryaquods (6.11-6.13)

This subgroup includes Cryaquods that have the profile of the orthic subgroup but lack permafrost within 75 cm. (30 inches) of the surface. A histic epipedon may be present or absent.

Profile 77, page 200, is a representative of this subgroup. The frost mounds and the profile are thought to be characteristic. The evidences of slow mixing of the horizons by the frost may be noted in the description.

Profile 78, page 201, illustrates something of the range in profile characteristics that may be encountered. This profile has a cemented B that apparently is not affected greatly by the frost action. For the present it is proposed that differences of the sort illustrated by these profiles be recognized as family differentiae. Similar differences probably can be found in the other subgroups of Cryaquods.

Alfic Cryaquods (6.11-7)

This subgroup includes the Cryaquods that have a sequum including an argillic horizon below the spodic horizon, and that lack permafrost within 75 cm. (30 inches) of the surface.

Humaquods (6.12)

The Humaquods are Aquods that have no duripan in the albic horizon; that have a mean annual temperature of less than 15.5° C. (60° F.), or a mean summer temperature more than 5° C. warmer than the mean winter temperature; and that have a spodic horizon enriched chiefly with humus, or aluminum and humus, in at least the upper 7-1/2 cm. (3 inches). In this upper 7-1/2 cm., or in all of the spodic horizon, there is essentially no more free iron than in any overlying albic horizon. The humus is in dispersed forms—coatings on sand grains or fillings in pores. Silt-sized pellets of humus, or of humus and iron, seem to be absent.

The Humaquods have been called Ground-Water Podzols. The brown colors of the humus in the lower part of the spodic horizon have often been confused with colors caused by iron, but if mottles are absent, the soil will turn white on ignition.

The spodic horizon may be hard or soft. The A horizon may be white sand, or it may be so rich in organic matter that it is very dark gray or even black. Below the spodic horizon, there may be another sequum with an argillic horizon.

The vast majority of these soils have sand textures, but some are silt loams.

Orthic Humaquods (6.120)

This subgroup includes Humaquods that have a spodic horizon that is either hard or very hard when dry and very firm when moist, or that is more than 10 cm. (4 inches) thick and contains more than 2 percent organic matter in the upper 10 cm. They have no argillic horizon and no histic epipedon.

Profile 21, page 86, is an example of an Orthic Humaquod that has a cemented spodic horizon. Table 13 gives chemical and mineralogical analyses of this soil. In Orthic Humaquods the spodic horizons that are cemented may be thinner and contain less organic matter than those that are not cemented. It is proposed that differences in consistence of the spodic horizon be tested as family criteria. The epipedon may be ochric or umbric; this difference is also being tested as a family criterion.

Entic Humaquods (6.12-1)

This subgroup includes Humaquods that have a spodic horizon that is firm to very friable when moist and that is either thinner than 10 cm. (4 inches) or has less than 2 percent organic matter in the upper 10 cm. These soils have no histic epipedon, and no sequum below the spodic horizon that contains an argillic horizon. The epipedon may be ochric or umbric. This difference is being tested as a family criterion.

Alfic Humaquods (6.12-7)

This subgroup includes Humaquods that have no histic epipedon but have a sequum below the spodic horizon in which there is an argillic horizon having a base saturation of 35 percent or more (by sum of cations) in some part, or in which there are tongues of an albic horizon.

Aquultic Humaquods (6.12-8.1)

This subgroup includes Humaquods that have no histic epipedon. They have, below the spodic horizon, a sequum that contains an argillic horizon. The argillic horizon has base saturation below 35 percent in all parts and has dominant chromas of 2 or less on ped surfaces, or in its matrix if it has no peds. It contains no tongues of an albic horizon.

Ochrultic Humaquods (6.12-8.2)

This subgroup is comparable to the Aquultic Humaquods, but the argillic horizon has chromas of more than 2 on the ped faces, or in the matrix if peds are absent.

Histic Humaquods (6.12-10)

This subgroup is provided for Humaquods that have a histic epipedon. More than one subgroup may be needed, perhaps as intergrades to the suborders or great groups of Histosols. This cannot be decided at this time, for the suborders and great groups of Histosols have not been defined.

Ferraquods (6.13)

The Ferraquods are the Aquods that have free iron in the upper 7-1/2 cm. (3 inches) of the spodic horizon. The spodic horizon, if very firm when moist, is more than 2 cm. thick and contains more free iron than any overlying horizon. The spodic horizon has some mottles and some rounded to subangular silt-sized pellets of humus, or of humus and iron.

The Ferraquods, like the Humaquods, have been called Ground-Water Podzols. So far as is known now, they are restricted to cool, humid climates, and to siliceous and usually sandy parent materials.

Few of these soils occur in the United States. Tentative definitions of possible subgroups are given in the Key to Aquods. Little more can be said at this time.

Placaquods (6.14)

This group of Aquods is restricted to perhumid climates. The Placaquods generally have a mottled albic horizon that rests abruptly on a thin, hard spodic horizon. The soils have been called Peaty Gley Podzols with thin ironpans. The ironpan is generally less than 1 cm. thick, is continuous, and is irregular or involute. It may rest on a variety of horizons, depending on the kind of soil in which it formed and the depth at which it formed. Commonly, there is an underlying profile that includes some diagnostic horizons. There may be an albic horizon, underlain by a spodic horizon and a fragipan. Or there may only be a fragipan. Occasionally, the ironpan seems to rest on a C layer. Figure 35 is a photograph of a typical Placaquod.

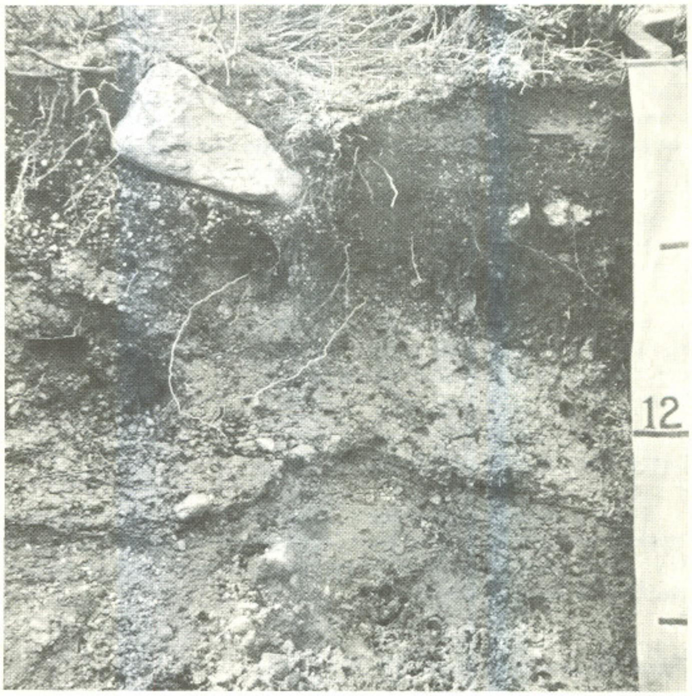

Figure 35.--Profile of a Placaquod. The thin ironpan varies in depth here from about 12 to 15 inches.

These soils are known in Great Britain, New Zealand, Tasmania, and Canada, and probably occur in other places. It is very common that there is, or has been, a layer of sphagnum peat of variable thickness at the surface. Subgroup definitions need to be prepared by others.

Thermaquods (6.15)

The Thermaquods are soils in tropical and subtropical regions. They have been called Ground-Water Podzols, for the most part. So far as is known, they are restricted to coarse-textured, very highly siliceous parent materials, usually nearly pure quartz. Some developed in thick beds of quartz sands or fine gravels. Others appear to have bisequum profiles, in which the spodic horizon has developed in the eluvial A horizon of another soil, often one that contains plinthite at some depth.

The Thermaquods are defined as Aquods that have mean temperature of 15.5° C. (60° F.) or more, and that have mean summer temperature no more than 5° C. warmer than the mean winter temperature. At least the upper 7-1/2 cm. (3 inches) of the spodic horizon is enriched chiefly with humus, or with humus and aluminum. The humus is in dispersed form; it occurs as coatings on sand grains and fillings in pores. Often the spodic horizon is an ortstein, and very firm when moist. The albic horizon may be very thick in some of these soils, apparently more than 2 meters in some places. In others it may be only a few decimeters.

The native vegetation may at times be difficult to determine, but the present vegetation may be savannah or a tropical rain forest.

Orthic Thermaquods (6.150)

This subgroup includes Thermaquods that have no argillic horizon underlying the spodic horizon, and no plinthite within 125 cm. (50 inches) of the surface. They have a spodic horizon that is hard or very hard when dry and very firm when moist (an ortstein), or they have a friable spodic horizon that is more than 10 cm. (4 inches) thick and contains at least 2 percent organic matter (1.16 percent organic carbon) in the upper 10 cm.

Normally, in these soils, the epipedon is ochric, and the albic horizon is prominent. In some places the albic horizon may be very thick, up to 2 meters or more. There is no argillic horizon underlying the spodic horizon, and there is no plinthite within 125 cm. (50 inches) of the surface.

Entic Thermaquods (6.15-1)

This subgroup includes Thermaquods that have a friable spodic horizon that either is thinner than 10 cm. (4 inches) or has less than 2 percent organic matter in the upper 10 cm.

Ultic Thermaquods (6.15-8)

This subgroup includes the Thermaquods that have an argillic horizon in a sequum below the spodic horizon, and that have no plinthite within 125 cm. (50 inches) of the surface. In this subgroup, the soils commonly have an albic horizon 25 to 75 cm. (10 to 30 inches) thick. At times the spodic horizon may lie on the argillic horizon, or even tongue into it along the ped faces.

Plintaquultic Thermaquods (6.15-8.11)

This subgroup includes the Thermaquods that have plinthite within 125 cm. (50 inches) of the surface that has not hardened and that is in an argillic horizon that underlies the spodic horizon. The spodic horizon may be hard or soft.

Duraquods (6.16)

The Duraquods have an indurated albic horizon, underlain by a spodic horizon that is often like that of the Humaquods. Whether spodic horizons like those of the Ferraquods occur below a duripan is not known to the authors.

The Duraquods are common in the "Kauri" Podzols of New Zealand. They also occur in Australia from Queensland to Tasmania. Some may occur in the United States, but so far have not been identified and studied. Since the pans occur so close to the surface, it seems doubtful that the underlying horizons have much relevance to classification. Perhaps only one or two subgroups will be needed, but information is not adequate to permit any decision at this time.

HUMODS (6.2)

The Humods are the Spodosols that lack the characteristics associated with wetness of the Aquods, and that have spodic horizons mainly enriched with humus or humus and aluminum. The humus in at least the upper 7-1/2 cm. (3 inches) is in dispersed forms; that is, coatings on the sand grains or fillings in pores. Pellets of humus, or humus and iron, of silt size seem to be absent in at least the upper part of the spodic horizon.

The Humods are not known in the United States. They are common in Western Europe, where they formed under the heath. At this time, only one great group is proposed, the Orthumods. A group that parallels the Thermaquods may be wanted in time.

The Orthic Orthumods are proposed tentatively as those Orthumods that lack an argillic horizon below the spodic horizon; that have at least 5 percent organic matter (2.9 percent organic carbon) in the upper 10 cm. (4 inches) of a continuous spodic horizon; that have more than 5 percent of feldspar, mica, ferromagnesium, and other weatherable minerals if the texture is sand or loamy sand; and that have no more than 30 cm. (12 inches) of a surface horizon that meets all requirements of a plaggen epipedon except that of thickness.

The Entic Orthumods would include the Orthumods that have no argillic horizon below the spodic horizon, and that have a continuous spodic horizon with less than 5 percent organic matter in the upper 10 cm. (4 inches).

The Orthumods with an argillic horizon form at least three subgroups. Udalfic Orthumods have an argillic horizon with base saturation of more than 35 percent or with tongues of an albic horizon. The solum is always moist in some part.

The Ustalfic Orthumods have an argillic horizon with more than 35 percent base saturation in some part, but the solum is dry at some season, unless irrigated. These soils can be found in Mediterranean climates and are the driest of the Humods.

The Ultic Orthumods have an argillic horizon with base saturation of less than 35 percent in all parts. The solum is always moist in some part.

ORTHODS (6.3)

The Orthods have been called Podzols and Brown Podzolic soils. They include the Spodosols that have spodic horizons enriched with both iron and humus. In at least some part of the upper 7.5 cm. (3 inches) of the spodic horizon there is measurable free iron, enogh to turn the material reddish on ignition. The humus is mainly in the form of silt-sized, rounded to subangular pellets (see figure 14) if the horizon is not cemented. If cemented, the spodic horizon contains appreciable amounts of iron (see figure 15).

The spodic horizon of the Orthods contains appreciable amounts of humus. The most weakly developed contain 1/2 percent organic matter (0.29 percent organic carbon) in some part. These have little humus and little iron. As the free iron increases, so does the humus. If the free iron content exceeds 3 percent, if organic matter is only 1/2 percent, and if humus pellets of silt size are missing, the limit between the Orthods and Ferrods has been passed. If free iron is less than 1 percent and organic matter less than 1/2 percent, the horizon is too weakly developed to be called a spodic horizon.

The Orthods are formed mostly in cool, humid climates. The parent materials are sandy or loamy, but rich in quartz. The native vegetation is most commonly coniferous forest, but some Orthods may have had a broadleaf deciduous forest. It should be noted that the name "Orthod" combines improperly in forming orthic intergrade subgroups; it needs to be changed.

Key to Orthods

6.31 Orthods with mean annual soil temperature less than 8.3° C. (47° F.), and, if cultivated and having no O horizon, with mean summer temperature in the solum of less than 15.5° C. (60° F.); or if with an O horizon, a mean summer temperature in the solum of 10° C. (50° F.).

Cryorthod, p. 197

6.310 Cryorthods with permafrost within 75 cm. (30 inches) or with the base of the spodic horizon less than 40 cm. (16 inches) below the mineral surface; with an orstein or at least 2 percent organic matter, but with not more than 10 percent organic matter in the upper 5 cm. of the spodic horizon.

Orthic Cryorthod, p. 198

6.31-1 Other Cryorthods with less than 2 percent organic matter (1.16 percent organic carbon) in the upper 5 cm. of the spodic horizon.

Entic Cryorthod, p. 198

6.31-6.2 Other Cryorthods with more than 10 percent organic matter (5.8 percent organic carbon) in the upper 5 cm. of the spodic horizon.

Humic Cryorthod, p. 198

6.31-6.33 Other Cryorthods with the base of the spodic horizon more than 40 cm. (16 inches) below the mineral surface and with no permafrost within 75 cm. (30 inches) of the surface.

Typic Cryorthod, p. 198

6.32 Other Orthods with a spodic horizon that is a thin (less than 2 cm.), wavy or involute, hard, continuous ironpan.

Placorthod, p. 198

6.33 Other Orthods.

Typorthod, p. 198

6.330 Typorthods with no argillic horizon underlying the spodic horizon; with a continuous spodic horizon that is very firm when moist (orstein), or that is more than 10 cm. (4 inches) thick and has more than 2 percent organic matter (1.16 percent organic carbon) but less than 10 percent organic matter in the upper 10 cm.; if plowed, and the upper part of the spodic horizon is mixed in the Ap, with more than 2 percent organic matter in the Ap; with no mottles that have chromas of 2 or less in the spodic horizon.

Orthic Typorthod, p. 198

6.33-1 Other Typorthods with a continuous spodic horizon that is less than 10 cm. (4 inches) thick, or that has less than 2 percent organic matter in the upper 10 cm; with no argillic horizon.

Entic Typorthod, p. 198

6.33-1 Other Typorthods with a spodic horizon that is discontinuous within each pedon; with no argillic horizon.

Ruptic Entic Typorthod, p. 198

6.33-6.1 Other Typorthods that have mottles with chromas of 2 or less within the spodic horizon and that have other properties of the orthic subgroup.

Aquic Typorthod, p. 198

6.33-6.2 Other Typorthods with more than 10 percent organic matter in the upper 10 cm. (4 inches) of the spodic horizon.

Humic Typorthod, p. 198

6.33-7 Other Typorthods with an argillic horizon that underlies the spodic horizon and that contains tongues of an albic horizon or has base saturation of more than 35 percent in some part.

Alfic Typorthod, p. 199

6.33-8 Other Typorthods with an argillic horizon that underlies the spodic horizon and has base saturation of less than 35 percent throughout.

Ultic Typorthod, p. 199

Cryorthods (6.31)

The Cryorthods are the Orthods in boreal or alpine sites that have been called Podzols. They have a mean annual temperature of less than 8.3° C. (47° F.), and, if cultivated or without an O horizon, a mean summer temperature in the solum of less than 15.5° C. (60° F.), or if with an O horizon, a mean summer temperature of less than 10° C. (50° F.). These temperature limits are tentative and may require some adjustments. The Cryorthods have a spodic horizon that contains more than traces of free iron, and unless it is an orstein, it has humus mainly in the form of silt-sized pellets. If the spodic horizon is a thin (less than 2 cm.), continuous, hard, ironpan, and the horizon directly under it is not a spodic horizon, the soil is excluded from the Cryorthods.

The albic and spodic horizons of the Cryorthods tend to be thinner than those of the Typorthods. The vegetation normally is boreal forest or shrubs. The parent materials tend to be less siliceous than those of most other Spodosols. Volcanic ash, loess, glacial drift, and other loamy materials containing abundant weatherable minerals are common parent materials.

Orthic Cryorthods (6.310)

This subgroup is the central concept of the Cryorthods. It includes Cryorthods in which the combined thickness of the albic and spodic horizons is less than 40 cm. (16 inches), or in which permafrost is within 75 cm. (30 inches) of the surface. The spodic horizon is continuous, and has, in its upper 5 cm., between 2 and 10 percent organic matter (1.16 to 5.8 percent organic carbon), or it is very firm when moist (an orstein). If loamy, these soils are apt to show evidences of frost churning in the form of more or less mixed horizons.

This definition for Orthic Cryorthods must be considered very tentative, as it has not been tested.

Entic Cryorthods (6.31-1)

This subgroup includes Cryorthods with a spodic horizon that has less than 2 percent organic matter in the upper 5 cm.

Humic Cryorthods (6.31-6.2)

This subgroup includes the Cryorthods that have more than 10 percent organic matter in the upper 5 cm. of the spodic horizon.

Typic Cryorthods (6.31-6.33)

This subgroup includes the Cryorthods with a continuous spodic horizon that has between 2 and 10 percent organic matter in the upper 5 cm. but that, in addition, have a combined thickness of the albic and spodic horizons of more than 40 cm. (16 inches). This depth limit is presented tentatively, as it has not been tested. These soils have no permafrost within 75 cm. (30 inches) of the surface.

Placorthods (6.32)

The Placorthods are not common. They have a thin (less than 2 cm.) cemented ironpan that is continuous and wavy or involute. There is no histic epipedon, and none of the other evidences of wetness above the ironpan that are listed as diagnostic of Aquods. These soils are not known in the United States, and no subgroups are defined.

Typorthods (6.33)

The Typorthods are so named because they are typical of the soils that have been called Podzols and Brown Podzolic soils.

They have a spodic horizon thick enough or deep enough to be demonstrable after several years of cultivation. The spodic horizon is either an orstein, and very firm when moist, or it is friable and has humus, dominated in the upper 7-1/2 cm. (3 inches) by silt-sized pellets of humus, or of humus and iron (see figures 14 and 15). The spodic horizon may be underlain by another sequum containing an argillic horizon, by a fragipan, or by C material. An albic horizon may be present or absent. There are no mottles in any albic horizon that may be present, nor are there mottles with chromas of 2 or less in the upper part of the spodic horizon.

Typorthods are dominantly found in cool, humid climates, under coniferous forest. A few have had a broadleaf deciduous forest vegetation.

Orthic Typorthods (6.330)

This subgroup includes Typorthods with a continuous spodic horizon that is very firm when moist (an orstein), or is more than 10 cm. (4 inches) thick and has from 2 to 10 percent organic matter (1.16 to 5.8 percent organic carbon) in the upper 10 cm. There are no mottles with chromas of 2 or less in the spodic horizon. If the soil has been plowed and the upper part of the spodic horizon has been mixed in the Ap, that horizon has more than 2 percent organic matter. There is no argillic horizon below the spodic horizon, but there may be a fragipan.

The presence or absence of a fragipan is being tested as a family criterion, for it seems to be related primarily to texture, particularly the content of silt and very fine sand.

Profile 20, page 85, is an example of an Orthic Typorthod. Chemical and mineralogical analyses are given in table 13, page 50. The reader is reminded that the mechanical analyses are misleading (see spodic horizon).

Entic Typorthods (6.33-1)

This subgroup includes Typorthods that have a friable spodic horizon that is continuous but that is thinner than 10 cm. (4 inches) or has less than 2 percent organic matter in the upper 10 cm.

Ruptic Entic Typorthods (6.33-1)

This subgroup includes Typorthods with a spodic horizon that is discontinuous within each pedon.

Aquic Typorthods (6.33-6.1)

This subgroup includes the Typorthods that have all of the properties of the orthic subgroup except that there are mottles with chromas of 2 or less within the spodic horizon.

Humic Typorthods (6.33-6.2)

This subgroup includes the Typorthods that have all of the properties of the orthic subgroup except that the upper 10 cm. (4 inches) of the spodic horizon has more than 10 percent organic matter.

Alfic Typorthods (6.33-7)

This subgroup includes the Typorthods that have an argillic horizon underlying the spodic horizon. The argillic horizon either has base saturation of more than 35 percent in some part or has tongues of an albic horizon.

This is a very common subgroup in the areas that lie between Spodosols and Alfisols. Profile 32, page 97, is an example of the soils of this subgroup. As a general rule, the spodic horizon is thin, for a given texture, in comparison with that of the Orthic Typorthods.

Ultic Typorthods (6.33-8)

This subgroup includes Typorthods that have, underlying the spodic horizon, an argillic horizon that has base saturation of less than 35 percent throughout and contains no tongues of an albic horizon. So far as is now known, the soils of this subgroup are polygenetic. They now have a climate and probably a vegetation that differs from those of earlier periods of the soil's genesis.

FERRODS (6.4)

The Ferrods are Spodosols that have spodic horizons in which iron has accumulated without comparable accumulations of humus. The spodic horizon has structure comparable to that of Typorthods, but normally lacks as much as 1/2 percent organic matter. Silt-sized pellets of humus, or humus and iron, and coatings of humus are lacking. Nevertheless, the iron accumulations may be very large and not accompanied by any increase in the content of clay.

The Ferrods have not been identified in the United States. Definitions of subgroups and families must be written by others.

Profile Descriptions for Chapter 13

(Colors for moist soil unless otherwise stated)

Profile No. 77

Area: Bardufoss, Norway.

Vegetation: Alpine birch and a ground cover of moss, heather, and some blueberry.

Parent material: Glacial outwash.

Topography: Very gently sloping to nearly level bench above river; surface is hummocky from frost mounds that are from 6 to 8 feet in diameter and about 2 feet high.

O	6 inches to 0 inch, moss and fresh organic matter.
A2	0 to 3 inches, light-gray (N 7/) silt loam; dark reddish-brown (2.5YR 3/4) mottles which may be bits of the B horizon; abrupt, irregular boundary; horizon 2 to 7 inches thick, depending on recency of heaving.
B2irh	3 to 11 inches, strong-brown (7.5YR 5/6) silt loam; a few patches of the light gray (N 7/) A2 horizon; few, small, prominent, olive (5Y 5/6) mottles; firm, brittle when moist; clear, wavy boundary; horizon 5 to 9 inches thick.
B3irh	11 to 14 inches, dark-brown (10YR 3/3) silt loam; few, small, prominent, olive (5Y 5/4) mottles; friable; diffuse, wavy boundary.
C1	14 to 26 inches, olive (5Y 4/3) very fine sandy loam; few, very fine, yellowish and reddish mottles too small for measurement; structureless; loose.
IIC2	26 inches +, coarse to medium, granitic sand.

Climatic data (Bardufoss, Norway)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1901-30 (deg. F.)	17	16	22	31	40	50	57	53	44	32	22	17	33
Mean precipitation, 1934-40 (inches)	2.9	2.0	1.5	1.6	1.3	1.7	2.5	2.1	3.1	3.0	2.2	1.7	25.8

Annual precipitation more than 19.2 and less than 32.4 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
6-0	O														
0-3	A2	0.2	0.7	0.5	2.1	27.1	66.9	2.5	71.4	24.0	0		1.38	26	0.8
3-11	B2irh	.3	1.0	.8	2.9	28.2	66.0	.8	73.8	22.5	0		1.26	21	2.7
11-14	B3irh	.0	.1	.3	2.0	26.9	68.9	1.8	72.6	24.6	0		.62	21	1.4
14-26	C1	.0	.1	.2	8.4	44.2	46.1	1.0	85.5	12.2	0		.14		.7
26+	IIC2	3.2	24.9	30.0	34.2	5.7	1.9	.1	20.8	.2	0		.10		.3

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:5	pH 1:10	Loss on ignition %	Base sat. % s
116.3	17.1	8.4	93.9	0.7	4.1		4.3	84	19
14.5	.6	.4	13.3	.1	.1	4.5			8
16.0	1.0	.4	14.5	.1	<.1	5.5			9
8.8	1.0	.3	7.4	.1	<.1	5.5			16
3.8	.4	.1	3.2	.1	<.1	5.3			16
1.1	.1	.1	.9	<.1	<.1	5.1			18

*Exchange acidity.

Profile No. 78
Area: Bardufoss, Norway.
Vegetation: Mainly blueberry, heather, and moss; scattered pine and fir trees; profile is located between a peat bog and an area covered by a good stand of pine and fir trees.
Parent material: Outwash of granitic origin.
Topography: A level to slightly depressed glacial bench above a river.

O — 8½ inches to 0 inch, peat; the upper two-thirds is raw, the lower one-third is well decomposed; abrupt boundary.

A2g — 0 to 2½ inches, light-gray to gray (5Y 6/1) fine sand; upper part is slightly whiter than the lower part; abrupt, smooth boundary.

B1h — 2½ to 6½ inches, dark yellowish-brown (10YR 4/4) sand; iron and organic stains occur at the water table; weak, very thick, platy structure; firm; gradual, smooth boundary.

B21rhm — 6½ to 16½ inches, black (5Y 2/1) coarse sand; strong, thick, platy structure; cemented, rocklike pan of iron and organic matter, which could be penetrated only through use of a crowbar even though the material was below the water table; gradual, smooth boundary.

B3irh — 16½ inches +, dark, multicolored sand; colors are caused by various kinds of sand and coatings inherent in the parent material; firm; weakly cemented.

Climatic data (Bardufoss, Norway)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1901-30 (deg. F.)	17	16	22	31	40	50	57	53	44	32	22	17	33
Mean precipitation, 1934-40 (inches)	2.9	2.0	1.5	1.6	1.3	1.7	2.5	2.1	3.1	3.0	2.2	1.7	25.8

Annual precipitation more than 19.2 and less than 32.4 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N m
8½-7	O												---	---
7-3	O												---	---
3-0	O												---	---
0-2½	A2g	2.8	12.4	14.6	25.0	18.2	26.3	0.7	45.3	12.4	1		0.65	46
2½-6½	B1h	5.0	22.8	20.5	24.0	10.6	14.7	2.4	29.9	7.2	2		1.22	39
6½-16½	B21rhm	4.6	31.9	28.3	17.6	6.4	8.9	2.3	18.4	4.3	1		2.63	32
16½+	B3irh	12.8	40.0	21.9	17.0	3.0	5.0	.3	10.2	2.2	4		1.58	36

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	pH 1:20	pH 1:10	Free iron oxides Fe_2O_3 %	Loss on ignition %	Base sat. % s
								3.9	N. D.**		20
155.0	12.2	16.7	123.1	1.2	1.8			4.2	N. D.	94	13
126.8	8.3	6.4	110.3	.7	1.1		4.0		N. D.	87	18
3.4	.3	.2	2.8	.1	< .1	4.4			< 0.1		8
14.1	.7	.3	13.0	.1	< .1	4.4			.7		3
34.5	.6	.4	33.4	.1	< .1	4.6			2.1		3
21.9	.3	.3	21.2	.1	< .1	4.6			1.2		

*Exchange acidity.
**Not determined.

Chapter 14. Alfisols

The Alfisols are the mineral soils that are usually moist and that have no mollic epipedon, or oxic, or spodic horizon. They do have an argillic or natric horizon that has base saturation of more than 35 percent, as measured by the sum of cations. The base saturation, if it is very high, remains constant with depth below the argillic horizon. Base saturation, if not high in the argillic horizon, increases with depth below the argillic horizon. The Alfisols also include soils with argillic horizons that have base saturations of less than 35 percent if there are tongues of an albic horizon in the argillic horizon, and if base saturation increases with depth in or below the argillic horizon but within the soil.

The Alfisols include most soils that have been called Noncalcic Brown soils, Gray-Brown Podzolic soils, and Gray-Wooded soils, many that have been called Planosols, some that have been called Half-Bog soils, and a few that have been called solodized Solonetz.

They may be found under boreal forests or deciduous broadleaf forests. Some are found in relatively dry climates where there is marked seasonal variation in rainfall and a cover of grass and scattered xerophytic trees, including Eucalyptus and some Quercus. A very few others, in humid climates, have had a tall grass vegetation; these have been called Planosols.

The relatively high base saturation of the argillic horizon limits the occurrence of these soils to places where there has been little movement of water through the soil, or to places where the parent materials are young, unweathered, and basic. So, in humid climates, the parent materials usually contain carbonates and the land surfaces are no older than late Pleistocene.

In cold or cool humid regions the Alfisols are almost entirely restricted to young calcareous parent materials. Here, the argillic horizon seems unstable and is usually at the base of the solum, adjacent to the calcareous parent material.

In subhumid regions the land surfaces may be older. Some Alfisols are possibly older than Pleistocene and have formed in old, very strongly weathered materials that contain plinthite. The present base saturation may reflect additions of bases from cyclic salts in rain or from dust from adjacent deserts.

Four suborders are recognized. These are discussed with their great groups and subgroups on the pages that follow.

AQUALFS (7.1)

The Aqualfs are those Alfisols that are saturated with water at some season or have artificial drainage and that have characteristics associated with wetness. These are the presence of mottles, iron-manganeses concretions, or chromas of 2 or less immediately below any Ap that may be present, or below any A1 that has color values darker than 3.5 when moist and rubbed. In addition, the Aqualfs must have one of the following combinations of colors in the argillic or natric horizon:

1. Dominant chromas of 1 to 2 in hues of 10YR or redder on the ped surfaces, or in the matrix if peds are lacking, accompanied by mottles of stronger chroma.
2. Dominant chromas of 1 to 3 in hues of 2.5Y or yellower on the ped surfaces, or in the matrix if peds are lacking, accompanied by mottles of stronger chroma and redder hue.
3. Dominant chromas of 1 or less on the ped surfaces or in the matrix if no peds are present, with or without mottles of stronger chroma.

The Aqualfs have been called Half-Bog soils and Planosols, for the most part. A few have been called solodized Solonetz. Some, having no other convenient name, have been called Low-Humic Gley soils in recent years. The common characteristics are seasonal saturation with water, low chromas, an argillic or natric horizon with moderate to high base saturation, and moisture held at tensions of less than 15 bars during most of the time that the soil is not frozen. There may be in addition, fragipans, duripans, or ca horizons.

Key to Aqualfs

7.11 Aqualfs with an abrupt textural change, with slow or very slow permeability in the argillic horizon, without tonguing of the albic horizon into the argillic horizon, and with no fragipan, duripan, or natric horizon.

Albaqualf, p. 203

7.110 Albaqualfs with no A1 that is both more than 15 cm. (6 inches) thick and darker than a moist value of 4, and no Ap that is darker than 4 when moist.

Orthic Albaqualf, p. 203

7.11-5 Other Albaqualfs with an epipedon that meets the requirements of a mollic epipedon except for thickness or base saturation.

Mollic Albaqualf, p. 203

7.12 Other Aqualfs that have no fragipan, duripan, or natric horizon but that have an albic horizon tonguing into an argillic horizon.

Glossaqualf, p. 203

7.120 Glossaqualfs with no histic epipedon, and with mean annual temperature greater than 8.3° C. (47° F.).

Orthic Glossaqualf, p. 203

7.12-7.2 Other Glossaqualfs that have no histic epipedon.

Altic Glossaqualf, p. 203

7.12-10 Other Glossaqualfs with a histic epipedon.

Histic Glossaqualf, p. 204

7.13 Other Aqualfs with an ochric epipedon, and with no fragipan, natric horizon, or duripan.

Ochraqualf, p. 204

7.130 Ochraqualfs that have an Al less than 15 cm. (6 inches) thick if its moist value is darker than 3.5, or an Ap with a moist value of 4 or more.

Orthic Ochraqualf, p. 204

7.13-5 Other Ochraqualfs with an epipedon that meets all requirements of a mollic epipedon except thickness and base saturation.

Mollic Ochraqualf, p. 204

7.13-7.14 Other Ochraqualfs.

Umbric Ochraqualf, p. 204

7.14 Other Aqualfs with an umbric epipedon but with no fragipan or natric horizon.

Umbraqualf, p. 204

7.15 Other Aqualfs with a fragipan.

Fragaqualf, p. 204

7.150 Fragaqualfs with no histic epipedon.

Orthic Fragaqualf, p. 204

7.15-10 Other Fragaqualfs with a histic epipedon.

Histic Fragaqualf, p. 204

7.16 Other Aqualfs with a natric horizon and no duripan.

Natraqualf, p. 204

Albaqualfs (7.11)

The Albaqualfs include soils that have been called Planosols and recently, "claypan" Planosols, to distinguish them from the soils with fragipans. They are the Aqualfs that have no natric horizon, and no fragipan or duripan, but that do have an abrupt textural change from an albic horizon to an argillic horizon without tonguing, and that have slow or very slow permeability in the argillic horizon. The definition of the abrupt, textural change requires that the clay content double, or show an increase of 20 percent or more (that is, 25 to 45 percent), within a 3-inch vertical distance. This definition is still not entirely satisfactory, partly because the lower part of the albic horizon commonly includes small remnants of the argillic horizon. When sampled for laboratory study in the normal manner, this horizon gives the appearance of either a transitional horizon, or of more clay in the albic horizon than is actually present. A definition that did not require separation of the remnants of argillic horizon would be more useful. An example of the difficulty may be seen in the data for profile 23, page 88. While it is believed that this profile has an abrupt textural change, the data do not support the belief. The description, when written did not mention inclusions of B, but indicated their presence by calling the horizon A2B1.

The Albaqualfs do not seem to occur in the more humid range of the Alfisols. They are common in areas where evapotranspiration exceeds rainfall appreciably during several months of the growing season, and in Mediterranean climates. Soils that are never or are rarely dry to depths of 50 cm. (20 inches) or more do not seem to have the abrupt textural change that is diagnostic of the Albaqualfs.

Orthic Albaqualfs (7.110)

The Orthic Albaqualfs have an ochric epipedon. If they are virgin, the Al must be thinner than 15 cm. (6 inches) or have a moist color value of 4 or more. If they are cultivated, the Ap must have a moist color value of 4 or more.

Profile 79, page 214, is an example of the Orthic Albaqualfs.

Mollic Albaqualfs (7.11-5)

The soils of this subgroup include the Albaqualfs with an ochric epipedon that approaches the properties of a mollic epipedon, but that is too thin, or has base saturation that is below 50 percent. The argillic horizon normally is darker in color than the albic horizon and often contains enough organic matter to make it a part of a mollic epipedon if no albic horizon were present.

Profile 23, page 88, is an example of the Mollic Albaqualfs. It should be remembered that this profile was sampled in such a way that the data do not confirm the presence of the abrupt textural changes, though it is believed to be present. Chemical analyses of the soil are given in table 13, page 50.

Glossaqualfs (7.12)

The Glossaqualfs are the Aqualfs with an albic horizon that tongues into the argillic horizon from above. They have no natric horizon, fragipan, or duripan.

The Glossaqualfs resemble the Albaqualfs closely but seem to be restricted to more humid climates and are less often dry in the solum. Many are also in a cooler climate and have the temperatures of the Altalfs. The native vegetation was primarily forest, chiefly deciduous broadleaf trees.

Orthic Glossaqualfs (7.120)

This subgroup includes Glossaqualfs that have a mean annual temperature of more than 8.3° C. (47° F.) and that have no histic epipedon.

Profile 80, page 215, is presented as the best available example of an Orthic Glossaqualf for which data are available. It has a darker epipedon than is characteristic of the Glossaqualfs and approaches the limits of a mollic epipedon. It may be decided, after additional study, that profile 80 should represent a Mollic Glossaqualf.

Altic Glossaqualfs (7.12-7.2)

This subgroup includes the Glossaqualfs that have no histic epipedon but that have mean annual temperature of less than 8.3° C. (47° F.).

Histic Glossaqualfs (7.12-10)

This subgroup includes the Glossaqualfs that have a histic epipedon. The soils of this class have been called Half-Bog soils.

Ochraqualfs (7.13)

The Ochraqualfs include the Aqualfs that have no abrupt textural change and no tonguing of the albic horizon into the argillic horizon. They have no fragipan, duripan, or natric horizon. Rather, the argillic horizon rests on C or R.

Orthic Ochraqualfs (7.130)

This subgroup represents the central concept of the Ochraqualfs. The soils have an ochric epipedon. If the soils are plowed, the Ap has a moist color value of 4 or more. If they are virgin, the Al is less than 15 cm. (6 inches) thick if its moist value is less than 3.5.

Profile 81, page 216, is an example of the Orthic Ochraqualf. It is marginal to the Udalfs, but has the characteristics of Aqualfs. The lower part of the argillic horizon is browner than is believed normal for the Ochraqualfs.

Mollic Ochraqualfs (7.13-5)

This subgroup includes Ochraqualfs that have surface colors too dark for the orthic subgroup and that approach those of a mollic epipedon. The Ap has darker color values than 4 and fits the definition of a mollic epipedon except for thickness or for base saturation. If the soil is virgin, the Al is thicker than 15 cm. (6 inches), has a color value of 3.5 or less, a carbon-nitrogen ratio of less than 17, and crumb, granular, platy, or blocky structure.

Umbric Ochraqualfs (7.13-7.14)

This subgroup is provided tentatively for Ochraqualfs that have colors too dark for the orthic subgroup and that have an Al or an Ap that is massive when dry, or that has carbon-nitrogen ratios of more than 17.

Umbraqualfs (7.14)

This group is tentative and may not be needed. Its definition is given in the key, and no subgroups are proposed.

Fragaqualfs (7.15)

The Fragaqualfs are the Aqualfs with a fragipan below the argillic horizon or in the argillic horizon. The base saturation is normally low for the Aqualfs and often is barely over the necessary 35 percent.

Parent materials have appreciable amounts of silt or very fine sand, or both. The native vegetation is a deciduous broadleaf forest, usually with one or more species of Quercus.

Orthic Fragaqualfs (7.150)

This subgroup presently includes all Fragaqualfs that have no histic epipedon.

Profile 82, page 217, is an example of the Fragaqualfs, but the brown horizon at depths between 9 and 14 inches suggests that it possibly should not be in the orthic subgroup. The base saturation is marginal between Alfisols and Ultisols, but this is characteristic of all Alfisols with fragipans.

Histic Fragaqualfs (7.15-10)

This subgroup includes the Fragaqualfs that have a histic epipedon.

Natraqualfs (7.15)

The Natraqualfs are the Aqualfs that have a natric horizon. In some, the only apparent source of the sodium is weathering of feldspars.

In others, cyclic salts may be a factor. The climate may be humid if permeabilities are low enough to preclude movement of water through the soil. Or, the climate may be Mediterranean and subhumid. At this time, no subgroups are proposed.

Profile 83, page 218, is an example of the Orthic Natraqualf. This soil has an epipedon that approaches the limits of a mollic epipedon and had grass vegetation when first seen by settlers. The sodium and the carbonates in this soil are presumed to have been derived through weathering of primary minerals, and to have accumulated because slow permeability prevented the movement of water through the soil.

ALTALFS (7.2)

The Altalfs are the Alfisols that have mean annual temperature of 8.3° C. (47° F.) or less. Many virgin profiles have a distinct albic horizon and at one time were called Podzols. Later, they were called Gray-Wooded soils. Some, if not most, Degraded Chernozems are included.

The Altalfs have developed mostly under boreal forests, chiefly conifers. A few are thought to have had a grass vegetation at one time, which was followed by the forest. Few, if any, are found in the tundra, but some might occur in the United States in alpine areas above the present timberline.

Key to Altalfs

7.21 Altalfs that have an umbric epipedon but no natric horizon.

Cryaltalf, p. 205

7.210 Cryaltalfs that have a mean summer temperature in the solum of less than 15.5° C. (60° F.) if they are cultivated or if they do not have an O horizon, or have a mean summer temperature in the solum of less than 10° C. (50° F.) if they have an O horizon.

Orthic Cryaltalf, p. 205

7.22 Other Altalfs with no fragipan or natric horizon.

Typaltalf, p. 205

7.220 Typaltalfs that have an Ap with a moist value of more than 3 or an A1 less than 15 cm. (6 inches) thick if the moist color value is less than 3.5; that have a base saturation of more than 60 percent in all horizons or contain a ca horizon; that have no mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon.

Orthic Typaltalf, p. 205

(7.22-5) Other Typaltalfs having an A1 or an Ap that is darker, or thicker and darker, than that of the orthic subgroup and having no mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon.

Mollic Typaltalf, p. 205

(7.22-7.1) Other Typaltalfs with color values in the A1 or Ap as in the orthic subgroup, but with mottles that have chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon.

Aquic Typaltalf, p. 205

(7.22-7.34) Other Typaltalfs, with base saturation less than 60 percent in some horizon, and with tonguing of an albic horizon into the argillic horizon.

Glossuldalfic Typaltalf, p. 205

7.23 Other Altalfs with a natric horizon.

Natraltalf, p. 205

7.24 Other Altalfs with a fragipan.

Fragaltalf, p. 206

7.240 Fragaltalfs that have no mottles with chromas of 2 or less in the argillic horizon.

Orthic Fragaltalf

7.24-7.1 Other Fragaltalfs that have mottles with chromas of 2 or less in the argillic horizon.

Aquic Fragaltalf

Cryaltalfs (7.21)

The Cryaltalfs are thought to occur only above timberline in alpine climates. They have an umbric epipedon and low temperatures. They have been little studied in the United States, and subgroup definitions have not been developed beyond that of the orthic subgroup. The orthic subgroup includes the Cryaltalfs that have mean summer temperature in the solum of less than 15.5° C. (60° F.) if they are cultivated or if they have no O horizon, and less than 10° C. (50° F.) if there is an O horizon.

Typaltalfs (7.22)

The Typaltalfs include soils that have been called Podzols or Gray Wooded soils, and Degraded Chernozem. They have developed under a boreal forest, chiefly conifers, for at least a part of their genesis. Some presumably have had a grass vegetation until relatively recent times and retain some of the properties of the Altolls. The parent materials are most often calcareous in the United States. The land surfaces on which these soils occur have been dated no older than the later part of the Wisconsin glaciation.

Orthic Typaltalfs (7.220)

The Orthic Typaltalfs have, if cultivated, an Ap that has a color value of more than 3, and if virgin, an A1 that is thinner than 15 cm. (6 inches) if its moist color value is less than 3.5. Commonly, there is no A1 horizon. Base saturation is more than 60 percent in all horizons, or the soils have a ca horizon. There are no mottles that have chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon. Chromas in the albic horizon, if the soil is virgin, or in the Ap, if it is cultivated, are 3 or less.

Profile 22, page 87, is an example of an Orthic Altalf. Chemical and mineralogical analyses of this profile are given in table 13, page 50.

Mollic Typaltalfs (7.22-5)

This subgroup includes many soils that have been called Degraded Chernozems. If cultivated, they have an Ap with a moist color value of 3 or less. If virgin, they have an A1 that is darker than 3.5 and thicker than 15 cm. (6 inches). There are no mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon.

These soils are mainly on the border between Altolls and Altalfs. They represent transitional forms between the two. The forests apparently have been invading the prairies, and these soils have been under forest too short a time to have lost the characteristics they acquired under an earlier grass vegetation. In a few cases, they may have had an open forest with a grass cover below the trees for much of their genesis.

Aquic Typaltalfs (7.22-7.1)

This subgroup includes the Altalfs that have the colors of the orthic subgroup in the epipedon, but that have mottles of 2 or less in the argillic horizon. Base saturation is more than 75 percent in all horizons.

Glossudalfic Typaltalfs (7.22-7.34)

This subgroup is found in humid climates, in contrast to the Typaltalfs. The soils have base saturation of less than 60 percent in some or all horizons. In addition, they have an albic horizon that tongues into the argillic horizon.

Natraltalfs (7.23)

This group is provided for Altalfs that have a natric horizon. The soils have not been identified in the United States, and no subgroup definitions are proposed.

Fragaltalfs (7.24)

This group is provided for Altalfs that have a fragipan. These soils have been little studied in the United States, though some are thought to occur. No subgroup definitions are proposed beyond those given in the Key to Altalfs.

UDALFS (7.3)

The Udalfs include the Alfisols that lack the characteristics associated with wetness definitive of the Aqualfs; that have mean annual temperature of more than 8.3° C. (47° F.); and that are usually or always moist in some part of the solum. Parts of the solum may be seasonally dry, but not for periods in excess of 3 months. The conductivity of the saturation extract is less than 1 millimho per cm. at 25° C. in all horizons.

The soils may have an albic horizon and a fragipan; they must have an argillic horizon and may have an agric horizon or a ca horizon. The epipedon may be anthropic or ochric. No other diagnostic horizons are known to be present, though some Udalfs may have a thin spodic horizon, so thin and close to the surface that it will be obliterated after liming and plowing for a few years. Such thin and shallow horizons are not diagnostic in this system. The Udalfs have been called Gray-Brown Podzolic soils in the United States. They are restricted to humid climates that usually, though not necessarily, have a summer maximum of rainfall. The native vegetation is primarily deciduous hardwood forest, but some have had a coniferous forest during at least the later part of their genesis.

The parent materials are most commonly calcareous, though some are not. The soils are primarily on land surfaces or deposits of Wisconsin age. A few may be as old as Illinoian, but it is believed they are not older than this.

Key to Udalfs

7.31 Udalfs that have an agric horizon.

Agrudalf, p. 207

7.310 With an anthropic epipedon and an agric horizon but no fragipan.

Orthic Agrudalf, p. 207

7.32 Other Udalfs with no fragipan and no albic horizon that tongues into the argillic horizon.

Typudalf, p. 207

7.320 Typudalfs with the following properties:
(a) The argillic horizon is free of mottles with chromas of 2 or less in at least the upper 25 cm. (10 inches).
(b) No abrupt textural change is present if there are mottles in the upper 25 cm. of the argillic horizon.
(c) The chroma of the argillic horizon is less than 6 if it is in a hue of 7.5YR or redder, or if base saturation is less than 50 percent.
(d) The Ap has a moist value of more than 3, or the A1 is less than 15 cm. (6 inches) thick if its moist value is lower than 3.5.
(e) There is no interfingering of an albic horizon into the argillic horizon, with penetrations of the albic horizon that are too small to constitute tongues, or that occupy less than 15 percent of the mass of the upper part of the argillic horizon.
(f) There is no anthropic epipedon.
(g) The argillic horizon is continuous horizontally, is continuous vertically for at least the upper 15 cm. (6 inches), and has a texture finer than loamy sand.
(h) Exchangeable sodium is less than 10 percent of the capacity throughout the argillic horizon.

Orthic Typudalf, p. 207

7.32-1.2 Other Typudalfs in which the argillic horizon consists of lamellae in the upper 15 cm. (6 inches) or in which the argillic horizon has a texture as coarse or coarser than loamy sand.

Psammentic Typudalf, p. 208

7.32-5 Other Typudalfs that have an Ap with a moist value of 3 or less or have an A1 as thick or thicker than 15 cm. (6 inches) with a moist value of less than 3.5; that have no distinct or prominent mottles, including some with chromas of 2 or less, within the upper 25 cm. (10 inches) of the argillic horizon.

Mollic Typudalf, p. 208

7.32-5.3 Other Typudalfs that have the surface colors of Mollic Typudalfs but have distinct or prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon.

Aquollic Typudalf, p. 208

7.32-7.1 Other Typudalfs that have distinct or prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon; that have no abrupt textural change; and that have less than 10 percent exchangeable sodium in the argillic horizon.

Aquic Typudalf, p. 208

7.32-7.11 Other Typudalfs that do not have an anthropic epipedon but have distinct or prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon; that have an abrupt textural change; and that have less than 10 percent exchangeable sodium in the argillic horizon.

Albaqualfic Typudalf, p. 208

7.32-7.16 Other Typudalfs that do not have an anthropic epipedon but have distinct or prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon, and have 10 percent or more exchangeable sodium in some part of the argillic horizon.

Natraqualfic Typudalf, p. 208

7.32-7.31 Other Typudalfs with an anthropic epipedon.

Agric Typudalf, p. 208

7.32-8.2 Other Typudalfs with chromas of 6 or more dominant in the argillic horizon in hues of 7.5YR or redder, or with chromas of 6 or more with base saturation of less than 50 percent.

Ochrultic Typudalf, p. 208

7.32-7.34 Other Typudalfs with an albic horizon that interfingers with the upper part of the argillic horizon, surrounding some peds but occupying less than 15 percent of the mass of the upper part of the argillic horizon, or with penetrations too small to constitute tongues.

Glossic Typudalf, p. 208

7.33 Other Udalfs with a fragipan, and with no albic horizon tonguing into the argillic horizon from above.

Fragudalf, p. 209

7.330 Fragudalfs that have an Ap with a moist color value of more than 3, or with an A1 having a moist color value of more than 3.5 if it is thicker than 15 cm. (6 inches); with an argillic horizon that has dominant colors in its upper part that are redder than 10YR or that has chromas of 3 or more in values of 4, or chromas of 4 or more in values of 5 or more.

Orthic Fragudalf, p. 209

7.33-5 Other Fragudalfs that have an Ap with a moist color value of 3 or less, or that have an A1 that has a moist color value of 3.5 or less and is thicker than 15 cm. (6 inches).

Mollic Fragudalf, p. 209

7.34 Other Udalfs with no fragipan but with an albic horizon that tongues into the argillic horizon from above, or in sands and loamy sands, an albic horizon that consists of disconnected tongues of bleached sand extending into the argillic horizon.

Glossudalf, p. 209

7.340 Glossudalfs with no prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon; with the argillic horizon finer in texture than loamy sand and continuous vertically for at least the upper 15 cm. (6 inches); with chromas in the argillic horizon of 2 or more in hues of 10YR, and of more than 2 in hues yellower than 10YR.

Orthic Glossudalf, p. 209

7.34-1.2 Other Glossudalfs with colors as in orthic subgroup, but with an argillic horizon that has a texture of loamy sand or coarser or that consists of lamellae in the upper 15 cm. (6 inches).

Psammentic Glossudalf, p. 209

7.34-7.1 Other Glossudalfs with mottles nearer the surface or that have lower chromas than those of the orthic subgroup.

Aquic Glossudalf, p. 209

7.35 Other Udalfs with a fragipan, and with an albic horizon that tongues into the argillic horizon from above.

Fraglossudalf, p. 209

7.350 Fraglossudalfs with no prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon, and with chromas in the argillic horizon of 2 or more in hues of 10YR, and of more than 2 in hues yellower than 10YR.

Orthic Fraglossudalf, p. 209

7.35-7.1 Other Fraglossudalfs.

Aquic Fraglossudalf, p. 209

Agrudalfs (7.31)

The Agrudalfs are those Udalfs that have an agric horizon. They are not known to occur in the United States. It is suggested that the orthic subgroup should include the Agrudalfs that have an anthropic epipedon, an agric horizon, and no fragipan. Those Agrudalfs that have an ochric epipedon should then be Typic Agrudalfs. The definitions however need to be developed by others.

The Agrudalfs have had no particular recognition in earlier classifications.

Typudalfs (7.32)

The Typudalfs are the "typical" Gray-Brown Podzolic soils. The virgin profiles have an ochric epipedon that has a clear or gradual boundary with an argillic horizon. The argillic horizon, in turn, rests on C or R. These soils have no albic horizon that tongues into the argillic horizon. In virgin soils the normal chromas between the A1 and the argillic horizon are 4 to 5. This color, and the nature of the transition from the A to the B, are two important distinctions in virgin profiles between the Typudalfs and the Typaltalfs. These distinctions do not persist in cultivated and eroded soils.

The Typudalfs perhaps have been studied more intensively than any other grouping. It may be for this reason that more subgroups are recognized. Even here, the list of subgroups is incomplete. No provisions have been made for transitional forms to the Andepts or Altalfs, though they exist.

Orthic Typudalfs (7.320)

The properties of this subgroup are listed in the key to Udalfs, and little can be added here to clarify them.

Profile 11, page 76, is an example of an Orthic Typudalf. Chemical and clay mineral analyses are given in table 10. This soil has developed in moderately thick loess of Wisconsin age and is near the center of the range of even the Orthic Typudalfs. Weatherable minerals are abundant, both in the clay and the silt fraction. The ratio of free iron to clay is constant in all horizons.

Most Orthic Typudalfs have had carbonates in the parent material. If the carbonates are of gravel size, there may be an argillic horizon in the zone where carbonates have been partially removed. This horizon, which has been called a "Beta" horizon, normally has a darker color and more clay than the overlying horizons, and it is about neutral in reaction. It may underlie and be separated from the main argillic horizon; it may be the lower part of a single argillic horizon; or it may be the only argillic horizon in the soil. The "Beta" horizon is an argillic horizon, but it seems unstable, for it is at the top of the calcareous parent material. The "Beta" horizon may occur in the Orthic Typudalfs, but probably should not be the only argillic horizon. Profile 11 has no "Beta" horizon.

Psammentic Typudalfs (7.32-1.2)

This subgroup includes the Typudalfs that have an argillic horizon of sand or loamy sand texture. It also includes the Typudalfs having an argillic horizon composed entirely of lamellae (see fig. 12). Soils such as the one illustrated in figure 12 can be orthic because the lamellae start in the lower part of the argillic horizon. If a soil has as much as 15 cm. (6 inches) of argillic horizon above the lamellae, and the texture is as fine as sandy loam, the soil is excluded from the Psammentic Typudalfs.

Mollic Typudalfs (7.32-5)

The Mollic Typudalfs differ from the Orthic Typudalfs in the color of the epipedon. If the soil is cultivated, the Ap has a moist color value of 3 or less. The Ap is dark enough to be a mollic epipedon but is too thin. If the soil is virgin, the A1 is as thick or thicker than 15 cm. (6 inches) and has a moist color value of less than 3.5. In this situation, the A1 is too thin to be a mollic epipedon or has too light a color when dry.

It is common but not essential that the argillic horizon of the Mollic Typudalfs have coatings on the peds of the argillic horizon that have dark colors; colors of 2/2 or 3/2 are common.

Some soils of this subgroup have had a forest vegetation, presumably for too short a time for the forest to destroy the characteristics that were acquired under an earlier grass vegetation. These soils were changing from Argudolls to Typudalfs at the time the forest was cut.

Other Mollic Typudalfs had a grass vegetation and seem to have been changing from Typudalfs to Argudolls. These soils lack dark coatings in the argillic horizon. New subgroups may be needed for these differing profiles, but the definitions are not attempted here.

A third group of soils in this subgroup seem to be Argudolls that have lost so much of their A horizon by erosion under cultivation that they no longer have a mollic epipedon. The best method of identifying and handling these soils in the classification is undetermined.

Aquollic Typudalfs (7.32-5.3)

This subgroup includes Typudalfs that have mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon, that have no abrupt textural change, and that have either an Ap with moist colors darker than 3 or an A1 that is thicker than 15 cm. (6 inches) and that has a moist color value of less than 3.5.

Aquic Typudalfs (7.32-7.1)

This subgroup includes Typudalfs that have mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon, and that have either an Ap with a moist color value of 3 or more or an A1 that is thinner than 15 cm. (6 inches) if its moist color value is darker than 3.5. The argillic horizon has less than 10 percent saturation with sodium.

Albaqualfic Typudalfs (7.32-7.11)

The subgroup includes Typudalfs that have an abrupt textural change, and that have an argillic horizon with distinct or prominent mottles within the upper 25 cm. but with less than 10 percent saturation with exchangeable sodium throughout.

Natraqualfic Typudalfs (7.32-7.16)

This subgroup includes the Typudalfs that have 10 percent of more saturation with exchangeable sodium in some part of the argillic horizon, and that have distinct or prominent mottles within the upper 25 cm. (10 inches) of the argillic horizon.

Agric Typudalfs (7.32-7.31)

This subgroup includes the Typudalfs that have an anthropic epipedon. They have not been identified and described in the United States.

Glossic Typudalfs (7.32-7.34)

This subgroup includes Typudalfs that have an albic horizon that interfingers with the argillic horizon. The transition is one in which the peds have centers consisting of material normally found in an argillic horizon and have exteriors consisting of the kind of material normal for an albic horizon. The extensions of the albic horizon surround some parts of the argillic horizon, but are too small to be tongues, as they are defined, or the extensions occupy less than 15 percent of the mass of the upper part of the argillic horizon. The interfingering produces horizons that are best designated A and B, or B and A, rather than A3 and B1.

Above the albic horizon there is often a browner horizon that could be considered a cambic horizon, but that would be considered an A2 horizon if there were no underlying albic horizon. There may also be a very thin sequum in the surface 2 or 3 inches that has an albic horizon and what appears to be a very thin spodic horizon. These horizons, though common, are too thin and too close to the surface to be diagnostic.

Profile 84a, page 220, is an example of a Glossic Typudalf. If the horizons from 16 to 21 inches had a larger proportion and larger size penetrations of the 10YR 5/3 gravelly loam, this soil would be considered a Glossudalf.

Ochrultic Typudalfs (7.32-8.2)

This subgroup includes Typudalfs that have chromas of 6 or more in the argillic horizon if the argillic horizon has hues as red or redder than 7.5YR or has base saturation of less than 50 percent. It is possible that intergrades to specific great groups of Ochrults may be needed.

Fragudalfs (7.33)

The Fragudalfs are Udalfs that have fragipans, but that have no albic horizon that lies above the argillic horizon and tongues into it from above. There may be an albic horizon between the argillic horizon and the fragipan, and tongues of this albic horizon may, and often do, extend upward into the argillic horizon.

The Fragudalfs have silty or loamy textures and contain weatherable minerals in the silt fraction and 2:1 lattice clays. Loess, glacial drift, and alluvium of Wisconsin age are the most common parent materials in the United States. The native vegetation is usually a deciduous broadleaf forest.

Orthic Fragudalfs (7.330)

The Orthic Fragudalfs have an Ap with a moist color value of more than 3, or an A1 that is thinner than 15 cm. (6 inches) if its moist color value is darker than 3.5. In its upper part the argillic horizon has dominant colors that are redder than 10YR, or that, when moist, are in chromas of 3 or more in values of 4, or in chromas of 4 or more in values of 5.

Profile 84, page 219, is an example of the Orthic Fragudalf. The reader should turn to Orthic Fragochrults for a discussion of the necessity of both groups.

Mollic Fragudalfs (7.33-5)

This subgroup includes Fragudalfs that have an Ap that has moist color values of 3 or less, or have an A1 that is thicker than 15 cm. (6 inches) and has a moist color value of 3.5 or less.

Glossudalfs (7.34)

The Glossudalfs are Udalfs that have no fragipan, but that have an albic horizon above the argillic horizon, and tonguing into the argillic horizon. In some cases, the tongues pass through the argillic horizon. They may even penetrate deeply into what would normally be called a C horizon and terminate at what seems to be a second argillic horizon. Figure 28, p. 65, is a photograph of such tongues.

The tonguing indicates destruction of the argillic horizon, and thin sections show that the clays are being stripped from the tongues. The tongues terminate in a deep horizon that shows many very thick clay skins, which suggests that the upper argillic horizon is unstable, will disappear in time and will be replaced by a very thick albic horizon. Soils with albic horizons several feet thick have been observed but have not been studied in detail. They may or may not represent the final product of the destruction of the upper argillic horizon, and their classification is still undetermined. It is therefore possible that this great group is really a subgroup intergrading toward a presently unknown great group, or even toward several groups.

Orthic Glossudalfs (7.340)

This subgroup includes Glossudalfs that show no prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon; that have chromas in the argillic horizon of 2 or more in hues of 10YR or redder, or more than 2 in the yellower hues. They have an argillic horizon that has a texture finer than loamy sand, and that does not consist entirely of lamellae. The argillic horizon may be interrupted horizontally by the tongues of the albic horizon. If it should be determined that the Glossudalfs are one or more subgroups, the Orthic Glossudalfs will become one or more subgroups bearing the other group names as adjectives modifying Typudalf.

Psammentic Glossudalfs (7.34-1.2)

The Psammentic Glossudalfs have an argillic horizon that has a texture of loamy sand or sand. Or the argillic horizon consists entirely of lamellae; there is no uninterrupted upper argillic horizon as much as 15 cm. (6 inches) thick. The tongues of the albic horizon are often discontinuous tongues of grayish sand because the horizon above the argillic horizon may be too brown to be called an albic horizon. The remnants of the lamellae or of the argillic horizon may show considerable enrichment with free iron, enough to form firm crusts on the outside of the aggregates.

Aquic Glossudalfs (7.34-7.1)

This subgroup includes the Glossudalfs that have mottles nearer the surface or that have lower chromas than those of the orthic subgroup.

Fraglossudalfs (7.35)

The Fraglossudalfs are the Udalfs that have a fragipan and have an albic horizon that is above the argillic horizon and that tongues into the argillic horizon. These soils have had little study in the United States.

Orthic Fraglossudalfs (7.350)

This subgroup includes the Fraglossudalfs that have no prominent mottles in the upper 25 cm. (10 inches) of the argillic horizon, and that have chromas in the argillic horizon of 2 or more in hues of 10YR or redder, and of more than 2 in yellower hues.

Profile 85, page 221, is used to represent this subgroup, for lack of a better example. The fragipan in this soil has formed partly in the argillic horizon. The presence of allophane in the clay of this soil suggests it might better be an Andeptic Fraglossudalf than an Orthic Fraglossudalf.

Aquic Fraglossudalfs (7.35-7.1)

This subgroup includes the Fraglossudalfs that have mottling nearer the surface or have lower chromas than those of the orthic subgroup.

USTALFS (7.4)

The Ustalfs, like all Alfisols, are usually moist. However, the Ustalfs are defined as having periods in excess of 3 months when some part or all of the solum is dry, unless irrigated, or having conductivity of the saturation extract in excess of 1 millimho per cm. at

25°C., or both. In the United States the Noncalcic Brown soils, some Red-Yellow Podzolic soils, and some Reddish Prairie soils are included.

This definition is not entirely satisfactory but does seem to make the desired separation approximately. The Ustalfs are found in climates with a warm or hot dry season. In temperate regions this requires a Mediterranean climate. In the subtropics and tropics it requires only a marked seasonal distribution of rainfall.

The virgin profiles of the orthic subgroups of all but the Rhodustalfs can usually be distinguished from other virgin Alfisols by the nature of the A horizons. The argillic horizons, however, are not easily distinguished. Consequently, profiles that have lost their A horizons may appear very similar in all respects save that of the soil-moisture regime.

The A horizons of most Ustalfs are massive, and when moist are friable or very friable. When dry they are hard or very hard. Bars or picks are needed to dig through A horizons with sandy loam textures when they are dry. The hard-setting A horizons do show polygonal forms, and the polygons are a foot or a few feet in size. Figure 36 shows the typical appearance of these massive A horizons in road cuts. The B horizon slakes into the cuts and leaves the A horizon as a hard overhanging shelf.

The native vegetation is most commonly grass with scattered trees. Drought-resistant species of Quercus, and Eucalyptus are common.

Because the low rainfall may limit leaching, the Ustalfs may be found on old as well as on young land surfaces. Some of the surfaces date from the late Pleistocene; others may be older.

Key to Ustalfs

7.41 Ustalfs with a duripan below the argillic horizon.

Durustalf, p. 211

7.42 Other Ustalfs with a natric horizon.

Natrustalf, p. 211

7.43 Other Ustalfs with an argillic horizon that has colors in hues redder than 5YR, with moist values of less than 4 and dry values no more than 1 unit higher than the moist value, and that has cation exchange capacities of more than 40 milliequivalents per 100 grams of clay.

Rhodustalf, p. 211

7.430 Rhodustalfs with an argillic horizon more than 15 cm. (6 inches) thick and continuous through each pedon.

Orthic Rhodustalf, p. 211

7.43-R Other Rhodustalfs with R directly below but not interruping the argillic horizon.

Lithic Rhodustalf, p. 211

7.44 Other Ustalfs with clays that have exchange capacities of less than 40 milliequivalents per 100 grams.

Ultustalf, p. 211

Figure 36.–The hard massive A horizons of Ustalfs often form overhanging shelfs in road cuts.

7.45 Other Ustalfs.

Typustalf, p. 211

7.450 Ustalfs with an argillic horizon that has texture finer than loamy sand, is not composed entirely of lamellae but in at least its upper 15 cm. (6 inches) is continuous both horizontally and vertically; the argillic horizon has a base saturation of 75 percent or more, and has no mottles with chromas of 2 or less. If there is an A1 it is less than 10 cm. (4 inches) thick, or has a moist value of more than 3.5 below a depth of 10 cm., or has less than 1.2 percent organic matter. If there is an Ap, it has a moist color value of 3.5 or more, or it contains less than 1.2 percent organic matter.

Orthic Typustalf, p. 211

7.45-1.2 Other Typustalfs having an argillic horizon that is of sand or loamy sand texture or that is composed of lamellae in its upper 15 cm. (6 inches).

Psammentic Typustalf, p. 212

7.45-5 Other Typustalfs that have a higher content of organic matter and a thicker or darker A1 or a darker Ap than have those of the orthic subgroup; and in the argillic horizon there are no mottles that have chromas of 2 or less.

Mollic Typustalf, p. 212

7.45-5.3 Other Typustalfs that have mottles with chromas of 2 or less within the argillic horizon, and the colors and organic matter content of the mollic subgroup.

Aquollic Typustalf, p. 212

7.45-7.11 Other Typustalfs that have mottles with chromas of 2 or less in the argillic horizon, and with an abrupt textural change from the A to the argillic horizon.

Albaqualfic Typustalf, p. 212

7.45-8.2 Other Typustalfs that have base saturation of less than 75 percent in the argillic horizon, and that have no mottles with chromas of 2 or less in the argillic horizon.

Ochrultic Typustalf, p. 213

Durustalfs (7.41)

The Durustalfs are those Ustalfs that have a duripan underlying the argillic horizon. The duripan may differ from those found in the Aridisols or Spodosols. At times it is apparently cemented with both iron and an alkali-soluble cement. Repeated alternating treatment with acid and alkali are needed to soften the pans. In the field, structures resembling clay skins may be seen, but they are the hard cement. In thin sections these hard structures show the same banded patterns and birefringence as the clayskins. Figure 37 shows two photographs of a thin section taken from the upper 2-1/2 millimeters of one of these duripans. Figure 19, page 56, is a photograph of a Durustalf. No subgroups are proposed for the Durustalfs because the profiles seem remarkably similar except for differences that seem appropriate for defining families and series.

Profile 86, page 222, is an example of a representative Durustalf.

Natrustalfs (7.42)

The Natrustalfs include the Ustalfs with a natric horizon. So far as is known, these do not have duripans like those of the Durustalfs, though they often have ca horizons, and may have duripans like those found in the Aridisols. Figure 13 has a photograph of a Natrustalf.

The Natrustalfs are rare in the United States, and subgroup definitions need to be written by others.

Profile 87, page 223, is presented here as an example of a Natrustalf. It is not orthic. The abundance of plinthite in the profile and the physiographic position suggest that the plinthite developed in a climate different from that of today. It is suggested that this profile should be in a Plinthitic Natrustalf subgroup.

Rhodustalfs (7.43)

The Rhodustalfs have not been identified in the United States. They include many but not all of the soils called Terra Rosa. They are common on hard limestone, but may also be formed on basic igneous rocks. Subgroup definitions are suggested very tentatively in the key to Ustalfs. The orthic subgroup, it is suggested, should have a continuous argillic horizon more than 15 cm. (6 inches) thick. If the argillic horizon is thinner than 15 cm., the soil should be in a lithic subgroup. If the argillic horizon is interrupted by rock in each pedon, the soil should be in a ruptic lithic subgroup.

Profile 10, page 75, is thought to be a good example of the Orthic Rhodustalfs. This soil has a continuous argillic horizon about 70 cm. (26 inches) thick. Chemical and mineralogical analyses are given in table 10. Free iron is a little less than 10 percent of the clay. The potassium content of both the clay and whole soil indicate the presence of weatherable minerals. Thin sections confirm the presence of the clay skins mentioned in the description. The lack of textural differentiation between the Ap and the upper part of the B may indicate only that the soil has been eroded, and that the plow layer is now in what was formerly part of the argillic horizon.

Figure 2, page 4, shows the variable depth to rock so common in these soils if the parent material is limestone. Perhaps the normal condition is to have rock outcrops spaced at intervals of a few feet.

Ultustalfs (7.44)

The Ultustalfs are the Ustalfs that have a clay fraction with an exchange capacity of less than 40 milliequivalents per 100 grams. Geomorphic evidence indicates that many of these soils are on old land surfaces. Plinthite is commonly present, and weatherable minerals are scarce. Only a few Ultustalfs are found in the United States; consequently, subgroup definitions can be best developed by others.

Profile 88, page 224, is an example of the soils of this great group. It probably should either be in an orthic or in an ultic subgroup. The base saturation is lower than the limit proposed for the Orthic Typustalfs, but there is no need to use the same limits in both groups.

Typustalfs (7.45)

The Typustalfs are the Ustalfs that have clay fractions with more than 40 milliequivalents exchange capacity; that have no duripan or natric horizon; and that have an argillic horizon with hues no redder than 5YR, or with moist values of 4 or more, or with dry values more than 1 unit greater than the moist values. The horizon boundary between the A and B is normally abrupt, but a few have a clear or gradual boundary.

The Typustalfs are thought to be the most representative Ustalfs, though they are perhaps minor in area, because they have parent materials of mixed mineralogy, and are thought to be monogenetic--that is they are of late Pleistocene age and have not undergone previous weathering cycles under different climates and vegetations. They typically have more weatherable minerals than the Ultustalfs.

There are few Typustalfs in the United States, but most of the Ustalfs that are here are Typustalfs. The subgroup definitions that follow are incomplete but cover most of the conditions known in the United States.

Orthic Typustalfs (7.450)

This subgroup includes the Typustalfs that have an argillic horizon meeting these requirements: texture finer than loamy sand; at least the upper 15 cm. (6 inches) not composed of lamellae and continuous horizontally through each pedon; base saturation of more than 75 percent; no mottles with chromas of 2 or less; and hues as yellow or yellower than 5YR, or moist values of 4 or more, or dry values more than 1 unit

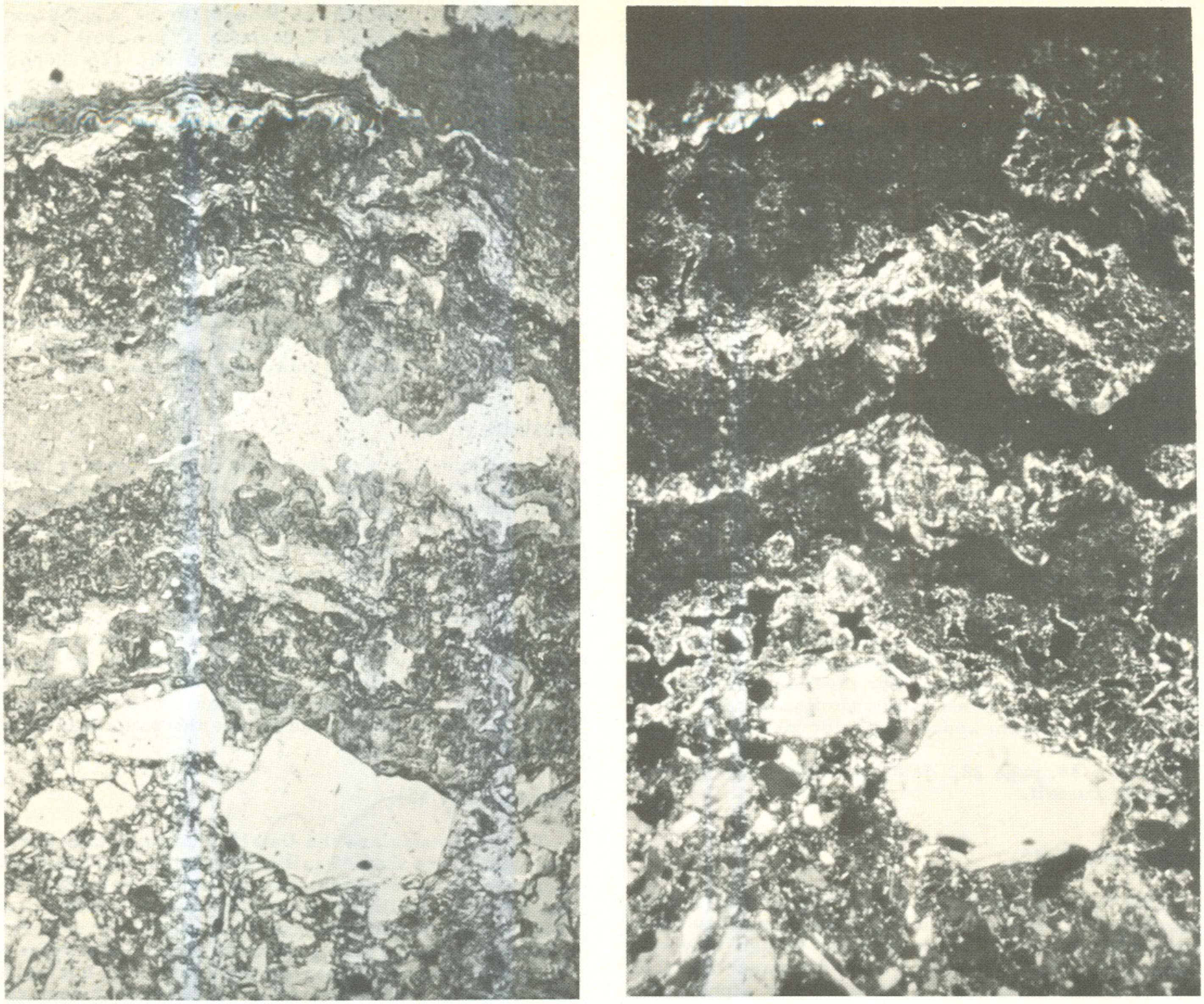

Figure 37.–Thin section from upper 2.5 mm. of a duripan in a Durustalf: On left, photograph under ordinary light. The irregular light-colored area (center right) is a pore. The angular light areas (lower left) are quartz grains. On right, photograph under crossed polarizers. Note that the areas showing pronounced layering in the photograph on the left exhibit birefringence and are bright in this photograph.

higher than moist values. If the soil is virgin, the A1 is thinner than 10 cm. (4 inches), or has a moist value of more than 3.5 below 10 cm., or has less than 1.2 percent organic matter. If the soil is cultivated, the Ap has a moist value of 3.5 or more or has less than 1.2 percent organic matter.

Profile 89, page 225, is an example of this subgroup. This profile is redder in hue than many, but otherwise is representative of the subgroup.

Psammentic Typustalfs (7.45-1.2)

This subgroup includes the Typustalfs that have an argillic horizon, with textures of sand or loamy sand, or that has lamellae in its upper 15 cm. (6 inches).

Mollic Typustalfs (7.45-5)

This subgroup includes Typustalfs that have no mottles with chromas of 2 or less in the argillic horizon. They have, if virgin, an A1 that is thicker than 10 cm. (4 inches) and darker than a moist value of 3.5, and that has 1.2 percent organic matter (0.7 percent organic carbon) or more. If cultivated, these soils have an Ap that is darker than 3.5 when moist and that has more than 1.2 percent organic matter.

Aquollic Typustalfs (7.45-5.3)

In this subgroup are the soils that have colors and content of organic matter as defined for the mollic subgroup, but do have mottles with chromas of 2 or less in some part of the argillic horizon.

Albaqualfic Typustalfs (7.45-7.11)

This subgroup includes Typustalfs that have an abrupt textural change from the A to the argillic horizon and that have mottles with chromas of 2 or less in some part of the argillic horizon.

It should be noted that abrupt boundaries between the A and B horizons are normal. Abrupt textural changes are also very common. The abrupt boundaries and the textural changes are not adequate for recognition of the Albaqualfic Typustalfs. There must also be some evidence of wetness.

Ochrultic Typustalfs (7.45-8.2)

This subgroup includes the Typustalfs that have base saturation of less than 75 percent in some part of the argillic horizon and that have no mottles with chromas of 2 or less in the argillic horizon. Base exchange capacity is computed by sum of cations.

The soils of this subgroup have been called Red-Yellow Podzolic soils, for the most part. They are found in the more humid range of the climates of the Ustalfs.

Profile 9, page 74, is an example of this subgroup. It will be noted that the base saturation is less than 75 percent throughout all horizons. There is an A2 horizon, lighter in color than the B, that is suggestive of the uneroded profiles of most Ochrults. This A2 horizon has not been made diagnostic, for erosion seems to remove it quickly if the soils are cultivated.

Profile Descriptions for Chapter 14

(Colors are for moist soil unless otherwise stated)

Profile No. 79

Area: Acadia Parish, Louisiana.

Vegetation: Pine-hardwood forest (loblolly pine, oak, and pinehill bluestem grass)

Parent material: Old alluvium.

Topography: Less than 1 percent slope; terrace; a few pimple mounds.

A1 0 to 1 inch, dark grayish-brown (10YR 4/2) silt loam; moderate, fine, granular structure; very friable; abrupt, smooth boundary.

A21 1 to 4 inches, light brownish-gray (10YR 6/2) silt loam; weak, medium, platy structure; friable; few, fine, reddish concretions; clear, smooth boundary.

A22g 4 to 8 inches, light-gray (10YR 7/2) silt loam; few, large, faint mottles of grayish brown (10YR 5/2); massive; brittle when moist, firm; many, fine, medium, dark and reddish concretions; many, fine pinholes; clear, smooth boundary.

A23g 8 to 12 inches, light-gray (2.5Y 7/2) silt loam; common, medium, distinct mottles of brownish yellow (10YR 6/6); massive; friable, somewhat brittle when moist; few, fine, dark and reddish concretions; abrupt, smooth boundary.

B1tg 12 to 17 inches, light brownish-gray (10YR 6/2) silty clay loam; common, medium, distinct mottles of brownish yellow (10YR 6/6); moderate, fine, blocky structure; firm; few, fine, reddish concretions; clear, wavy boundary.

B21tg 17 to 28 inches, light brownish-gray (10YR 6/2) silty clay loam; many, medium, prominent mottles of red (2.5YR 5/8); weak, coarse, prismatic, breaking to moderate, very fine, blocky structure; firm; few, large crayfish burrows or root channels filled with gray (10YR 5/1) silt loam; gradual, wavy boundary.

B22t 28 to 34 inches, yellowish-brown (10YR 5/6) silty clay loam; many, medium mottles of light brownish gray (10YR 6/2); weak, coarse, prismatic, breaking to moderate, fine and medium, blocky structure; firm; few, fine, dark concretions; few, large root channels or crayfish burrows filled with gray (10YR 5/1) silt loam; diffuse, wavy boundary.

B23t 34 to 46 inches, yellowish-brown (10YR 5/6) silty clay loam; many, medium mottles of light brownish gray (10YR 6/2); weak, coarse, prismatic, breaking to moderate, fine and medium, blocky structure; firm; few, fine, dark concretions; many, fine, dark remains of roots; few, large root channels or crayfish burrows filled with gray (10YR 5/1) silt loam; diffuse, wavy boundary.

C 46 to 60 inches +, light brownish-gray (10YR 6/2) silty clay loam; many, medium, distinct mottles of yellowish brown (10YR 5/6); weak, coarse, prismatic, breaking to moderate, medium, blocky structure; very firm; common, medium, dark concretions; few root channels or crayfish burrows filled with gray (10YR 5/1) silt loam.

Climatic data (Crowley, La.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	53	56	60	67	75	81	82	82	78	70	59	54	68
Mean precipitation, 1931-52 (inches)	5.9	4.0	4.7	4.0	5.1	4.9	6.4	6.2	4.3	2.6	4.8	5.7	58.5

Annual precipitation more than 28.1 and less than 88.9 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	C/N (k)
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate												
0-1	A1	0.8	0.5	0.2	3.8	16.8	71.2	6.7	46.7	44.9	Tr.		1.94	23
1-4	A21	.7	.6	.2	4.0	17.0	70.9	6.6	46.5	45.3	Tr.		1.04	19
4-8	A22g	1.6	1.0	.2	3.6	15.6	67.7	10.3	42.9	43.8	Tr.		.17	9
8-12	A23g	.8	.6	.1	3.3	15.5	65.7	14.0	41.8	42.6	Tr.		.10	7
12-17	B1tg	.6	.4	.1	2.5	12.0	55.3	29.1	32.7	37.0	Tr.		.16	8
17-28	B21tg	.2	.1	---	2.3	11.4	48.0	38.0	28.9	32.7	--		.14	9
28-34	B22t	---	.1	---	2.5	12.8	51.0	33.6	31.6	34.7	Tr.		.09	
34-46	B23t	.1	.2	.1	2.8	13.6	51.8	31.4	33.9	34.2	Tr.		.09	
46-60+	C	.3	.3	.1	2.9	14.9	48.9	32.6	34.8	31.8	Tr.		.06	

Cation exch. cap (b)	Ca	Mg	H*	Na	K	Base sat. % (s)	pH 1:1	Cation exch. cap. (s)	Moisture tensions 1/3 atmos. %	Moisture tensions 15 atmos. %
	Extractable cations, meq./100 gm.									
9.5	3.6	1.3	6.5	0.1	0.1	44	5.6	11.6	26.3	4.3
6.6	2.5	1.1	4.0	.1	---	48	5.6	7.7	23.9	3.8
5.8	1.9	1.1	3.2	.1	---	49	5.2	6.3	21.8	4.8
7.7	1.2	1.0	6.1	.3	.1	30	5.0	8.7	22.8	6.0
17.9	2.8	2.5	11.5	.9	.2	36	4.7	17.9	27.9	12.9
20.7	5.2	4.2	11.1	2.0	.3	51	4.6	22.8	30.6	16.1
20.4	6.6	5.1	6.2	2.7	.3	70	4.8	20.9	29.6	14.6
19.6	8.3	5.6	2.0	3.5	.3	90	5.8	19.7	28.7	13.5
20.4	9.6	6.2	.8	4.6	.3	96	7.3	21.5	30.2	14.6

*Exchange acidity.

Profile No. 80

Area: Lewis County, Washington.

Vegetation: Bentgrass and Alta fescue; (natural) mixed stands of Douglas fir, western red cedar, aspen and oregon white oak.

Parent material: Alluvium from basic volcanic materials.

Topography: 1 percent slope; upland basin; elevation 370 feet.

Ap 0 to 7 inches, very dark grayish-brown (10YR 3/2) silt loam, grayish brown (10YR 5/2.5) when dry; moderate, fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; abundant roots; clear, smooth boundary.

A21 7 to 12 inches, very dark grayish-brown (10YR 3/2) silt loam, light brownish gray (10YR 6/2) when dry; few, fine, yellowish-red (5YR 4/6) mottles; moderate, fine, subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; plentiful roots; clear, wavy boundary.

A22 12 to 15 inches, very dark grayish-brown (10YR 3/2) silt loam, light brownish gray (10YR 6/2) when dry; common, medium, yellowish-red (5YR 4/6) mottles; moderate, fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many fine tubular pores; plentiful roots; abrupt, smooth boundary.

A23 15 to 17 inches, grayish-brown (10YR 5/2) silt loam, white (10YR 8/2) when dry; common, medium, yellowish-red (5YR 5/8) mottles; massive; slightly hard, friable, slightly sticky, slightly plastic; many, fine tubular pores; plentiful roots; abrupt, wavy boundary.

B&A 17 to 19 inches, olive-gray (5Y 5/2) silty clay, light olive gray (5Y 6/2) when dry; grayish-brown (10YR 5/2) tongues of silt loam, 2 to 10 millimeters thick; white coatings on peds and white flecks inside peds; strong, medium prismatic structure; extremely hard, very firm, very sticky, very plastic; thick, continuous clay films; common, fine tubular pores; plentiful roots only on faces of prisms; gradual, wavy boundary.

B21t 19 to 27 inches, olive-gray (5Y 5/2) clay, light olive gray (5Y 6/2) when dry; grayish-brown (10YR 5/2) tongues of silt loam, 1 to 3 millimeters thick and 4 to 6 inches apart; few, white flecks inside of peds; strong, coarse and strong fine prismatic structure; extremely hard, very sticky, very plastic; thick, continuous clay films; common, fine and very fine, tubular pores; few, fine roots only on prism faces; gradual, wavy boundary.

B22t 27 to 36 inches, olive-gray (5Y 5/2) clay, light olive gray (5Y 6/2) when dry; with white (10YR 8/1) silty coatings about 1 millimeter thick on faces of large prisms; strong, coarse and strong, fine prismatic structure; extremely firm, very sticky and very plastic; thick, continuous clay films; common, very fine, tubular pores; gradual, wavy boundary.

B23t 36 to 75 inches, olive-gray (5Y 5/2) clay, light olive gray (5Y 6/2) when dry; strong, coarse prismatic structure; extremely hard, extremely firm, very sticky, very plastic; thick, continuous clay films; common, very fine, tubular pores.

C 75 to 80 inches, olive-gray gravelly clay; common, medium, yellowish-red (10YR 5/8) mottles; massive, extremely hard, extremely firm, slightly sticky, very plastic; common, very fine tubular pores.

Climatic data (Centralia, Wash.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	39	42	46	52	57	61	65	65	61	54	45	42	52
Mean precipitation, 1931-52 (inches)	5.8	5.7	4.6	2.5	1.9	1.8	0.7	0.9	1.8	4.4	6.4	7.9	44.4

Annual precipitation more than 31.2 and less than 57.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	CaCO3 equiv. %
0-7	Ap	0.3	1.2	1.4	5.1	5.1	69.6	17.3	33.7	44.5			4.35	17	--
7-12	A21	.2	1.2	1.5	5.1	5.2	68.6	18.2	33.7	43.7			2.60	15	--
12-15	A22	.2	1.0	1.4	5.1	5.3	67.8	19.2	33.2	43.4			1.80	15	--
15-17	A23	.3	1.0	1.2	4.9	5.6	67.4	19.6	33.0	43.5			.64	12	--
17-19	B&A	.1	.7	1.0	3.9	4.3	56.7	33.3	27.4	36.4			.40	9	--
19-27	B21t	.1	.7	.7	3.1	3.7	47.9	43.8	20.8	33.0			.20	5	--
27-36	B22t	.1	.8	1.0	3.5	3.8	43.8	47.0	19.4	30.7			.11	3	--
36-75	B23t	.3	.7	.7	2.3	2.7	34.6	58.7	14.2	24.6			.14		--
75-80	C	3.2	4.3	2.5	4.9	4.2	35.4	45.5	17.3	25.3			.05		--

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH sat. paste	pH 1:10	Est. salt %	E. C. mmhos. per cm. 25° C.	Gypsum meq./100 gm. soil	Moisture tensions: 1/3 atmos. %	15 atmos. %
25.3	3.8	1.1	20.6	0.2	0.2	20	5.5	5.8	--	--	--	37.2	11.6
19.8	2.1	.9	18.0	.1	.1	15	5.6	5.7	--	--	--	34.8	10.1
18.1	2.1	1.1	15.6	.1	.1	18	5.5	5.7	--	--	--	32.0	9.9
14.4	2.8	1.8	8.7	.3	.1	36	5.4	5.9	--	--	--	28.0	8.8
20.0	4.5	3.6	9.0	.4	.1	49	4.9	5.9	--	--	--	29.1	14.2
25.7	8.8	5.7	9.0	.5	.1	63	4.7	6.0	--	--	--	34.0	19.0
25.4	10.5	6.9	5.0	.4	.1	78	5.1	6.4	--	--	--	34.8	21.1
31.0	13.6	9.4	9.2	.6	.1	72	5.8	7.0	--	--	--	41.8	24.7
35.2	16.5	11.7	3.7	.7	.1	88	6.0	7.0	--	--	--	40.5	22.4

*Exchange acidity.

Profile No. 81

Area: Wayne County, Indiana.
Vegetation: (natural deciduous forest consisting mainly of beech, maple, and elm.
Parent material: Thin loess over till.
Topography: Nearly level or in slight depressions in till plain.

A1 0 to 2 inches, gray (10YR 6/1-5/1) to light gray (10YR 7/1) silt loam; weak, fine, granular structure; friable.

A21 2 to 5 inches, grayish-brown (2.5Y 5/2) silt loam; massive to weak, thin, platy structure; friable.

A22g 5 to 11 inches, grayish-brown (10YR 5/2) to light brownish-gray (10YR 6/2) silt loam; common, medium mottles of yellowish brown (10YR 5/4) and few, fine mottles of weak red (2.5YR 4/2); massive to very weak, platy structure; slightly hard, friable.

B1t 11 to 15 inches, pale-brown (10YR 6/3) heavy silt loam; common, medium mottles of brown (7.5YR 5/4); few streaks of white silt loam; weak, medium, subangular, blocky structure; slightly hard, friable.

B21t 15 to 19 inches, brown (7.5YR 5/4) silty clay loam; common, medium, very dark gray (N 3/) mottles; moderate, coarse and very coarse, subangular blocky structure; hard; peds coated with grayish-brown (10YR 5/2) silt loam.

IIB22t 19 to 23 inches, yellowish-brown (10YR 5/4) heavy clay loam; weak, very coarse, prismatic, breaking to moderate, coarse, blocky structure; hard; thin, very dark grayish-brown (10YR 3/2) clay skins on surfaces of peds.

IIB23t 23 to 27 inches, dark-brown (10YR 4/3) or dark yellowish-brown (10YR 4/4), heavy clay loam; weak, very coarse, prismatic, breaking to moderate, coarse, subangular blocky structure; hard; thick, very dark grayish-brown (10YR 3/2-3/3), clay skins on surfaces of peds.

IIB3t 27 to 31 inches, brownish-gray (2.5Y 5/2) loam, light gray (2.5Y 7/2) to pale yellow (2.5Y 7/4) when dry; massive, breaking to coarse, blocky structure; hard; thin, continuous, very dark grayish-brown (10YR 3/2) coatings of clay on blocky peds.

IIC 31 to 43 inches, gray-brown (2.5Y 5/2) to light olive-brown (2.5Y 5/4) loam, light gray (2.5Y 7/2) to pale yellow (2.5Y 7/4) when dry; massive, breaking to coarse, blocky structure; hard; very thin, discontinuous films of clay on blocky peds; calcareous.

Climatic data (Richmond, Ind.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	30	31	39	49	60	70	73	71	64	53	41	31	51
Mean precipitation, 1931-52 (inches)	3.3	2.3	3.5	3.2	3.6	4.5	3.4	3.0	3.4	2.7	2.8	2.6	38.3

Annual precipitation more than 24.9 and less than 51.7 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate												
0-2	A1	1.1	2.9	3.5	6.4	3.8	67.8	14.5	33.0	42.0	1		4.39	
2-5	A21	.7	2.7	3.4	6.3	4.0	68.8	14.1	35.1	41.0	0		.69	
5-11	A22g	.9	2.6	2.8	5.3	3.6	67.9	16.9	31.9	42.4	1		.34	
11-15	B1t	.4	1.5	2.1	4.3	3.3	64.7	23.7	31.4	38.9	1		.22	
15-19	B21t	.4	1.4	2.3	5.6	4.2	52.9	33.2	27.7	32.5	2		.21	
19-23	IIB22t	1.6	4.5	6.6	13.4	8.2	27.8	37.9	26.4	16.9	3		.20	
23-27	IIB23t	2.0	6.2	11.4	22.8	9.7	15.7	32.2	28.3	8.7	9		.30	
27-31	IIB3t	1.4	3.4	8.0	28.4	11.3	20.1	27.4	35.0	11.1	3		.26	
31-43	IIC	5.0	6.5	6.7	14.1	10.7	39.6	17.4	36.1	22.1	15		.18	

Cation exch. cap. s	Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Mi	Vm	Mt	Kl
	Extractable cations, meq./100 gm.							Clay minerals			
14.7	1.0	2.2	11.2	<0.1	0.3	24	5.4	x	xxxx	x	x
11.8	1.1	.4	10.2	<.1	.1	14	4.6	x	xxxx	x	x
10.2	1.6	.5	8.0	<.1	.1	22	4.9	x	xxxx	x	xx
14.8	3.3	2.0	9.2	.1	.2	38	4.8	xx	xxx	xx	x
22.0	7.7	5.2	8.6	.1	.4	61	5.0	xx	xx	xxx	x
26.7	12.3	8.2	5.4	.2	.4	80	6.2	xx	xx	xxx	x
23.3	11.6	7.9	3.4	.1	.3	85	7.1	xx	xx	xxx	x
20.5	10.2	6.1	3.8	.1	.3	81	7.7	xxx	xx	xx	x

*Exchange acidity.

Profile No. 82 (Lab. data by Ohio Agr. Expt. Sta.)
Area: Clinton County, Ohio.
Vegetation: Mixed grasses and whiteclover and weeds.
Parent material: Silty mantle, 31 inches thick, over till.
Topography: 0 to 1 percent slope, till plain; elevation about 1,020 feet.

Ap — 0 to 6 inches, dark grayish-brown (10YR 4/2) silt loam, light brownish gray (10YR 6/2) to light gray (10YR 7/2) when dry; weak, fine, granular structure; hard, friable; abrupt boundary.

A21 — 6 to 9 inches, light brownish-gray (10YR 6/2) silt loam, light gray (10YR 7/1) when dry; numerous mottles of light yellowish brown (10YR 6/4); massive, breaking to weak, medium, platy structure; hard, friable when removed (firm plowsole); irregular boundary.

A22 — 9 to 14 inches, yellowish-brown (10YR 5/6) to light yellowish-brown (10YR 6/4) silt loam, pale brown (10YR 6/3) when dry; when dry, mottled with light gray (10YR 7/2), light gray (2.5Y 7/2), and flecks of white (10YR 8/1); massive or very weak, coarse, subangular blocky, breaking to very weak, platy structure; hard, friable; diffuse boundary.

B1g — 14 to 23 inches, light-gray (10YR 6/1-7/1) coarse silty clay loam, white (10YR 8/1) when dry; common mottles of yellowish brown (10YR 5/4)-5/6) and reddish yellow (7.5YR 6/6); numerous flecks of white (10YR 8/1); very weak, subangular blocky, breaking to weak, platy structure; hard, friable; gradual boundary.

B21g — 23 to 31 inches, mottled gray (10YR 6/1) and strong-brown (7.5YR 5/8) silty clay loam, light gray (10YR 7/1) and yellowish brown (10 YR 5/6) when dry; faces of prisms coated with gray (10YR 6/1) silt having numerous flecks of white (10YR 8/1); weak, fine, prismatic, breaking to weak, coarse, subangular blocky structure; hard, firm, sticky, plastic; gradual boundary.

IIB22xg — 31 to 48 inches, gray (N 5/) silty clay loam, gray (10YR 6/1) when dry; numerous, coarse mottles of yellowish brown (10YR 5/8); yellowish brown (10YR 5/4) when dry; weak, medium, prismatic, breaking to weak, coarse, subangular and angular blocky structure; extremely hard, very firm, sticky, plastic; large black coatings on ped faces; few soft, black nodules; diffuse boundary.

IIB23x — 48 to 63 inches, mottled gray (N 5/) and dark yellowish-brown (10YR 4/4) clay loam, light gray (N 7/) and yellowish brown (10YR 5/6) when dry; weak, fine, medium and coarse, subangular and angular blocky structure; extremely hard, very firm, sticky, plastic; a few black coatings on ped faces.

IIB24 — 63 to 76 inches, gray (N 5/) clay loam, light gray (N 7/) when dry; numerous, coarse mottles of yellowish brown (10YR 5/4) and light olive brown (2.5Y 5/4); very hard, firm, sticky, plastic.

IIB3 — 76 to 104 inches, mottled yellowish-brown (10 YR 5/8), dark brown (10YR 4/4), and gray (10 YR 6/1) clay loam, yellowish brown (10YR 5/8) and gray (N 6/) when dry; very hard, very firm, sticky, plastic.

Climatic data (Wilmington, Ohio)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	32	33	42	52	63	73	76	74	67	56	43	33	54
Mean precipitation, 1931-52 (inches)	4.3	3.4	4.8	4.3	4.0	4.3	4.1	3.6	3.4	2.2	3.2	3.4	45.1

Annual precipitation more than 32.3 and less than 57.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	Total sands	Fine clay .0002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
0-6	Ap	0.9	1.8	1.2	5.3	4.2	69.3	17.3	13.4	6.2			2.5	
6-9	A21	.6	1.4	.9	4.4	4.3	70.3	18.1	11.6	7.1			1.1	
9-14	A22	.7	1.4	1.0	4.0	3.7	68.0	21.1	10.8	8.6			.8	
14-23	B1g	.3	1.1	.7	3.3	3.1	63.1	28.4	8.5	14.1			.7	
23-31	B21g	1.2	1.8	2.0	3.6	2.0	57.2	32.0	10.8	17.4				
31-48	IIB22xg	.6	1.6	1.5	8.2	7.7	41.5	38.9	19.6	19.0				
48-63	IIB23x	.5	1.5	1.6	8.9	8.1	46.4	33.0	20.6	21.5				
63-76	IIB24	.4	1.3	1.3	9.9	9.7	42.4	35.0	22.6	21.7				
76-90+	IIB3	.5	1.7	1.6	8.5	8.6	41.6	37.5	20.9	21.6				

Cation exch. cap. (s)	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
13.9	8.7	0.7	4.4		.06	68	6.9
10.7	2.2	.6	7.9		.03	28	5.0
12.4	1.7	1.1	9.5		.05	23	4.8
17.0	2.2	2.6	12.1		.12	29	4.8
20.6	3.2	4.2	13.0		.20	37	4.8
22.9	6.3	7.8	8.7		.14	62	5.1
24.5	8.7	9.0	6.7		.14	73	5.2
25.3	11.8	9.8	3.6		.12	86	6.5
25.0	12.3	9.4	3.2		.12	87	7.1

*Exchange acidity.

Profile No. 83

Area: Jasper County, Illinois.
Vegetation: Grass.
Parent material: Loess over till.
Topography: Less than ¼-percent slope; very slightly higher than surrounding, flat area.

Ap 0 to 8 inches, dark grayish-brown (10YR 4/2) silt loam; moderate, medium, granular structure; friable; abrupt, smooth boundary.

A2 8 to 12 inches, mixed light brownish-gray (10YR 6/2) and grayish-brown (10YR 5/2) silt loam; few, fine, faint mottles of yellowish brown (10YR 5/4); weak, medium, platy structure; friable; common, dark wormcasts of grayish-brown (10YR 4/2) in upper part; abrupt, smooth boundary.

B21tg 12 to 18 inches, gray (10YR 5/1, 6/1) silty clay loam; many, medium mottles of dark yellowish brown (10YR 4/4); weak, medium, prismatic, breaking to moderate, medium, blocky structure; firm; common dark-gray (10YR 4/1) organic and clay coatings on ped faces; clear, smooth boundary.

B22tca 18 to 27 inches, light-gray (10YR 6/1) silty clay loam; common, medium mottles, yellowish brown (10YR 5/6); weak, coarse, blocky structure; firm; few, clay skins in upper part; few concretions of iron and calcium carbonate; gradual, smooth boundary.

B3tca 27 to 36 inches, light brownish-gray (10YR 6/2) silty clay loam; common, medium mottles of dark yellowish brown (10YR 4/4); very weak, blocky structure; firm; few concretions of iron and calcium carbonate; gradual, smooth boundary.

IIC1 36 to 47 inches, brownish-gray (10YR 5/2) silty clay loam; many, medium and coarse mottles of dark yellowish brown (10YR 4/4); weak, medium and coarse, blocky structure; firm; few pebbles; numerous concretions of iron and calcium carbonate; gradual, smooth boundary.

IIC2 47 to 57 inches, light brownish-gray (10YR 6/2) silty clay loam; common, medium mottles of dark brown (7.5YR 4/4); weak, medium to coarse, blocky structure; firm; few pebbles; numerous concretions of iron and common concretions of calcium carbonate.

Climatic data (Newton, Ill.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1944-59 (deg. F.)	32	36	45	56	65	75	78	76	69	59	44	35	56
Mean precipitation, 1931-52 (inches)	3.0	2.1	3.8	3.7	4.6	4.3	3.1	3.3	3.3	2.8	3.4	2.4	39.8

Annual precipitation more than 29.7 and less than 49.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-8	Ap	1.1	4.4	6.8	10.7	4.9	60.5	11.6	33.7	36.6	Tr.		1.03	10	0.7
8-12	A2	2.6	5.0	6.8	10.2	4.7	59.6	11.1	31.6	37.4	Tr.		.50	9	1.1
12-18	B21tg	1.4	2.6	3.8	6.4	3.4	56.2	26.2	26.8	35.9	Tr.		.46	9	1.3
18-27	B22tca	.6	2.5	4.5	6.9	3.4	56.3	25.8	26.3	36.7	Tr.		.16	8	1.0
27-36	B3tca	1.0	2.4	3.4	5.8	3.0	55.8	28.6	23.9	37.7	8.5		.07	5	1.5
36-47	IIC1	2.1	3.7	5.1	8.1	3.8	53.7	23.5	27.1	34.2	7.8		.06	5	1.8
47-57	IIC2	1.6	3.6	5.3	8.7	4.2	54.2	22.4	27.7	34.7	Tr.		.06	5	1.8

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % b	pH 1:1	E. C. mmhos. per cm. 25° C.	$CaCO_3$ equiv. % v	Moisture tensions 1/3 atmos. %	15 atmos. %	Sat. ext., sol. (meq./l.) Na	K	Exch. Na %	H_2O at sat. %
7.8	4.2	1.5	4.8	0.2	0.3	79	5.5	1.3		23.4	4.8	1.5	0.4	1	39.5
5.4	2.3	1.0	3.6	.3	.1	68	5.7	.7		21.4	5.6	3.0	.1	4	32.6
13.8	7.0	4.0	4.5	1.2	.2	90	5.9	.5		26.0	11.5	3.6	<.1	7	51.5
15.6	10.9	4.4	.8	3.1	.2	119	8.1	1.1	8	27.4	11.7	8.6	<.1	17	60.4
19.1	15.4	5.0	<.1	6.9	.2	144	8.5	1.3	5	33.7	14.2	11.0	<.1	32	74.4
16.6	16.4	4.4	<.1	5.1	.2	157	8.5	1.3	<1	28.1	12.0	11.6	<.1	26	65.0
15.5	9.0	3.8	1.6	3.2	.2	104	7.7	1.0	<1	26.3	11.1	8.2	<.1	18	53.6

*Exchange acidity.

Profile No. 84

Area: Knox County, Indiana.
Vegetation: Idle land covered by numerous weeds.
Parent material: Loess.
Topography: 3 to 5 percent slope; upland.

- Ap 0 to 7 inches, brown (10YR 5/3) silt loam; weak, fine, granular structure; friable; abrupt, smooth boundary.
- A3 7 to 10 inches, brown (7.5YR 4/4) to strong-brown (7.5YR 5/6) silt loam; weak, medium, platy, breaking to moderate, fine, subangular blocky structure; friable; cracks, root channels, and wormcasts infiltered by material from Ap horizon; clear, wavy boundary.
- B21t 10 to 15 inches, brown (7.5YR 4/4) to strong-brown (7.5YR 5/6), heavy silt loam; moderate, fine and medium, subangular blocky structure; friable; a few peds coated with pale brown (10YR 6/3); gradual, smooth boundary.
- B22t 15 to 19 inches, brown (7.5YR 4/4) to strong-brown (7.5YR 5/6) silty clay loam; strong, medium, subangular and angular blocky structure; firm; numerous, dark-brown (7.5YR 4/4) to reddish-brown (5YR 4/4) clay skins; many peds coated with pale brown (10YR 6/3) or light yellowish brown (10YR 6/4); cracks filled with pale-brown (10YR 6/3) silt; clear, wavy boundary.
- B23t 19 to 25 inches, brown (7.5YR 4/4), heavy silt loam; strong, medium and coarse, subangular and angular blocky structure; numerous, dark reddish-brown (5YR 3/4) clay skins; peds are thinly coated and cracks are filled by pale brown (10YR 6/3); a few small very dark-brown (10YR 2/2) streaks; gradual, wavy boundary.
- A'2 25 to 31 inches, yellowish-brown (10YR 5/4) to dark yellowish-brown (10YR 4/4) silt loam; moderate, coarse, subangular and angular blocky structure; friable; pale brown (10YR 6/3) silt coats peds and is in numerous vertical cracks; a few, thin, splotches of very dark brown (10YR 2/2); common, dark-brown (7.5YR 4/4) clay skins; gradual, wavy boundary.
- B'2x 31 to 44 inches, yellowish-brown (10YR 5/6) to dark yellowish-brown (10YR 4/4), heavy silt loam; massive to very weak, very coarse, subangular blocky structure; firm, brittle when moist; grayish-brown (10YR 5/2) silt coats peds and is in cracks; sides of cracks are bleached as much as ¼ inch; cracks decrease in number with depth; numerous, dark-brown (7.5YR 4/2) clay skins; diffuse, wavy boundary.
- C1x 44 to 58 inches, dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/6) silt loam; massive to weak, very coarse, prismatic structure; hard, firm, brittle when moist; light-gray (10YR 7/2) material borders vertical cracks and is as much as ½ inch wide; few, very fine, very dark brown (10YR 2/2) streaks; few, dark-brown (7.5YR 4/4) clay skins; few, firm, dark-colored nodules; gradual, wavy boundary.
- C2x 58 to 73 inches +, dark yellowish-brown (10YR 4/4) to yellowish-brown (10YR 5/6) silt loam; massive; friable; light-gray (10YR 7/2) material largely along vertical cracks which decrease in number with depth.

Climatic data (Edwardsport, Ind.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	32	34	43	54	65	75	79	77	69	58	43	34	55
Mean precipitation, 1931-52 (inches)	3.9	2.5	4.1	4.0	3.9	4.4	3.6	3.3	3.4	2.5	3.3	2.9	41.7

Annual precipitation more than 27.8 and less than 55.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-7	Ap	--	0.2	0.3	1.0	1.9	80.9	15.7	50.5	32.9	--		0.55	9
7-10	A3	--	.1	.2	.7	1.6	78.8	18.6	38.1	42.7	--		.45	9
10-15	B21t	--	--	.1	.4	1.4	71.3	26.8	35.6	37.3	--		.24	7
15-19	B22t	--	--	.1	.3	1.6	70.4	27.6	39.2	33.0	--		.21	6
19-25	B23t	--	.1	.1	.3	2.7	70.8	26.0	42.1	31.6	--		.15	
25-31	A'2	--	.2	.2	.5	2.9	72.5	23.7	44.2	31.5	--		.10	
31-44	B'2x	--	.1	.2	.4	1.5	70.9	26.9	45.6	27.0	--		.08	
44-58	C1x	--	--	--	.3	.8	80.0	18.9	43.1	37.9	--		.07	
58-73+	C2x	.1	.4	.6	3.7	4.2	74.8	16.2	45.4	36.3	--		.06	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Moisture tensions: 1/3 atmos. %	15 atmos. %	Cation exch. cap. s
6.8	2.2	1.0	3.6	--	0.2	48	5.2	24.9	4.8	7.0
7.9	2.1	1.4	5.7	--	.2	39	5.0	25.7	6.2	9.4
12.8	3.2	3.1	8.2	--	.3	44	4.8	29.4	10.1	14.8
13.9	2.8	3.3	9.7	.1	.3	40	5.0	29.8	10.7	16.2
13.7	2.4	3.5	11.7	.1	.3	35	4.9	31.1	10.7	18.0
13.2	2.4	4.2	8.2	.1	.3	46	5.0	29.8	10.4	15.2
16.2	3.7	6.0	7.8	.2	.3	57	5.1	32.0	11.8	18.0
12.0	3.3	4.5	5.3	.2	.2	61	5.3	30.1	8.5	13.5
9.9	3.6	4.2	2.0	.2	.2	80	5.6	24.9	6.8	10.2

*Exchange acidity.

Profile No. 84a

Area: Cayuga County, New York.

Vegetation: Cutover woodlot having a few, large sugar maple, basswood, and red oak trees and saplings of sugar maple, beech, black birch, and hornbeam.

Parent material: Glacial till.

Topography: 3 percent slope, facing east; near crest of low rise that resembles a drumlin; rolling till plain.

A1 — 0 to 4 inches, very dark grayish-brown (10YR 3/2) silt loam; moderate, fine, subangular blocky and medium, granular structure; friable; abundant, fine and plentiful, medium roots; common, partly rounded gravel; clear, wavy boundary, although locally, fine tongues extend to a depth of 9 inches.

A21 — 4 to 8 inches, yellowish-brown (10YR 5/4) gravelly silt loam; very weak, fine, subangular blocky, breaking to very weak, very fine, granular structure; very friable; plentiful, fine and medium, woody roots; few, partly rounded stones and common, partly rounded gravel; horizon is locally discontinuous; gradual, wavy boundary.

A22 — 8 to 16 inches, brown (10YR 5/3) gravelly loam; very weak, medium and thick, platy structure to almost massive; firm; common, fine and few, medium, woody roots; gradual, wavy boundary.

A&B — 16 to 18 inches, brown (10YR 5/3) gravelly loam that encloses spheres of dark-brown (10YR 4/3) gravelly clay loam that are as much as 1/8 to 1/4 inch in diameter; weak, medium, subangular blocky structure; firm; few, fine and medium, woody roots; clear, wavy boundary.

B&A — 18 to 21 inches, dark-brown (10YR 4/3) gravelly clay loam that forms the centers of moderately developed, medium, subangular blocky peds; peds have coats of brown (10YR 5/3) loam ranging in thickness from 1/32 to 1/4 inch, firm; few, fine and medium, woody roots; clear, wavy boundary.

B2t — 21 to 27 inches, dark-brown (10YR 4/3), gravelly, heavy loam; moderate, medium and fine, subangular blocky structure; firm; very dark brown (10YR 3/3), continuous clay skins; very few, fine and medium roots; abrupt, wavy boundary.

C1 — 27 to 42 inches, brown (10YR 5/3) very gravelly loam; weak, medium and thick, platy structure, which is characteristic of basal till; very firm; few, medium roots; many partly rounded stones and pebbles firmly embedded in the loam matrix; many fragments of limestone; calcareous.

C2 — 70 to 80 inches, similar to C1 horizon but sampled to represent the deep substratum.

Climatic data (Ithaca, N. Y.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	26	24	23	45	57	66	71	69	62	51	40	29	48
Mean precipitation, 1931-52 (inches)	1.9	1.9	2.9	2.7	3.7	3.3	4.1	3.5	3.3	2.9	2.6	2.4	35.1

Annual precipitation more than 26.5 and less than 43.7 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % (w)	C/N (m)	Free iron oxides Fe_2O_3 %
0-4	A1	1.3	2.7	3.9	13.6	18.0	49.7	10.8	48.5	28.3	9		3.17	16	1.1
4-8	A21	1.7	3.2	4.2	14.1	18.4	48.5	9.9	48.9	27.6	13		1.17	15	1.1
8-16	A22	2.7	3.6	4.4	14.6	19.6	46.7	8.4	49.1	26.9	12		.38	11	1.0
16-18	A&B	1.8	3.4	4.3	14.5	19.2	45.4	11.4	48.5	26.0	12		.30	9	1.4
18-21	B&A	1.6	3.3	4.1	13.7	18.3	43.0	16.0	46.1	24.5	11		.35	10	1.8
21-27	B2t	1.8	3.2	4.0	12.3	16.6	38.7	23.4	41.6	22.1	12		.48	12	2.6
27-42	C1	5.0	5.1	4.7	12.3	16.1	49.0	7.8	43.6	29.6	20		.10		.8
70-80	C2	5.4	6.4	4.9	12.0	15.1	46.7	9.5	40.8	28.5	3		.12		.8

Cation exch. cap. (s)	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % (s)	pH 1:1	$CaCO_3$ equiv. % (n)	Cation exch. cap. (e)	Moisture tensions: 1/3 atmos. %	15 atmos. %
23.2	7.9	1.8	13.1	0.1	0.3	44	5.4			27.0	8.6
12.5	1.1	.3	10.9	.1	.1	13	4.8			21.4	5.1
6.7	.9	.2	5.4	.1	.1	19	5.2			20.9	3.5
7.9	1.4	.5	5.8	.1	.1	26	5.1			17.2	5.3
10.4	2.7	1.2	6.4	.1	.1	38	5.4			17.4	6.9
9.7	3.8	1.4	4.4	<.1	.1	55	6.9			19.3	10.0
Calcareous							8.0	31.4	10.4	14.9	4.0
Calcareous							8.2	34.6	11.2	13.5	4.2

*Exchange acidity.

Profile No. 85

Area: Clarke County, Washington
Vegetation: Oat stubble; (natural) Douglas-fir.
Parent material: Old alluvium, probably of volcanic ash origin.
Topography: 4 percent slope; convex; terrace.

Ap 0 inch to 7½ inches, very dark grayish-brown (10YR 3/2) silt loam; moderate, fine, granular structure; soft, friable, slightly sticky; slightly plastic; abundant roots; many, fine pores; many wormcasts; few pellets.

B1 7½ to 26 inches, dark-brown (10YR 4/3) clay loam; moderate, coarse, prismatic, breaking to moderate, medium, subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; clay skins evident; roots follow faces of prisms; numerous pores.

B21 26 to 33 inches, dark-brown (10YR 4/3) to dark yellowish-brown (10YR 4/4) clay loam; moderate, coarse, prismatic, breaking to moderate, blocky structure; clay skins continuous on blocky peds; prism peds coated with grayish brown (2.5Y 5/2); few pores.

B22x 33 to 43 inches, dark-brown (10YR 4/3) clay loam; strong, coarse, prismatic, breaking to strong, medium, blocky structure; very hard, very firm, slightly sticky, slightly plastic; clay skins continuous on blocky peds, prisms coated with grayish brown (2.5Y 5/2); few pores; few flakes of mica.

B23x 43 to 72 inches, dark-brown (10YR 4/3) silty clay; strong, coarse, prismatic structure; very hard, extremely firm; continuous clay skins; common, dark mottles; tongues of light brownish gray (2.5Y 6/2) extend between prisms; few pores.

IIC1x 72 to 96 inches, dark-brown (7.5YR 4/4) silty clay loam; strong, coarse, prismatic, breaking to moderate, coarse, blocky structure; extremely hard, extremely firm, sticky, plastic; continuous clay skins; many, blocky peds completely coated with black (10YR 2/1); tongues of grayish brown (2.5Y 5/2) extend vertically between prisms; very few pores; very few pebbles of quartzite.

IIC2x 96 inches +, dark yellowish-brown (10YR 4/4) silty clay; very strong, coarse, prismatic, breaking to strong, blocky structure; extremely hard, extremely firm, very sticky, very plastic; thick, continuous clay skins on blocky peds; numerous peds coated with black (10YR 2/1); tongues of grayish brown extend vertically between prisms; very few pores; common pebbles of quartzite as much as 2½ inches in diameter.

Climatic data (LaCenter, Wash.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1898-39 (deg. F.)	38	40	44	49	55	60	64	64	59	52	44	39	51
Mean precipitation, 1898-39 (inches)	6.9	6.0	5.2	3.3	2.7	2.1	0.7	1.1	2.5	4.1	7.6	7.9	50.1

Annual precipitation more than 35.6 and less than 64.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) u	Organic matter: C % w	N % m	Clay by decantation <.002
0-7½	Ap											1.34	1.39	0.117	18.0
7½-26	B1											1.47	.18	.025	20.8
26-33	B21											1.46	.14	.021	21.8
33-43	B22x											1.44	.13	.020	25.8
43-72	B23x											1.46	.31	.069	40.3
72-96	IIC1x												.21	.051	35.5
96+	IIC2x												.16	.043	39.0
															19.6
															28.3

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Clay fraction: Illite	Vermiculite	Interstratified montmorillonite and vermiculite	Montmorillonite	Amorphous clay	Kaolin %
19.1	3.9	1.6	11.3	0.1	2.2	41	4.8	x	xxxx			xx	5
13.5	4.8	1.2	7.3	.1	.1	46	5.5	xx	xxxx			xx	10-12
18.6	6.6	2.1	6.8	.1	.1	56	5.5	xxx	x	xxx		x	12
22.6	10.4	4.6	7.2	.2	.2	68	5.5	xx		xx	xx		8
20.4	9.7	3.2	7.1	.2	.2	65	5.5	xxxx					25
17.4	7.8	3.2	6.1	.2	.1	65	5.6	xxxx					27
17.6	7.7	3.3	6.3	.2	.1	64	5.7	xxxx					30
15.8	7.6	2.2	5.8	.1	.1	63		xx		xxx			10
19.3	11.0	.6	7.3	.2	.2	62		xx		xxxx			15

*Exchange acidity.

Profile No. 86

Area: Tehama County, California.
Vegetation: Annual grasses and weeds in a sheep pasture formerly cultivated.
Parent material: Old alluvium
Topography: About 1 percent slope; terrace, midway between mound and intermound areas; elevation about 315 feet.

Ap 0 to 8 inches, dark reddish-brown (2.5YR 3/4) gravelly loam, yellowish red (5YR 5/6) when dry; massive when dry; hard, very friable, slightly plastic; plentiful fine roots; gradual boundary.

A21 8 to 14 1/2 inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; massive when dry; hard, friable, slightly plastic; plentiful, fine roots but less than in Ap horizon; gradual boundary.

A22 14 1/2 to 19 1/2 inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; massive; hard, friable, slightly plastic; plentiful roots; abrupt, wavy boundary.

B2t 19 1/2 to 22 inches, red (2.5YR 4/6) clay, yellowish red (5YR 4/6) when dry; glazed surface of soil is dark red (2.5YR 3/6); strong, blocky, breaking to prismatic structure; extremely hard, extremely firm, very plastic, very compact; very few roots; coatings of manganese oxide present; a small amount of gravel; abrupt, wavy boundary.

C1m 22 to 24 1/2 inches, red (2 5YR 4/6) gravelly loam, yellowish red (5YR 4/6) when dry; glazed surface is dark red (2.5YR 3/6); massive; indurated; coatings of manganese oxide present; gradual, boundary.

C2m 24 1/2 to 35 inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; massive; strongly cemented; coatings of manganese oxide present; pH, as determined in field, ranges from 6 where manganese oxide is present to 7 where manganese oxide is absent.

Climatic data (Red Bluff, Cal.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	45	50	54	60	68	76	83	81	75	65	55	47	63
Mean precipitation, 1921-50 (inches)	3.7	3.5	2.6	1.8	1.1	0.5	0	0.1	0.3	1.5	2.3	4.2	21.6

Annual precipitation more than 9.9 and less than 33.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C %	C/N k
0-8	Ap	9.1	8.6	4.3	10.0	18.2	40.2	9.6		19.8	25		0.36	9
8-14½	A21	8.2	7.9	4.5	10.3	19.1	39.1	10.9		19.9	21		.18	6
14½-19½	A22	10.1	7.5	4.3	9.7	17.5	38.7	12.2		19.5	19		.14	5
19½-22	B2t	6.1	4.9	2.2	4.4	7.4	19.5	55.5		11.1	14		.35	6
22-24½	C1m	28.5	15.5	4.6	6.5	5.0	13.9	26.0		10.0	51		.18	
24½-35	C2m	25.1	13.9	4.4	5.3	5.7	19.6	26.0		14.9	44		.05	

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
7.5	3.2	1.3	2.6	Tr.	0.38	65	5.7
8.0	3.2	1.9	2.6	<0.01	.25	67	5.6
8.6	3.2	2.6	2.6	.03	.17	70	5.5
32.8	12.6	13.4	6.2	.29	.29	81	5.3
33.0	13.5	13.5	5.4	.37	.28	84	5.5
28.1	12.6	12.2	2.9	.20	.21	90	6.8

*Exchange acidity.

Profile No. 87

Area: San Diego County, California.

Vegetation: Dominantly chamise, buckwheat, sumac, and laurel; understory of cheatgrass, "wild alfalfa" (Melilotus alba), and salvia.

Parent material: Mixed Coastal Plain material.

Topography: Flat; top of old sea terrace or crest of old beach line; elevation about 400 feet.

A11 0 to 6 inches, dark-brown (7.5YR 3/2) gravelly sandy loam, brown (7.5YR 4/2) when dry; weak; fine, granular structure; massive when dry; hard; very little digestion with H_2O_2; few iron concretions 5 to 10 millimeters in diameter; gradual boundary.

A12 6 to 12 inches, dark-brown (7.5YR 3/3) gravelly sandy loam; brown (7.5YR 4/4) when dry; weak, fine, granular structure; massive when dry; hard, friable, slightly sticky; very little digestion with H_2O_2; common, iron concretions of reddish brown (5YR 4/4) about 5 millimeters in diameter.

A21cn 12 to 18 inches, dark-brown (7.5YR 4/4) very gravelly sandy loam, brown (7.5YR 5/4) when dry; massive; friable, slightly plastic; more than 50 percent of the soil mass consists of iron concretions ranging less than 0.5 to 25 millimeters in diameter.

A22 18 to 24 inches, dark-brown (7.5YR 4/4) gravelly sandy loam, light brown (7.5YR 6/4) when dry; massive; nonsticky, nonplastic; numerous concretions; abrupt boundary.

B1t 24 to 30 inches, strong-brown (7.5YR 5/6) gravelly sandy loam, light yellowish brown (10YR 6/4) when dry; massive, breaking to fine, subangular blocky structure; friable, slightly plastic; common, moderately hard nodules or concretions which are less numerous and not quite so hard as in the A22 horizon.

B21t 30 to 36 inches, strong-brown (7.5YR 5/6) sandy clay loam, reddish yellow (7.5YR 6/6) when dry; weak, prismatic, breaking to weak, medium, subangular blocky structure; plastic; very few moderately hard nodules.

B22t 36 to 45 inches, yellowish-red (5YR 5/6) sandy clay loam, strong brown (7.5YR 5/6) when dry; prismatic structure; sticky, plastic.

B3t 45 to 55 inches, mottled red, gray, and brown sandy clay loam; plastic; the gray part is the most plastic and finest textured and appears to swell and contract more than the adjacent red and brown material.

Bm 55 inches plus, reticulate mottled iron hardpan with coarse prismatic structure.

Climatic data (San Diego, Cal.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	55	56	58	61	63	66	69	70	69	65	61	57	62
Mean precipitation, 1921-50 (inches)	1.7	2.3	1.5	0.8	0.3	0	0	0.1	0.2	0.6	0.8	2.6	10.9

Annual precipitation more than 3.2 and less than 18.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C % w	C/N k
0-6	A11	1.4	21.8	25.5	17.7	3.8	21.8	8.0	24.2	9.1	23		2.24	16
6-12	A12	.4	17.6	26.7	22.1	4.4	21.3	7.5	28.2	7.6	32		.83	16
12-18	A21cn	.6	17.2	27.2	25.0	4.4	19.2	6.4	28.6	6.8	54		.40	13
18-24	A22	1.0	15.9	25.9	26.4	4.9	20.3	5.6	30.3	7.8	46		.24	11
24-30	B1t	4.0	17.4	23.6	21.2	3.7	16.8	13.3	20.2	10.2	21		.11	
30-36	B21t	.6	16.5	24.4	20.6	2.9	13.8	21.2	17.9	8.2	3		.11	
36-45	B22t	.2	16.3	23.4	19.7	2.9	11.8	25.7	16.6	7.2	0		.11	
45-55	B3t	.3	15.0	22.2	17.5	2.9	8.6	33.5	13.8	5.6	0		.09	

Cation exch. cap. f	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH Sat. paste	E. C. mmhos. per cm. 25° C.	Base sat. % s	Moisture at sat. %	Clay minerals: Mi	Vm	Mt	K	Q	Exch. Na %
16.0	9.6	11.5	2.7	0.4	0.3	6.7	1.3	89	27.6	x			xx	xx	2
10.3	5.4	6.8	1.6	.2	.2	6.9	.5	89	20.6	x			xx	xx	2
6.2	2.4	3.6	1.0	.2	.1	6.7	.5	86	17.2	x	x		xx	xx	3
5.0	1.0	2.2	.9	.3	.1	6.9	.5	80	14.8	x	x	x	xxx	xx	6
6.4	1.1	3.0	1.2	.5	.1	6.6	.8	80	17.5	x			xxx	xx	8
8.5	1.0	3.8	1.4	.8	.1	6.7	.9	80	22.9	x			xxx	xx	9
10.1	1.1	4.5	.9	1.2	.1	6.8	1.1	88	26.2	x			xxx	x	12
16.3	1.6	7.9	2.8	2.3	.1	6.9	1.5	81	34.0				xxx	x	14

*Exchange acidity.

Profile No. 88

Area: Tehama County, California.

Vegetation: Sparse cover of annual plants dominated by alfileria (*Erodium cicutarium*); pasture.

Parent material: Alluvium from uplands underlain by a wide variety of rocks, mostly hard, metasedimentary rocks.

Topography: Less than 1 percent slope; terrace; elevation about 340 feet.

Ap 0 to 6 inches, dark reddish-brown (2.5YR 3/4) loam, reddish brown (5YR 4/4) when dry; strong, granular structure; slightly hard, friable, slightly plastic; plentiful roots; few concretions of manganese oxide; a small amount of gravel; abrupt, smooth boundary.

A12 6 to 10½ inches, dark reddish-brown (2.5YR 3/4) loam, reddish brown (5YR 4/4) when dry; strong, granular structure; slightly hard, friable, slightly plastic; plentiful roots; few concretions of manganese oxide; a small amount of gravel; clear, wavy boundary.

A3cn 10½ to 19½ inches, dark reddish-brown (2.5YR 3/4), heavy loam, reddish brown (5YR 4/4) when dry; strong, granular structure; slightly hard, friable, slightly plastic; few, fine roots; numerous mottles and concretions of manganese oxide; a small amount of gravel less than 0.5 inch in diameter; abrupt, irregular boundary.

B2t 19½ to 27 inches, weak-red (10R 4/4) clay loam, red (2.5YR 4/6) when dry; strong, blocky structure, weakly cemented by iron oxide; hard, firm, plastic, brittle when moist; few roots; streaks of manganese oxide, particularly in lower part, which are more in evidence than in any other horizon; gradual boundary.

B22t 27 to 37 inches, weak-red (10R 4/4) clay loam, red (2.5YR 4/6) when dry; strong, blocky structure, weakly cemented by iron oxide; hard, firm, plastic, brittle when moist; few roots; streaks of manganese oxide evident; very small amount of gravel; gradual boundary.

B23t 37 to 55 inches, weak-red (10R 4/4) gravelly clay loam, red (2.5YR 4/6) when dry; strong blocky structure; weakly cemented by iron oxide; hard, firm, plastic, brittle when moist; few roots; streaks of manganese oxide evident; gradual boundary.

B3t 55 to 64 inches, weak-red (10R 4/4) gravelly clay loam, red (2.5YR 4/) when dry; weak, blocky structure; compact, very weakly cemented; hard, firm, plastic, brittle when moist; few roots; manganese oxide evident; diffuse boundary.

C 64 to 72 inches, weak-red (10R 4/4) sandy clay loam, very near loam and clay loam, red (2.5YR 4/6) when dry; weak, blocky structure, compact, very weakly cemented; hard, firm, plastic, few roots; brittle when moist; a small amount of gravel.

Remarks: Most of the gravel in the profile is less than one-half inch in diameter.

Climatic data (Red Bluff, Cal.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	45	50	54	60	68	76	83	81	75	65	55	47	63
Mean precipitation, 1921-50 (inches)	3.7	3.5	2.6	1.8	1.1	0.5	0	0.1	0.3	1.5	2.3	4.2	21.6

Annual precipitation more than 9.9 and less than 33.3 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % d	C/N k
0-6	Ap	8.9	8.2	4.5	9.4	14.2	32.0	22.8		17.0			0.61	9
6-10½	A12	7.7	8.9	4.8	9.0	13.7	30.7	25.2		17.4			.22	5
10½-19½	A3cn	5.5	7.7	4.9	10.1	15.1	31.3	25.4		17.2			.18	5
19½-27	B2t	6.9	6.2	3.7	7.4	11.9	29.7	34.2		16.3			.11	
27-37	B22t	6.4	6.1	3.5	6.9	12.1	28.7	36.3		15.6			.09	
37-55	B23t	6.7	5.8	3.4	6.9	11.7	28.8	36.7		15.9			.07	
55-64	B3t	8.7	7.1	3.6	7.8	12.4	28.4	32.0		15.5			.06	
64-72	C	11.5	7.0	3.9	8.3	12.6	27.3	29.4		14.9			.04	

Cation exch. cap. 8	Ca	Mg	H*	Na	K	Base sat. % 8	pH 1:1
8.2	1.8	0.6	5.1	0.01	0.68	38	5.0
7.5	1.6	.4	4.7	.02	.76	37	4.9
7.6	1.6	1.0	4.3	.02	.72	44	5.0
8.8	2.3	1.7	4.2	.03	.62	53	5.0
8.9	2.6	1.9	4.0	.00	.41	55	5.0
8.8	2.9	2.1	3.5	.02	.31	61	5.2
7.6	2.9	1.9	2.5	.02	.30	67	5.2
7.5	2.9	2.0	2.4	.07	.16	68	5.4

*Exchange acidity.

Profile No. 89

Area: Tehama County, California.
Vegetation: Short, annual grasses and associated plants; (natural) dominantly alfileria (Erodium cicutarium).
Parent material: Old valley-fill material of mixed origin.
Topography: About 2 percent slope; low, hummocky microrelief; terrace; elevation about 350 feet.

Ap 0 to 7 inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; weak, granular structure; hard, friable, slightly plastic; plentiful, fine roots; gradual, smooth boundary.

A3 7 to 15½ inches, red (2.5YR 4/6) gravelly loam, yellowish red (5YR 5/6) when dry; hard, friable, slightly plastic; few, fine roots; abrupt, wavy boundary.

B21t 15½ to 20 inches, red (2.5YR 4/6) gravelly clay loam, yellowish red (5YR 5/6) when dry; weak, blocky structure; very hard, firm, plastic; compact; very few roots; gradual boundary.

B22t 20 to 26 inches, red (2.5YR 4/6) clay loam, yellowish red (5YR 5/6) when dry; coarse, blocky structure; very hard, firm, plastic; very few roots; compact, weakly cemented; a small amount of gravel, mostly less than one-half inch in diameter; gradual boundary.

B23t 26 to 32 inches, red (2.5YR 4/6) gravelly loam; surfaces of peds red (10R 4/6); strong, coarse, blocky structure; compact, weakly cemented; very hard, firm, plastic; very few roots; gradual, wavy boundary.

B3t 32 to 41 inches, red (2.5YR 4/6) gravelly clay loam (nearly gravelly sandy clay or gravelly sandy clay loam), yellowish red (5YR 4/6) when dry; massive; very compact; extremely hard, very firm, plastic; very few roots; gradual boundary.

C 41 to 50 inches, red (2.5YR 4/6) sandy clay loam (nearly sandy clay), yellowish red (5YR 4/6) when dry; massive; very compact; extremely hard, very firm, plastic; very few roots; a small amount of gravel, mostly less than one-half inch in diameter.

Remarks: Most of the gravel in the profile is less than one-half inch in diameter.

Climatic data (Red Bluff, Cal.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	45	50	54	60	68	76	83	81	75	65	55	47	63
Mean precipitation, 1921-50 (inches)	3.7	3.5	2.6	1.8	1.1	0.5	0	0.1	0.3	1.5	2.3	4.2	21.6

Annual precipitation more than 9.9 and less than 33.3 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % d	C/N k
0-7	Ap	10.8	9.0	4.8	8.1	11.6	44.9	10.8		23.5			0.39	8
7-15½	A3	12.3	8.7	4.7	8.0	11.2	43.3	11.8		23.1			.21	6
15½-20	B21t	10.8	7.2	3.9	6.4	9.1	32.5	30.1		18.1			.29	6
20-26	B22t	9.2	7.0	4.1	7.2	9.1	33.0	30.4		18.1			.17	6
26-32	B23t	9.3	7.4	4.4	7.3	9.1	32.4	30.1		18.7			.10	
32-41	B3t	12.5	10.6	6.0	7.9	6.5	22.2	34.3		14.5			.06	
41-50	C	7.9	15.3	12.9	8.9	5.0	16.6	33.4		11.5			.05	

Cation exch. cap. 5B	Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Ca/Mg	Ratio exch. cap. to pct. separates < 0.005
10.5	3.1	4.0	3.2	0.05	0.13	69	5.5	0.8	0.63
11.7	5.3	3.3	2.8	.26	.08	76	5.9	1.6	.65
22.8	5.3	13.3	3.0	1.10	.12	87	6.6	.4	.65
23.7	4.8	15.2	2.1	1.49	.10	91	7.5	.3	.67
24.2	4.8	15.8	1.6	1.91	.11	93	7.5	.3	.68
27.6	6.9	16.5	1.9	2.16	.18	93	7.5	.4	.70
23.1	6.8	12.7	1.6	1.83	.13	93	7.3	.5	.63

*Exchange acidity.

Chapter 15. Ultisols

The Ultisols include most soils that have been called Red-Yellow Podzolic soils, Reddish-Brown Lateritic soils, and Rubrozems in the United States. Also included are some very acid soils that have been called Humic Gley and Low-Humic Gley soils, and some called Ground-Water Laterite soils.

The Ultisols have no oxic or natric horizon, but they have an argillic horizon. The argillic horizon is not permitted to have tongues of an albic horizon penetrating from the top. The argillic horizon has less than 35 percent base saturation (measured by sum of cations), or base saturation decreases with depth either in the argillic horizon or in the C. In addition, the Ultisols may have a mollic, umbric, ochric, or histic epipedon or a fragipan. Plinthite is often present. These horizons and the plinthite are used to define the classes of Ultisols.

The Ultisols are restricted to humid climates ranging from the temperate zones to the tropics. Land surfaces are commonly old, or if they are of late Pleistocene age, the parent materials were highly weathered before they were deposited. The native vegetation may have been forest, savannah, or even marsh or swamp flora.

Perhaps it should be pointed out that the exclusion of oxic horizons from the Ultisols requires that the Ultisols have some weatherable minerals. There may be very small amounts of micas or feldspars in the silt or sand fraction. Or, there may be allophane or 2:1 lattice clays in the clay fraction. The amount of weatherable minerals need not be large, but there must be enough to identify. This concept is presented for testing.

It is normal in the Ultisols that the amount of weatherable minerals is small in the silt and sand fractions. The definition of the order might have been on this basis, had it not been for the enormous difficulty of determining percentages of the various minerals in the silt fraction. There is, however, no requirement that the amount of weatherable minerals be small. Some Ultisols have a large amount of 2:1 lattice clay. Others have a very appreciable content of feldspar or mica in the silt fraction.

Three suborders are recognized. Their definitions, keys, and the definitions of the great groups and subgroup follow.

AQUULTS (8.1)

The Aquults are those Ultisols that have been called Low-Humic Gley and Humic Gley soils. They are saturated with water at some season or they have artificial drainage. Immediately below any A1 or Ap that has a moist value of 3.5 or less there are mottles, iron-manganese concretions, or moist chromas of 2 or less. In addition, the argillic horizon has colors that are dominant on the ped faces, or dominant in the matrix of structureless horizons, as follows:

1. In hues as red or redder than 10YR, chromas of 1 to 2 if there are mottles with higher chromas.
2. In hues yellower than 10YR, chromas of 1 to 3 if there are mottles with redder hues or higher chromas.
3. Chromas of 1 or less.

The Aquults may have fragipans, and when virgin, an umbric or ochric epipedon. With liming and cultivation, the umbric epipedon may become mollic. No distinction is made in the Aquults between umbric and mollic epipedons, There may also be plinthite in the argillic horizon, particularly in tropical and subtropical regions.

Key to Aquults

8.11 Aquults that have within the argillic horizon, or within 125 cm. (50 inches) of the surface, plinthite that has not hardened.

Plintaquult, p. 226

8.110 Plintaquults in which the plinthite forms a continuous phase

Orthic Plintaquult, p. 226

8.11-8.12 Other Plintaquults.

Ochraquultic Plintaquult, p. 227

8.12 Other Aquults with an ochric epipedon, and with no fragipan.

Ochraquult, p. 227

8.13 Other Aquults with an umbric or mollic epipedon and no fragipan.

Umbraquult, p. 227

8.14 Other Aquults with a fragipan.

Fragaquult, p. 227

Plintaquults (8.11)

The Plintaquults are the Aquults that have, at depths of less than 125 cm. (50 inches), plinthite that has not hardened. They, like the Ultisols, have argillic horizons with low base saturation, and either some weatherable minerals in the silt or sand fraction, or some 2:1 lattice clay in the clay fraction. Colors are gray, but the epipedon may be ochric or umbric. The nature of the epipedon in these soils is not considered diagnostic for the great group or for the subgroups. Whether the nature of the epipedon should be diagnostic for families or only for series is not determined, because few if any of these soils occur in the United States. For the most part, these soils are restricted to the tropics and subtropics.

Orthic Plintaquults (8.110)

This subgroup includes the Plintaquults that have plinthite as a continuous phase. That is, the red mottles are connected and will form a sheet of porous ironstone if they harden.

Profile 91, page 231, is an example of an Orthic Plintaquult. While the description is not specific concerning the continuity or discontinuity of the red mottles, a nearby drainage ditch has exposed the plinthite to drying, and the sides of the ditch are lined with a porous ironstone.

Ochraquultic Plintaquults (8.11-8.12)

This subgroup differs from the orthic in having the plinthite in the form of disconnected red mottles. On hardening, the mottles will form a nodular or pisolitic plinthite.

Ochraquults (8.12)

The Ochraquults are those Aquults that do not have, within 125 cm. (50 inches) of the surface, a plinthite that has not hardened; and that have an ochric epipedon. No fragipan is present. They have developed chiefly under forest. No subgroups are proposed at this time.

Profile 92, page 232, is an example of an Ochraquult that is considered orthic. No clay skins were identified in the field, but thin sections show that they are well developed.

Umbraquults (8.13)

The Umbraquults are those Aquults that have an umbric or a mollic epipedon and that have no fragipan. If they are virgin, the Umbraquults are thought to have only an umbric epipedon. When cultivated and limed, they can develop a mollic epipedon. This change is not considered significant to the classification of even the soil series.

No subgroup definitions are proposed at this time. Profile 6, page 71, is an example of an Orthic Umbraquult.

Fragaquults (8.14)

The Fragaquults are the Aquults that have fragipans. Normally these lie below the argillic horizon, and may be separated from it by a distinct albic horizon. In others, the argillic horizon seems to rest directly on the fragipan. As a rule, in these soils, there are thick coatings of clay on the large prisms in the fragipan. The epipedon normally is ochric. It is very common in the United States that the fragipan has formed in a soil buried by loess. If the loess mantle is thinner than about 40 cm. (16 inches), the fragipan seems to develop in the lower horizons of the buried soil. If the loess mantle is between about 40 and 75 cm. (16 and 30 inches) thick, the surface of the fragipan normally coincides with the surface of the buried soil. If the loess is thicker than 75 cm., the fragipan is normally partly or entirely in the loess.

Profile 94, page 233, is an example of a Fragaquult that is thought to be orthic. This soil has a mantle presumed to be loess that is about 20 inches thick. The surface of the fragipan is at the base of this mantle. Some mixing of the two materials is evident.

The Fragaquults grade into the Fragochrults by a gradual increase in chroma or a slow increase in the redness of the horizons from depths of 1 or 2 inches to about 12 inches. However, no definitions of the subgroups have been written.

OCHRULTS (8.2)

The Ochrults include most of the soils that have been called Red-Yellow Podzolic soils and Reddish-Brown Lateritic soils in the United States. They also include some soils that have been called Lithosols but that have argillic horizons, and some that have been called Gray-Brown Podzolic soils but that have very low base saturation.

The Ochrults are Ultisols that have higher chromas than the Aquults; and that either have an ochric epipedon, or have argillic horizons with moist values of less than 4 and chromas of 6 or less throughout, and dry value no more than 1 unit higher than the moist value. The distinction between ochric and umbric, or even mollic, epipedons has little significance in soils with argillic horizons that are dark colored whether moist or dry.

The Ochrults are restricted to humid climates but may be found from the tropics to relatively cool temperate regions. Many are on what appear to be very old land surfaces, but some are in relatively siliceous deposits of Wisconsin age. The native vegetation has been forest.

Key to Ochrults

8.21 Ochrults that have, in the argillic horizon, plinthite that has not hardened and that is within 125 cm. (50 inches) of the surface.

Plintochrult, p. 228

8.210 Plintochrults in which the plinthite forms a continuous phase.

Orthic Plintochrult, p. 228

8.21-8.23 Other Plintochrults.

Typic Plintochrult, p. 228

8.22 Other Ochrults with argillic horizons having moist values of less than 4 and dry values not more than 1 unit higher than the moist values; having no Ap with a moist value of 4 or more, nor an epipedon with a moist value in any part of more than 4.

Rhodochrult, p. 228

8.220 Rhodochrults with an argillic horizon that is continuous vertically and horizontally and that has a texture finer than loamy sand in some part.

Orthic Rhodochrult, p. 228

8.22-1.2 Other Rhodochrults with an argillic horizon no finer than loamy sand.

Psammentic Rhodochrult, p. 229

8.22-R Other Rhodochrults with an argillic horizon that is interrupted by ledges of hard bedrock (R).

Ruptic Lithic Rhodochrult, p. 229

8.23 Other Ochrults with no fragipan.

Typochrult, p. 229

8.230 Typochrults with the following properties: (a) With no mottles having chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon. (b) With textures finer than loamy sand in some part of the argillic horizon, and with an argillic horizon that, in at least its upper 25 cm. (10 inches), has no lamellae.
(c) With no interruptions of the argillic horizon by ledges of bedrock, and with less than 75 percent of the argillic horizon consisting of bedrock larger than gravel.
(d) With all parts of the argillic horizon having a moist value of 4 or more.
(e) With an Ap that has a moist value of more than 3 and a dry value of more than 5, or an A1 that is thinner than 15 cm. (6 inches) if its moist value is less than 3.5 and its dry value is less than 5.5.

Orthic Typochrult, p. 229

8.23-1.2 Other Typochrults having argillic horizons with textures no finer than the loamy sands or with lamellae in the upper 25 cm. (10 inches) of the argillic horizon, and with no mottles having chromas of 2 or less within the upper 25 cm. of the argillic horizon.

Psammentic Typochrult, p. 229

8.23-8.3 Other Typochrults having an Ap horizon with moist values of 3 or less, or an A1 horizon that is 15 cm. (6 inches) or more thick and that has moist color values of less than 3.5 and dry color values of less than 5.5; and that have no mottles with chromas of 2 or less in the upper 25 cm. (10 inches) of the argillic horizon.

Umbric Typochrult, p. 229

8.23-8.1 Other Typochrults having mottles that have chromas of 2 or less within the upper 25 cm. (10 inches) of the argillic horizon.

Aquic Typochrult, p. 229

8.23-8.22 Other Typochrults having argillic horizons that, in some part, have moist values of less than 4.

Rhodic Typochrult, p. 229

8.24 Other Ochrults with a fragipan.

Fragochrult, p. 229

8.240 Fragochrults that, in the upper part of the argillic horizon, are free of distinct or prominent mottles and that have hues redder than 10YR, or that have in the upper part of the argillic horizon hues of 10YR or yellower and either chromas of 3 or more in values of 4, or chromas of 4 or more in values of 5 or higher.

Orthic Fragochrult, p. 229

8.24-8.1 Other Fragochrults.

Aquic Fragochrult, p. 229

Plintochrults (8.21)

The Plintochrults are the Ochrults that have, within 125 cm. (50 inches) of the surface, plinthite that has not hardened. They differ from the Plintaquults in having dominant chromas of 3 or more in at least the upper part of the argillic horizon. They normally have low chromas in the horizons where soft plinthite occurs.

The Plintochrults may include some soils that have been called Ground-Water Laterite soils. It should be noted however, that the present definition of an oxic horizon may have eliminated this group of soils. They are not known to occur in the United States. The tentative definition of an orthic subgroup is given in the Key to Ochrults.

Rhodochrults (8.22)

The Rhodochrults have been called Reddish-Brown Lateritic soils. They have an argillic horizon that has moist color values of less than 4, and dry values no more than 1 unit higher than the moist values. The epipedon has moist values of 4 or less in all parts. Hues may range from the reds to the browns, with some indications that the brown soils have cooler or more humid climates, or both. There is little relation between the amount of free iron and the hue. The free iron content ranges from about 12 to more than 30 percent of the clay fraction, well within the range of the oxic horizons. There are many resemblances between the Rhodochrults and some of the Oxisols, and they seem to occur side by side in places. Yet there are perhaps even more similarities to the other Ochrults.

The parent materials of the Rhodochrults are primarily basic igneous rocks and limestones. Some contain silica in the form of chert or quartz, but few come from parent materials with a high content of combined silica. The Rhodochrults are found in humid climates ranging from cool-temperate regions to the tropics. They grade into the Rhodustalfs of drier climates, and, as parent rocks become less basic, into Typochrults. The gradation to Oxisols is not well understood, nor can the boundary be defined with precision at this time.

Orthic Rhodochrults (8.220)

This subgroup includes the Rhodochrults that have an argillic horizon with texture finer than loamy sand and that is continuous laterally within each pedon. Soils with thin argillic horizons resting on bedrock at shallow depths probably should be excluded, but no limits can be suggested at this time.

Profile 95, page 234, is an example of an Orthic Rhodochrult. It lies near the center of the range in color and thickness but has a relatively high base-exchange capacity and base saturation and a high content of organic matter for the orthic soils. In the upper horizons it has a few "shot," or rounded, very firm, sesquioxide accumulations. Only the lowest horizon shows evidences of poor dispersion under mechanical analysis.

The sesquioxide segregations, or "shot," in the surface horizon probably are near the limit for the orthic soils. Soils otherwise similar, but having 20 to 30 percent of shot in the surface horizon, should be excluded from the orthic subgroup. A limit of 5 to 10 percent shot in orthic soils should be reasonable, but there has been no discussion of this limit.

Psammentic Rhodochrults (8.22-1.2)

This subgroup includes the Rhodochrults with an argillic horizon that has sand or loamy sand textures.

Typochrults (8.23)

The Typochrults include chiefly the soils that have been called Red-Yellow Podzolic soils. A few soils with acid argillic horizons are included that have been called Gray-Brown Podzolic soils, and Lithosols.

The Typochrults are restricted to humid climates ranging from the cool-temperate regions to the tropics. The parent materials are not highly basic. Although the parent materials include limestones, they do not seem to include the ultrabasic igneous rocks. The native vegetation is forest.

The central concept of the Typochrults is one of soils with only a few weatherable minerals in the silt and sand fractions, and with only small quantities of 2:1 lattice clays. The clay fractions have low base-exchange capacities, less than 40 milliequivalents per 100 grams of clay. No provision has been made for exclusion from Orthic Typochrults of soils with large amounts of weatherable minerals or 2:1 lattice clays, but some distinction seems needed. It is possible that another great group is needed that differs from the Typochrults as the Typustalfs differ from the Ultustalfs. Profile 12, page 77, is an example of an Ochrult that has considerable amounts of weatherable minerals and of 2:1 lattice clays. Chemical and mineralogical analyses for profile 12 are given in table 10.

Orthic Typochrults (8.230)

The definition of the Orthic Typochrults given in the Key to Ochrults needs no elaboration. It is as yet incomplete, and makes no provision for several subgroups that probably are needed.

Profile 96, page 235, is an example of an Orthic Typochrult. It should be noted that the hue of this soil is redder than that of many Typochrults. The small content of silt that is between 2 and 20 microns in diameter is typical. The decrease in the content of clay below the B is probably due to stratification of the parent material in this soil. It is, however, common to find that the clay content increases or decreases with depth.

Profile 12, page 77, like profile 96, has been considered a Red-Yellow Podzolic soil. The data on profile 12, however, show that appreciable amounts of weatherable minerals are present in the silt and sand fractions, and that montmorillonite is an important constituent of the clay.

The mottling of the lower horizons of profile 12 is quite characteristic of many Orthic Typochrults. This mottling is absent in profile 96. As the iron content increases in the red mottles of the lower horizons, the mottles grade into plinthite.

Many of the Typochrults have apparently gone through several weathering and erosion cycles. In those that have formed in the red mottled horizons of earlier soils as a result of partial truncation, one finds hard, irregular, gravel-sized, iron-cemented nodules that come within the definition of plinthite. The amount of this material that should be permitted in the Orthic Typochrults is under discussion. Some Typochrults have none; in others up to 30 percent of the upper horizons may be plinthite in the form of hardened ironstone gravel. The Typochrults grade into the Plintochrults, but no limits can be suggested at this time.

Psammentic Typochrults (8.23-1.2)

This subgroup includes the Typochrults that have argillic horizons with textures of sand or loamy sand, or that have lamellae in the upper 25 cm. (10 inches) of the argillic horizon. There are no mottles with chromas of 2 or less in the upper 25 cm. of the argillic horizon. Figure 12, page 44, is a photograph of a Typochrult that is excluded from the Psammentic subgroup by the absence of lamellae in the upper part of the argillic horizon. If this part of the argillic horizon had a loamy sand texture, it would be a Psammentic Typochrult.

Aquic Typochrults (8.23-8.1)

This subgroup includes the Typochrults that have mottles with chromas of 2 or less within the upper 25 cm. (10 Inches) of the argillic horizon. In addition, they have an Ap horizon with moist values of more than 3 or an A1 horizon thinner than 15 cm. (6 inches) if the moist color value is less than 3 and the dry color value is less than 5.5.

Rhodic Typochrults (8.23-8.22)

This subgroup includes the Typochrults that have, in some part of the argillic horizon, moist color values of less than 4. They are not Rhodochrults, either because the dry color value of the argillic horizon may be more than 1 unit higher than the moist value, or because the epipedon or the argillic horizon has a moist color value of more than 4 in some part.

Umbric Typochrults (8.23-8.3)

This subgroup includes Typochrults that have no mottles within the upper 25 cm. (10 inches) of the argillic horizon. They have an Ap that has a moist color value of 3 or less, or if virgin, they have an A1 that is 15 cm. (6 inches) or more thick and has a moist color value of 3.5 or less and a dry color value of 5.5 or less.

Fragochrults (8.24)

The Fragochrults are the Ochrults with fragipans. They have been called Planosols (with fragipans) or Red-Yellow Podzolic soils.

Fragochrults are restricted to humid climates, and largely to temperate regions. The group is being retained tentatively, although there is a serious question about the need for it. The Fragochrults differ from the Fragudalfs so little that it is quite possible a more useful classification would result if the two groups were combined. Many if not most of the Fragochrults differ from the Fragudalfs only in having a base saturation of 20 to 35 percent in the argillic horizon, as compared to a base saturation of 35 to 45 percent in the argillic horizon of the Fragudalfs. In both, base saturation normally increases in the fragipan.

A few Fragochrults appear more closely related to the Typochrults. These have reddish argillic horizons with high chromas. In these the base saturation may be very low in the fragipan. These soils perhaps could be handled better in subgroups than in great groups.

Profile 97, page 236, is an example of one of these Fragochrults. It is within the definition of the orthic subgroup, as given in the Key to Ochrults. It resembles the Typochrults in the low exchange capacities of the clay fraction, the low base saturation, and the high chroma of the argillic horizon. Weatherable minerals are presumed to be few.

Profile 98, page 237, is another example of a soil that fits the definition of the Orthic Fragochrults. It represents perhaps the most common Fragochrult. Base saturation in the argillic horizon is just below the 35 percent limit. Exchange capacities of the clay are moderate. Weatherable minerals are abundant. Comparison of profile 98 with profile 84, page 219, will indicate the great similarities of some of the Fragochrults to the Fragudalfs.

UMBRULTS (8.3)

The Umbrults include the soils called Rubrozems. These have an umbric or mollic epipedon, and the argillic horizon that is diagnostic of Ultisols. The argillic horizon lacks the dark colors of that in the Rhodochrults. Consequently, the argillic horizon has moist color values of 4 or more, or dry color values that are more than 1 unit higher than the moist values.

The Umbrults are not important in the United States, and only sketchy definitions can be proposed.

If Umbrults occur that have unhardened plinthite within 125 cm. (50 inches) of the surface, they should be recognized as Plintumbrults.

The other Umbrults, it is thought, have an umbric or mollic epipedon resting on an argillic horizon. No other horizons are known to occur. These are the Typumbrults.

(Colors for moist soil unless otherwise stated)

Profile No. 91

Area: San Juan, Puerto Rico.

Vegetation: Plowed field on which sugar cane had been grown recently.

Parent material: Coastal Plain clay.

Topography: Less than 1 percent slope; lowland; elevation about 10 feet.

Ap 0 to 10 inches, very dark grayish-brown (10YR 3/2) clay; massive or weak, fine, subangular blocky, breaking to fine, granular structure; firm, slightly sticky, plastic; abundant roots; abrupt, smooth boundary.

B1t 10 to 13 inches, mottled dark grayish-brown (2.5Y 4/2) and yellowish-brown (10YR 5/6) clay; moderate, fine, subangular blocky structure; firm, slightly sticky, very plastic; thin, patchy, clay films on peds; number of films decrease as depth increases; plentiful roots; streaks of dark gray (10YR 4/1) in root channels and in cracks decrease with depth; clear, wavy boundary.

B21tg 13 to 23 inches, mottled gray (5Y 6/1) and yellowish-brown (10YR 5/6) clay; few, fine mottles of red (10R 4/6); very weak, very coarse prismatic, breaking to moderate, medium, subangular and angular blocky structure; firm, slightly sticky, very plastic; thin, patchy, clay films on peds; plentiful roots; gradual, smooth boundary.

B22tg 23 to 36 inches, light-gray (5Y 6/1-7/1) clay; many, fine and coarse mottles of strong brown (7.5YR 5/6) and common, medium and coarse mottles of dark red (10R 3/6); a few specks of red; very weak, very coarse, prismatic, breaking to moderate, medium, subangular and angular blocky structure; very firm, slightly sticky, slightly plastic; thin, patchy, clay films on peds, few roots; gradual, smooth boundary.

B23tg 36 to 48 inches, white (5Y 8/1-8/2) clay; many, fine to coarse, dusky-red (10R 3/4) and strong-brown (7.5YR 5/6) mottles; weak, coarse, prismatic, breaking to weak, medium, subangular and angular blocky structure; very firm, slightly sticky, very plastic; thin, patchy clay films on vertical and horizontal faces of peds; clear, smooth boundary.

B24tg 48 to 56 inches, white (5Y 8/1) clay; many, coarse mottles of dusky red (10YR 3/4) and common, fine and coarse mottles of strong brown (7.5YR 5/8); weak, coarse, prismatic, structure or massive; very firm, slightly sticky, very plastic; thin, patchy, clay films on vertical faces of peds; clear, smooth boundary.

B25tg 56 to 70 inches +, white (5Y 8/1) clay; many, coarse mottles of dusky red (10R 3/4) and few, fine mottles of red (10R 4/8) and strong brown (7.5YR 5/8); weak, coarse, prismatic structure or massive; very firm, slightly sticky, very plastic; very few patchy films on vertical faces of peds.

Remarks: From 23 to 70 inches there are few to common, firm to extremely firm nodules of plinthite (pisolitic laterite).

Climatic data (San Juan, P. R.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1921-50 (deg. F.)	75	75	76	77	79	80	80	81	81	80	78	77	78
Mean precipitation, 1921-50 (inches)	4.7	2.7	2.4	3.8	6.5	5.2	6.0	6.3	6.0	5.3	6.4	4.8	60.0

Annual precipitation more than 43.8 and less than 76.2 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxide Fe_2O_3 %
0-10	Ap	0.8	3.1	2.6	5.8	4.0	28.0	55.7	15.8	19.3	Tr.		3.25	13	3.9
10-13	B1t	.4	1.4	1.3	2.9	2.1	15.5	76.4	8.6	10.5	--		1.18	10	5.4
13-23	B21tg	.5	1.5	1.1	2.7	2.1	15.9	76.2	8.4	11.0	--		.74	10	7.0
23-36	B22tg	.4	1.7	1.5	3.7	3.3	19.7	69.7	11.3	13.8	Tr.		.31	7	6.6
36-48	B23tg	1.2	2.4	1.9	4.2	3.4	21.8	65.1	11.9	15.7	Tr.		.21		6.8
48-56	B24tg	1.2	2.7	2.1	4.9	3.5	22.9	62.7	11.5	17.5	--		.20		5.8
56-70+	B25tg	.4	1.7	1.5	3.6	2.8	24.9	65.1	10.0	19.7	--		.11		4.1

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	Moisture tensions 1/3 atmos. %	15 atmos. %	Base sat. % s	Cation exchange cap. s	Clay minerals Mo	K %
14.2	1.1	0.6	23.6	0.1	0.2	4.2	40.2	25.6	8	25.6	x	35
12.7	2.6	.4	18.7	.1	.1	4.2	49.2	32.2	15	21.9	x	40
12.2	1.7	.4	17.1	.1	.1	4.4	47.7	31.8	12	19.4	x	35
11.4	.7	.8	17.9	.1	.1	4.3	41.2	28.2	9	19.6	xx	35
12.4	.3	.8	17.0	.2	.1	4.3	38.0	25.5	8	18.4	x	40
11.6	.3	.8	16.2	.2	.1	4.2	36.0	24.2	8	17.6	x	45
13.6	.4	.1	15.8	.4	.1	4.1	36.0	23.6	11	17.8	xx	45

*Exchange acidity.

Profile No. 92

Area: Jenkins County, Georgia.

Vegetation: Mixed forest consisting of slash and longleaf pines, post and water oaks, and blackgum and sweetgum.

Parent material: Alluvium from Coastal-Plain material.

Topography: Less than 1 percent slope; terrace.

A1 0 to 1 inch, very dark gray (10YR 3/1) fine sandy loam, gray (10YR 5/1) when dry; single grained.

A2 1 to 5 inches, grayish-brown (10YR 5/2) fine sandy loam, light gray or gray (10YR 6/1) when dry; weak, medium and fine, granular structure; loose; numerous root channels; gradual boundary.

A3 5 to 7½ inches, grayish-brown (10YR 5/2) fine sandy loam, light grayish brown (10YR 6/2) when dry; brownish-yellow (10YR 6/8) mottles, yellow (10YR 7/8) when dry; mottles disappear when soil is crushed; weak, medium and coarse, blocky, breaking to fine, blocky structure; friable; numerous fine roots; few wormcasts.

B1t 7½ to 12 inches, pale-yellow (5Y 7/3) fine sandy loam, light gray (5Y 7/1) when dry; yellow (10YR 7/8) and reddish-yellow (5YR 6/8) mottles, pale yellow (5Y 8/4) and reddish yellow (7.5YR 6/8) when dry; strong, coarse, blocky, breaking to fine blocky structure; firm; few pockets of gray (10YR 5/1) fine sandy loam.

B21t 12 to 14½ inches, mottled brownish-yellow (10YR 6/8) and gray (5Y 6/1) sandy clay loam; few fine mottles of red (10R 4/8); moderate, medium and coarse, blocky, breaking to medium and fine, blocky structure; firm.

B22tg 14½ to 23 inches, light-gray (10YR 7/1) sandy clay, clay loam, or sandy clay loam; mottles of brownish yellow (10YR 6/8) and dark red (10R 3/6), strong brown (7.5YR 5/8), and red (2.5YR 5/8) when dry; strong, medium and coarse, blocky structure; hard, plastic.

B3tg 23 to 32 inches, light-gray (10YR 7/1) clay loam; mottles of brownish yellow (10YR 6/8) and dark red (10R 3/6), strong brown (7.5YR 5/8) and red (2.5YR 5/8) when dry; weak, medium and coarse, blocky structure; hard, plastic.

IIC 32 to 47 inches, light-gray (10YR 7/1) clay; distinct mottles of brownish yellow (10YR 6/8) and prominent mottles of dark red (10R 3/6); weak, medium and coarse, blocky structure; very plastic; common, root channels and wormholes; common, very small lenses and pockets of fine sand.

Climatic data (Millen, Ga.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	51	52	59	66	74	81	82	82	77	67	57	50	67
Mean precipitation, 1931-52 (inches)	3.1	3.8	4.4	3.5	3.4	4.4	4.8	4.9	3.7	2.3	2.3	3.8	44.3

Annual precipitation more than 30.7 and less than 57.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter by H_2O_2 %
0-1	A1	2.3	10.9	11.5	27.7	12.8	25.7	9.1		13.8			5.2
1-5	A2	4.0	14.0	12.1	27.6	13.8	20.8	7.7		10.0			1.8
5-7½	A3	4.4	14.6	11.7	27.9	13.6	19.6	8.2		9.2			1.2
7½-12	B1t	3.6	13.5	9.7	22.6	13.0	20.3	17.3		10.2			0.4
12-14½	B21t	4.8	11.2	7.7	17.1	10.6	18.1	30.5		9.5			.5
14½-23	B22tg	1.4	6.2	5.4	18.2	12.5	19.7	36.6		10.2			.3
23-32	B3tg	1.0	5.9	6.0	19.6	9.3	20.2	38.0		11.0			.2
32-47	IIC	.8	4.0	4.3	17.3	8.9	16.6	48.1		9.8			.1

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Mn	K	Base sat. % s	pH 1:5	Clay minerals: Vm	K %	Q %	Gb %
14.0	2.7	1.3	9.9	0.13	0.1	29	5.1				
5.9	.4	.4	5.0	Tr.	.1	15	4.9		40		0
4.2	.2	.2	3.8	.02	.1	9	5.0				
5.0	.1	.3	4.6	Tr.	T	8	4.7	x	50		0
9.0	.1	.4	8.4	Tr.	.1	8	4.5		50	5	0
10.9	.1	.6	10.1	Tr.	.1	7	4.5		50		0
11.3	.1	.8	10.3	Tr.	.1	9	4.6	x	60		0
13.4	.1	.6	12.6	.01	.1	6	4.6				

*Exchange acidity.

Profile No. 94   Area: Prince George's County, Md.

Vegetation: Second-growth forest consisting of white and red oaks, redgum, blackgum, maple, and Virginia pine; understory mostly blueberry and azalea.

Parent material: Alluvium from coastal plains material.

Topography: Less than 1 percent slope; undissected-flat terrace.

01 2 inches to 1 inch, undecomposed forest litter.

02 1 inch to 0, black (10YR 2/1) decomposed forest litter; abundant roots.

A1 0 to 1 inch, dark-gray (5Y 4/1) silt loam; weak, medium, granular structure; friable; plentiful roots; abrupt, wavy boundary.

A2 1 to 5 inches, light brownish-gray (2.5Y 6/2) to light yellowish-brown (2.5Y 6/4) silt loam; common, medium mottles of light gray (N 7/) and light olive brown (2.5Y 5/4); massive, breaking to weak, fine, platy structure; friable; abundant roots; clear, smooth boundary.

B1t 5 to 9 inches, light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2) silt loam or silty clay loam; many, medium mottles of light brownish gray (2.5Y 6/2) and olive yellow (2.5Y 6/6); weak, coarse, subangular blocky structure; firm; plentiful roots; clear, smooth boundary.

B21t 9 to 12 inches, light olive-brown (2.5Y 5/4) to grayish-brown (2.5Y 5/2) silty clay loam; many, medium mottles of yellowish brown (10YR 5/4) and light brownish gray (2.5Y 6/2); moderate, medium, subangular blocky structure; firm; surfaces of peds are grayish brown (2.5Y 5/2); plentiful roots; clear, smooth boundary.

B22tg 12 to 17 inches, grayish-brown (2.5Y 5/2) silty clay; many, medium mottles of strong brown (7.5YR 5/6) and gray (N 6/); strong, medium and coarse, subangular blocky, breaking to very coarse, platy structure; firm; continuous, thin, dull, clay skins on faces of peds; plentiful roots; clear, smooth boundary.

A'21g 17 to 21 inches, discontinuous bands of strong-brown (7.5YR 5/6) and gray (N 5/) silty clay loam; moderate, coarse, platy structure; friable; firm in place; peds generally have gray exteriors and strong-brown interiors; few roots; abrupt, smooth boundary.

IIA'22mg 21 to 31 inches, gray (2.5Y 5/1), heavy loam; many mottles of yellowish-brown (10YR 5/4) and gray (N 5/); wedges of clay that have peripheries of strong brown extend vertically and decrease in width and expression as depth increases; massive, breaking to platy structure in the upper 6 inches; moderately vesicular; very firm in place, brittle when moist; thin films of clay in vesicles and along the few, vertical and the numerous, discontinuous, horizontal cleavage planes; few roots along cleavage planes; diffuse boundary.

IIB'mg 31 to 49 inches, gray (5Y 5/1), heavy loam; many, coarse mottles of reddish yellow (7.5YR 7/6) and gray (N 5/); massive; very firm in place; brittle when moist; few vesicles; patchy, clay films; few roots, which occur in cleavage planes; diffuse boundary.

IICg 49 to 70 inches +, gray (N 5/), heavy loam; many, coarse mottles of strong brown (7.5YR 5/6); massive, firm; few, patchy, clay skins; few roots in upper part, which follow the cleavage planes.

Climatic Data (Cheltenham, Md.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	36	35	44	53	64	72	76	75	68	57	47	37	55
Mean precipitation, 1931-52(inches)	3.9	2.7	3.7	3.8	4.3	3.8	4.8	5.1	4.5	3.2	3.5	3.0	46.1

Annual precipitation more than 34.4 and less than 57.8 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-1	A1	0.6	2.0	2.2	3.2	6.3	71.4	14.3	30.5	48.9	0		3.58	29	1.1
1-5	A2	.3	1.6	1.8	1.7	4.7	70.2	19.7	25.2	50.6	<1		.53	12	1.8
5-9	B1t	.3	1.0	1.4	1.6	4.4	65.2	26.1	23.9	46.6	<1		.51	17	2.3
9-12	B21t	.1	.4	.8	1.0	5.0	57.2	35.5	22.1	40.6	0		.35	9	3.9
12-17	B22tg	.1	.5	1.0	1.2	4.5	49.3	43.4	20.6	33.9	0		.35	9	3.5
17-21	A'21g	.2	2.3	4.6	3.6	3.1	52.0	34.2	17.9	38.8	<1		.45	14	2.2
21-31	IIA'22mg	.6	5.4	10.6	8.2	4.3	47.3	23.6	18.5	36.6	2		.20		.8
31-49	IIB'mg	.8	5.9	11.3	8.7	4.4	43.0	25.9	16.8	34.4	2		.05		1.5
49-70+	IICg	1.5	6.4	12.6	9.1	4.3	40.8	25.3	17.2	31.9	2		.20		1.4

Cation exch. cap. s	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
15.2	0.2	0.3	14.5	0.02	0.18	5	3.9
8.1	.1	.1	7.8	.01	.11	4	4.3
10.1	.1	.2	9.7	.02	.10	4	4.4
15.0	.1	.6	14.1	.03	.14	6	4.4
20.5	.1	1.2	19.0	.03	.17	7	4.3
17.8	.1	1.5	16.0	.05	.14	10	4.4
11.5	.1	1.2	10.1	.04	.08	12	4.4
12.5	.2	1.3	10.9	.06	.07	13	4.3
10.4	.1	.9	9.3	.04	.07	11	4.4

*Exchange acidity.

Profile No. 95

Area: Benton County, Oregon.

Vegetation: Douglas-fir, hazelnut, madrone, bigleaf maple, dogwood, thimbleberry, blackberry, poison oak, fern, and grass.

Parent material: Residuum from basalt.

Topography: 15 percent slope, facing northwest; hilly upland; elevation 1,000 feet.

A1 0 to 4 inches, dark reddish-brown (5YR 2/2) silty clay, dark reddish brown (5YR 3/3) when dry; strong, medium, very fine, granular structure; very friable, slightly sticky, slightly plastic; abundant roots; common, fine pellets in the surface inch but few below; clear, smooth boundary.

A3 4 to 9 inches, dark reddish-brown (5YR 2/2) silty clay, dark reddish brown (5YR 3/2) when dry; strong, medium, subangular blocky, breaking to moderate, fine and very fine, subangular blocky, breaking to fine, granular structure; friable, slightly sticky, slightly plastic; abundant roots; few, fine pellets; clear, smooth boundary.

B1 9 to 14 inches, dark reddish-brown (5YR 3/3) silty clay, reddish brown (5YR 4/3) when dry; strong, fine, and very fine, blocky structure; friable, sticky, plastic; thin, continuous clay films; plentiful roots; few old root channels filled with material from horizons above; clear, smooth boundary.

B21 14 to 21 inches, dark reddish-brown (2.5YR 3/4) clay, reddish brown (2.5YR 4/4) when dry; moderate, fine and very fine, blocky structure; friable, sticky, plastic; thin, continuous, clay films; plentiful roots; gradual, smooth boundary.

B22t 21 to 29 inches, dark reddish-brown (2.5YR 3/4) clay, reddish brown (2.5YR 4/4) when dry; moderate, fine, blocky structure; friable, sticky, plastic; thin, continuous clay films; plentiful roots; gradual, smooth boundary.

B3t 29 to 44 inches, dark reddish-brown (2.5YR 3/4) clay, red (2.5YR 4/6) when dry; moderate, medium and fine, blocky structure; friable, sticky, plastic; thin, continuous clay films; few roots; few, black, splotches of manganese oxide; few fragments of basalt rock; gradual, smooth boundary.

B3&R 44 to 52 inches, dark-red (2.5YR 3/6) clay loam, red (2.5YR 4/8) when dry; moderate, medium and fine, blocky structure; friable, slightly sticky, slightly plastic; common, thin, patchy clay films; fragments of basalt rock make up about 50 percent of this soil volume.

Climatic data (Corvallis, Ore.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	40	43	47	53	58	62	67	67	63	55	46	42	54
Mean precipitation, 1931-52 (inches)	5.7	4.6	3.8	1.9	1.7	1.1	0.4	0.4	1.3	3.5	5.2	6.5	35.9

Annual precipitation more than 20.8 and less than 51.0 inches during 9 years out of 10.

Depth, inches	Hori-zon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-4	A1	1.8	3.0	2.1	3.8	3.1	44.2	42.0	13.8	35.5	3.7		5.38	16	10.7
4-9	A3	.7	2.3	2.2	3.6	3.0	43.8	44.4	14.5	34.5	2.0		4.42	17	11.5
9-14	B1	.7	2.1	2.2	3.9	3.3	43.7	44.1	14.9	34.4	2.2		3.69	19	11.5
14-21	B21	.3	1.6	2.0	3.9	3.4	39.2	49.6	14.6	30.4	---		1.69	16	12.5
21-29	B22t	.4	1.5	1.8	3.9	3.8	35.8	52.8	14.2	27.8	---		.95	15	13.4
29-44	B3t	.3	1.4	1.6	4.3	4.8	33.8	53.8	16.1	25.3	---		.60	13	14.7
44-52	B3&R	4.4	8.8	5.7	11.4	8.5	24.4	36.8	23.4	16.3	72.3		.29		14.0

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	pH 1:10	Cation exch. cap. s	Clay minerals K %	Vm	Moisture tensions 1/3 atmos. %	15 atmos. %
34.6	14.5	4.8	28.7	0.1	2.5	43	5.7	5.9	50.6			37.5	23.5
32.2	11.7	4.3	27.8	.1	1.5	39	5.5	5.8	45.4			36.9	23.3
29.6	9.1	4.5	26.6	.1	.9	35	5.3	5.6	41.2			35.5	23.2
24.7	6.1	4.0	23.2	.1	.6	32	4.9	5.0	34.0			33.3	23.2
22.6	6.0	3.5	20.6	.1	.5	33	4.8	5.0	30.7	40	x	33.9	24.7
28.5	6.2	4.2	19.9	.1	.3	35	4.8	5.0	30.7			38.0	27.5
31.0	6.2	4.2	31.7	.3	.1	25	4.5	4.6	42.5			39.9	28.4

*Exchange acidity.

Profile No. 96

Area: Houston County, Alabama.
Vegetation: Old pecan orchard; sod of bermudagrass, broomsedge, and weeds.
Parent material: Alluvium from Coastal Plain material.
Topography: Less than 1 percent slope, facing east; low terrace.

Ap 0 to 5 inches, brown or dark-brown (7.5YR 4/4) fine sandy loam, yellowish brown (10YR 5/4) when dry; single grained; loose; abundant roots; diffuse, wavy boundary.

A & B 5 to 10 inches, yellowish-red (5YR 4/6) sandy clay loam, yellowish red (5YR 5/6) when dry; an interfingering of fine sandy loam A horizon and sandy clay B horizon; sandy loam is firm; sandy clay is friable; few, very fine pores; numerous dark streaks along old root channels; gradual boundary.

B21t 10 to 20 inches, red (2.5YR 4/6), heavy sandy clay loam or sandy clay, red (2.5Y 5/6) when dry; crushed color slightly lighter than uncrushed; moderately fine and medium, blocky structure; firm, plastic; few, fine roots; common, very fine pores; few, dark specks and dark streaks along old root channels; gradual boundary.

B22t 20 to 25 inches, yellowish-red (5YR 5/6), heavy sandy clay loam, red (2.5YR 5/6) when dry; surfaces of peds slightly darker than interiors; moderate, fine and medium, blocky structure; friable, plastic; few roots; common, very fine pores; few, black specks and streaks along old root channels; gradual boundary.

B23t 25 to 30 inches, yellowish-red (5YR 5/8), light sandy clay loam, red (2.5YR 5/8) when dry; surfaces of peds slightly darker than interiors; weak, fine, blocky structure; friable, slightly plastic; few roots; common, very fine pores; gradual boundary.

B3t 30 to 37 inches, strong-brown (7.5YR 5/8), heavy fine sandy loam or loam, reddish yellow (5YR 6/8) when dry; very friable, very slightly plastic; few roots; gradual boundary.

C1 37 to 50 inches, reddish-yellow (7.5YR 6/8) sandy loam, reddish yellow (7.5YR 7/8) when dry; very friable.

IIC2 50 to 60 inches, yellow (10YR 8/6) coarse sand, dominantly yellow (2.5Y 8/6) when dry; a moderate amount of variegation caused by darker and lighter colors.

Climatic data (Blakely, Ga.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	53	54	59	66	74	81	81	81	77	69	58	53	67
Mean precipitation, 1931-52 (inches)	4.3	4.9	6.1	5.1	3.9	4.0	6.9	6.8	3.8	1.7	3.1	4.6	55.0

Annual precipitation more than 34.4 and less than 75.6 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter: C %	C/N
0-5	Ap	2.8	9.9	11.8	34.6	21.4	11.5	8.0		5.6			0.54	
5-10	A & B	1.1	4.1	6.6	25.8	25.2	15.9	21.3		8.1			.24	
10-20	B21t	.4	1.8	4.0	20.1	20.9	14.7	38.1		7.5			.24	
20-25	B22t	.2	1.7	6.2	25.2	17.5	15.3	33.9		8.3			.19	
25-30	B23t	.1	2.0	7.9	32.9	16.5	12.2	28.4		6.7			.14	
30-37	B3t	.1	2.2	9.3	39.2	16.6	9.7	22.9		6.3				
37-50	C1	3.4	10.8	16.6	38.9	12.5	4.7	13.1		3.3				
50-60	IIC2	23.1	33.4	26.0	13.7	1.5	.1	2.2		.9				

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Mn	K	Base sat. %	pH 1:5	Clay fraction: K %	Q %	Gb %
3.2	0.8	0.2	2.1	0.09	T	34	5.7			
3.6	1.4	.3	4.2	.10	0.1	31	4.7			
5.0	1.8	.5	3.6	T+	.1	28	4.7	50		5
8.0	1.3	.5	6.1	T+	.1	24	4.7			
6.9	.9	.4	5.5	T	.1	20	4.7	50	5	5
5.6	.4	.4	4.7	T	.1	16	4.5			
3.8	.1	.4	3.2	T+	.1	16	4.6			
.8	.1	.2	.5	.01	T	37	5.2			

*Exchange acidity.

Profile No. 97
Area: Covington County, Mississippi.
Vegetation: Mixed forest of pine and hardwood and an understory of dogwood, persimmon, sumac, blackgum, huckleberry, and maple saplings.
Parent Material: Coastal Plain material.
Topography: 3 percent slope, facing northwest.

O1 Thin litter of leaves, principally oak leaves and pine needles.

A1 0 inch to 3 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; coarse, medium, and fine, granular structure; very friable; abundant, coarse and fine roots; abrupt, smooth boundary.

A21 3 to 5 inches, yellowish-brown (10YR 5/4) to light olive-brown (2.5Y 5/4) fine sandy loam; medium and fine, platy structure and some weak, fine, subangular blocky structure; friable; clear, smooth boundary.

A22 5 to 10 inches, brown (10YR 5/3) to yellowish-brown (10YR 5/4) fine sandy loam; weak, medium and fine, granular structure; friable; few, fine roots; many pores filled with material from A1 horizon; many wormcasts; clear, smooth boundary.

B1t 10 to 13 inches, brown (10YR 4/3), yellowish-brown (10YR 5/4), or strong-brown (7.5YR 5/6) loam; weak, medium and fine, subangular blocky structure; friable; clear, smooth boundary.

B2t 13 to 24 inches, yellowish-red (5YR 4/8) loam; moderate, medium and fine, subangular blocky structure; friable, sticky, plastic; clay skins prominent in pores but faint and patchy around peds; clear, smooth boundary.

B3 24 to 32 inches, yellowish-red (5YR 4/8) to strong-brown (7.5YR 5/6) fine sandy loam; weak, medium and fine, subangular blocky structure; slightly sticky, slightly plastic; clay skins continuous along root channels; clear, smooth boundary.

A'2x 32 to 41 inches, yellowish-red (5YR 5/6) to strong-brown (7.5YR 5/6) fine sandy loam; breaks to moderate, medium and coarse, platy and subangular blocky structure; brittle when moist, firm in place, friable when removed; few roots, which are mainly in the gray streaks along faces of peds; few, coarse and fine roots; abrupt wavy boundary.

B'2x 41 to 56 inches, strong-brown (7.5YR 5/6) to very pale-brown (10YR 7/4) sandy loam; coarse, prismatic, breaking to blocky structure with vesicular peds; brittle when moist, firm in place, friable when removed; few roots along gray streaks.

Climatic Data (Laurel, Miss.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	51	52	58	65	73	80	82	82	77	68	56	51	66
Mean precipitation, 1931-52 (inches)	5.4	5.6	7.5	5.8	4.3	4.4	7.2	4.3	3.7	2.2	3.8	5.5	59.8

Annual precipitation more than 42.7 and less than 76.9 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-3	A1	0.6	3.8	16.6	24.4	2.4	46.6	5.6	27.4	27.8	--		2.92	27	0.4
3-5	A21	.1	3.5	16.7	26.3	2.5	45.5	5.4	28.1	26.9	--		.82	25	.5
5-10	A22	.2	3.6	17.6	25.8	2.2	44.7	5.9	27.8	25.5	--		.22	12	.5
10-13	B1t	.1	2.6	13.8	22.2	2.0	47.4	11.9	25.5	29.5	--		.17	6	1.0
13-24	B2t	.1	3.2	13.9	21.0	1.8	37.0	23.0	20.5	23.5	--		.18	6	2.3
24-32	B3	.1	4.1	21.2	34.0	2.9	27.9	9.8	22.4	17.3	--		.08		1.0
32-41	A'2x	.3	4.6	24.4	39.2	3.2	20.8	7.5	21.4	12.6	--		.04		.7
41-56	B'2x	.1	4.3	26.2	28.4	2.7	19.8	18.5	19.3	11.7	--		.06		1.8

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1	Moisture tensions 1/3 atmos. %	15 atmos. %	Cation exch. cap. s
9.2	1.4	0.4	11.9	0.1	0.2	15	4.9	19.9	3.8	14.0
3.8	.6	.4	3.6	<.1	.1	23	5.2	16.9	2.5	4.7
2.0	.2	.1	2.2	<.1	.1	15	5.2	15.5	2.0	2.6
3.4	.3	.8	3.2	<.1	.2	29	5.1	17.9	4.1	4.5
8.3	.3	2.2	6.4	.1	.3	31	5.0	20.4	8.8	9.3
3.0	<.1	.4	3.2	<.1	.1	14	5.0	12.7	3.6	3.7
2.3	<.1	.3	2.3	<.1	.1	15	5.0	10.3	2.9	2.7
4.1	.8	.4	4.1	<.1	.2	25	5.0	13.4	6.6	5.5

*Exchange acidity.

Profile No. 98

Area: Union County, Illinois.

Vegetation: Cutover, deciduous forest consisting mostly of oak.

Parent material: Loess.

Topography: 6 percent slope, facing north; upland.

A1 — 0 to 2 inches, very dark grayish-brown (10YR 3/2) to dark-brown (10YR 3/3) silt loam; moderate, medium, granular structure; friable; clear, smooth boundary.

A21 — 2 to 6 inches, brown (10YR 4/3) silt loam, somewhat mixed with very dark grayish brown (10YR 3/2); moderate, medium, granular structure; friable; clear, smooth boundary.

A22 — 6 to 10½ inches, yellowish-brown (10YR 5/4) to light yellowish-brown (10YR 6/4) silt loam, somewhat mixed with dark grayish brown (10YR 4/2) material; weak, coarse, platy, breaking to moderate, medium, granular structure; friable; clear, smooth boundary.

B1 — 10½ to 15½ inches, dark-brown (7.5YR 4/4), heavy silt loam; moderate, medium and fine, subangular blocky structure; firm; peds have thin coats of yellowish brown (10YR 5/6) or brownish yellow (10YR 6/6); clear, smooth boundary.

B21t — 15½ to 23 inches, dark-brown (7.5YR 4/4), light silty clay loam; strong, medium, subangular blocky structure; firm; peds have thin coats of yellowish brown (10YR 5/6) or brownish yellow (10YR 6/6); clear, smooth boundary.

A'2 — 23 to 27 inches, strong-brown (7.5YR 5/6) silt loam; common, medium mottles of yellowish brown (10YR 5/6) or brownish yellow (10YR 6/6); moderate, fine, subangular blocky structure; friable, firm in place; peds coated with light brownish gray (10YR 6/2 clear smooth boundary.

B'21x — 27 to 35 inches, yellowish-brown (10YR 5/4) silt loam; few, fine mottles of strong brown (7.5YR 5/6); medium, prismatic, breaking to moderate, fine, subangular blocky structure; friable, firm in place, brittle when moist; clay skins evident; prisms are coated with light brownish gray (10YR 6/2); common, medium, iron-manganese concretions; clear, smooth boundary.

B'22x — 35 to 42 inches, dark yellowish-brown (10YR 4/4) silt loam; few fine mottles of yellowish red (5YR 4/8); weak, medium, blocky structure; very firm, brittle when moist; exteriors of peds are light brownish gray (10YR 6/2); common, thin, patchy clay skins; few, fine, iron-manganese concretions; clear, smooth boundary.

B'3x — 42 to 50 inches, dark yellowish-brown (10YR 4/4) silt loam; few, fine mottles of yellowish brown (10YR 5/6); weak, coarse, blocky structure; very firm, brittle when moist; exteriors of peds light brownish gray (10YR 6/2); common, thin, patchy clay skins; common, fine iron-manganese concretions; clear, smooth boundary.

C — 50 to 60 inches, dark yellowish-brown (10YR 4/4) silt loam; many, medium, mottles of light brownish gray (10YR 6/2) and a few, fine mottles of yellowish brown (10YR 5/6); massive; very firm.

Climatic data (Anna, Ill.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	36	38	47	57	66	75	79	77	70	60	47	38	58
Mean precipitation, 1931-52 (inches)	4.4	3.7	5.1	4.9	5.1	4.5	2.8	4.3	4.0	3.6	4.2	3.5	50.2

Annual precipitation more than 33.3 and less than 67.1 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) u	Organic matter C % w	C/N
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate												
0-2	A1	0.1	0.3	0.2	0.5	1.3	83.6	14.0		41.3	0	1.17	2.72	
6-10½	A22	.0	.1	.2	.5	1.2	80.4	17.8		42.2	0	1.32	.35	
15½-23	B21t	.0	.2	.2	.5	1.2	70.9	27.0		39.1	0	1.40	.35	
23-27	A'2	.0	.4	.4	.7	1.1	72.1	25.3		40.4	0		.15	
27-35	B'21x	.0	.4	.4	.7	1.4	73.7	23.4		40.2	0	1.48	.12	
42-50	B'3x	.0	.4	.4	.8	1.5	71.8	25.1		38.7	0	1.51	.08	
50-60	C	.0	.1	.2	.5	1.2	71.3	19.7		41.6	0	1.48	.08	

Cation exch. cap. s	Extractable cations, meq./100 gm. Ca	Mg	H*	Na	K	Base sat. % s	pH 1:1
18.7	10.0	2.3	5.4	0.1	0.8	71	6.5
10.6	.6	.7	8.8	.1	.4	17	4.6
19.1	2.2	2.9	13.6	.1	.3	29	4.4
18.5	1.6	2.6	13.9	.1	.3	25	4.6
18.9	1.8	3.0	13.5	.3	.3	29	4.5
21.3	3.5	5.7	11.0	.8	.3	48	4.6
18.7	4.0	5.4	8.2	.8	.3	56	4.7

*Exchange acidity.

Chapter 16. Oxisols

The Oxisols include the soils that, in recent years, have been called Latosols, and many, if not most, of those that have been called Ground-Water Laterite soils. Earlier, they were called Laterite soils. All soils that have oxic horizons are included in the order. Their epipedons may be umbric or ochric, histic, and perhaps mollic. They may have argillic horizons. Plinthite, either hard or soft, may occur but is diagnostic for the order only if it occurs near the surface in a soft form.

So far as is known to the authors, the occurrence of Oxisols is restricted to tropical and subtropical regions, though it is possible that a few are present as relicts in temperate climates.

Oxisols commonly occupy old land surfaces, but they may occur on young surfaces if the parent materials were very strongly weathered before they were deposited.

The classification of Oxisols has progressed less than that of the other orders. There are several reasons for this. One reason is that, until recently, there has been little intensive study that included detailed mapping of the Oxisols. Also, for the Tropics as a whole, few laboratory data are available that are related to detailed morphologic studies. Another reason is that the soils are relatively featureless. Many properties that have been used for classifying soils of other orders have little relevance in Oxisols. And, most soil morphologists receive their training in temperate regions. Yet another reason is that there are few Oxisols in the United States and there has been little opportunity to test possible differentiae. This is the seventh approximation for the orders that have been discussed so far, but for the Oxisols it is really only about the third approximation of a classification. It is possible that more drastic changes will be needed in this part of the classification than in that that has preceded. For this reason, chapter 7 does not have a key to the suborders for Oxisols, though such keys are provided for the other orders. The key that follows must be considered provisional. Numbers, in place of names, are used for most great groups and subgroups. Suborder names are very tentative. Singular and plural forms for names of suborders and great groups are identical, as in pox.

Key to Suborders of Oxisols

9.1 Oxisols with one or more of the following evidences of present or former wetness:
(a) Plinthite that has not hardened, within 30 cm. (12 inches) of the surface.
(b) A histic epipedon.
(c) Chromas in the upper part of the oxic horizon of 2 or less if free of mottles of higher chroma, or 3 or less if with distinct or prominent mottles.

Aquox, p. 238

9.2 Other Oxisols that have, within 125 cm. (50 inches) of the surface, an oxic horizon with a positive charge or with no charge.

Acrox, p. 239

9.3 Other Oxisols that are permanently moist; and Oxisols that during occasional periods of less than 30 days are dry in some part of the solum, and that have less than 25 percent base saturation in the oxic horizon between depths of 50 and 125 cm. (20 and 50 inches).

Udox, p. 240

9.4 Other Oxisols that have periods when some horizons are dry, and that, between depths of 50 and 125 cm. (20 and 50 inches), have base saturation of less than 50 percent in the oxic horizon.

Ustox, p. 241

9.5 Other Oxisols that are usually dry, or that, between depths of 50 and 125 cm. (20 and 50 inches), have base saturation of more than 50 percent in the oxic horizon.

Idox, p. 242

AQUOX (9.1)

The Aquox include soils that have been called Ground-Water Laterite soils, and a few that fit the definition of Low-Humic Gley soils. They either have oxic horizons and are saturated with water at some season, or they have horizons now within 30 cm. (12 inches) of the surface in which there is plinthite that has not hardened, and, in addition, usually have low chromas on ped faces or low chromas in the matrix. The Aquox occur chiefly in wet sites, on flood plains, or at the base of slopes where there is or has been seepage, or possibly in old paddy fields. A few may occur on slopes where erosion has perhaps truncated a soil and left the plinthite close to the surface. In some of these, the low chromas seem absent.

The Aquox form primarily in tropical and subtropical climates. Pronounced wet-dry climates seem to favor their formation. The native vegetation is mostly forest or water-loving forbs, but some Aquox may now be under savannah, and a few are cultivated, primarily for rice.

The grouping of the soils included in the Aquox has been influenced by several assumptions that are not well documented, and that may not hold everywhere. One is that the plinthite hardens primarily as the result of movement of iron oxides to an exposed surface, followed by crystallization. Cut blocks of plinthite seem to harden irreversibly on the outside if wet and dried repeatedly, which indicates movement of iron oxides to the outsides of the blocks and crystallization there. Cut banks harden on their exposed faces, which again suggests movement of iron oxides to the face of the cut. Plinthite that is in place in the soil below depths of something like 20 or 30 cm. does not seem to harden irreversibly. It may be found now in dry Mediterranean climates, where it is moistened every winter and dried every summer, but it has not hardened in the soil. If exposed at the surface, it hardens irreversibly in a few years. Indurated plinthite, then, unless it is very close to the surface of the soil, is assumed either to have hardened elsewhere and to have been transported, or to have been buried.

A second assumption is that plinthite forms in horizons that are periodically saturated with water. The water may be permanent ground water, temporary ground water, or moving seepage water. The presence of plinthite is considered an evidence of present wetness, or wetness at some earlier period.

The soils that have low chromas but lack plinthite near the surface have little free iron. To have an oxic horizon, they must have appreciable amounts of aluminum oxides. The aluminum oxides seem less mobile in soils than the iron oxides, but a wet soil that contains appreciable amounts can be subject to hardening or to excessive granulation if it is dried. Thus, whether iron is present or absent, the Aquox have properties in common that are of high significance both to soil genesis and to soil behavior.

Key to Aquox

9.11 Aquox having, within 30 cm. (12 inches) of the surface, plinthite that has not hardened.

p. 239

9.110 Soils of 9.11 with plinthite that forms a continuous phase, with dominance of chromas of 2 or less on ped faces, or in the matrix not occupied by plinthite.

p. 239

9.11-9.12 Other 9.11 soils with mottles that have chromas of 2 or less.

p. 239

9.11-9.3 Other 9.11 soils lacking mottles of low chromas.

p. 239

9.12 Other Aquox that have dominant chromas of 2 or less in the matrix below any A1 that has moist color values of 3.5 or less; and Aquox that have dominant chromas of 3 or less if accompanied by distinct or prominent mottles.

p. 239

9.120 Soils of 9.12 having, within 1 meter (40 inches) of the surface, no plinthite that has not hardened.

p. 239

9.12-9.11 Other 9.12 soils having, within depths of less than 1 meter (40 inches), plinthite that has not hardened.

p. 239

Class 9.11

The 9.11 soils occur primarily at the bases of slopes in colluvial sites where they can receive seepage, or on flood plains of large rivers. They are most commonly found in pronounced wet-dry climates, and they are saturated or flooded during the rainy season. Colors in the oxic horizon are most commonly gray or light gray, mottled with dark red immediately below any A1 or Ap that may be present.

Only a very rough start has been made toward definition of the subgroups. It is believed that the orthic subgroup should have plinthite that forms a continuous phase. That is, the red mottles that harden are interconnected in a gray matrix, so that, if the plinthite hardens, a porous, massive ironstone results. Or, the plinthite is present as dark-red lamellae, that can harden into a platy ironstone. The hardening normally follows a change in drainage or in the vegetation. These changes in environment may be natural, or induced by man.

If the plinthite consists of discontinuous red mottles in a gray matrix, the hardening gives rise to a nodular or pisolitic ironstone. Soils with plinthite of this sort are thought best classified in a 9.11-9.12 subgroup.

The soils that are on slopes and that lack gray or light-gray mottles are thought to be truncated soils. They are best intergraded to the Udox or Ustox, according to their other properties.

The 9.11 soils will doubtless intergrade to many soils, but subgroups cannot be defined with present knowledge.

Class 9.12

The 9.12 soils are the aluminum-rich Aquox. If water movement is dominantly downward, the iron oxides, being more mobile than aluminum oxides, are carried deeper and in some places are largely removed from the soil. The 9.12 soils have a thin, dark A1 horizon that, for the most part, rests on a gray or light-gray oxic horizon. A few red or yellowish mottles are normally present, but the plinthite is deep down in the profile or absent.

If the 9.12 soils are permitted to dry, the aluminum oxides may crystallize. If the amounts of aluminum oxides are large, they can cement the soil into sand- and gravel-sized aggregates and thus cause excessive granulation and loss of water-holding capacity. The authors have not observed such granulation in these soils, but it has been observed in the Oxic Andepts. No 9.12 soils are known to occur in the United States, and the classification needs to be developed by others. It can be suggested that the orthic subgroup should not have plinthite within 1 meter of the surface, or possibly within 125 cm. (50 inches). If the plinthite is at a shallower depth, it should indicate a 9.12-9.11 subgroup.

ACROX (9.2)

The Acrox (Gk. akros, at the top, or extreme; and ox, from Oxisol, signifying the most highly weathered) are the Oxisols with oxic horizons that, within 125 cm. (50 inches) of the surface, have net positive charges or are electrically neutral. The soil particles in suspension either migrate toward the cathode or do not migrate. A simple field test is available for identification. If the pH in a 1 normal KCl solution is equal to or higher than the pH in water, the soil should be neutral or have a positive charge. The Acrox have very low silica-sesquioxide ratios in the clay fraction of the oxic horizon.

So far as is known, the Acrox are formed only from highly basic parent materials. The ages of the land surfaces are mostly unknown, but some, at least, seem to be quite old. Humid climates or sites that have rainfall augmented by runoff seem essential to the formation of Acrox, but once formed, the soils may be preserved intact through a change in climate. Consequently, no firm statements about present climates seem safe. The Acrox are thought to occur in Cuba, Puerto Rico, Hawaii, and Brazil. They undoubtedly occur on many of the older Pacific islands, and they should occur in other places where there are old surfaces and basic rocks.

Only one great group is proposed at this time, the Haplacrox, but others may easily occur. The Orthic Haplacrox should not have, within 125 cm. (50 inches) of the surface, plinthite that has not hardened, and should have a net positive charge in the oxic horizon within 75 cm. (30 inches) of the surface; the charge below 75 cm. should be positive or neutral in all horizons to a depth of 125 cm. or more.

Profile 27 is an example of an Orthic Haplacrox. The description is on page 92. Chemical and mineralogical analyses are given in table 15. It seems probable that the quartz in the clay of this soil is not normal to the Haplacrox. The soil is close to the ocean, and additions of quartz by wind action seem quite possible.

Too little is known of the distribution and of the properties of other Haplacrox to suggest much about subgroup definitions. It is thought that the Haplacrox having oxic horizons with negative charges extending deeper than 75 cm. (30 inches) should be in intergrade subgroups. Those that have electrically neutral oxic horizons could be placed either in orthic or intergrade subgroups. The placement of such soils has had little discussion because none have been identified.

UDOX (9.3)

The Udox are extensive, compared with the Aquox and Acrox. They are the Oxisols that are always moist in all horizons, and those that have some horizons that are dry for periods of less than 30 days and that have base saturation of less than 25 percent in the oxic horizon between depths of 50 and 125 cm. (20 and 50 inches). They are therefore found in humid regions that have no dry seasons, as well as in humid regions that have short dry seasons. The Udox have been called Latosols. It has been a common practice to identify the great group by the color. The native vegetation is mostly rain forest, but some areas are in savannah. The savannah commonly follows cultivation or burning, and it is probable that most, if not all, of the savannah on the Udox is anthropic.

Since the climates are humid and the soils contain few or no primary minerals, the Udox normally have low base saturation in the oxic horizon. If bases have been mobilized by collector plants, the Udox have base saturation that decreases with depth in the oxic horizon. An attempt is being made to define the Udox partly on the base status. The limit of 25 percent is proposed tentatively for testing but may need to be changed or dropped. Data at hand are adequate only to allow suggesting the kinds of groupings that will result if base saturation is used as an identifying property for the suborders of Oxisols.

The Udox range widely in their content of organic matter. Clay skins may be present or absent, and texture may vary widely. Some may have argillic horizons, though this is not certain. Plinthite may be present or absent, and if present, may be soft or hard. Bedrock may be very deep, or moderately shallow. These are the main properties that can be used to define great groups and subgroups, unless color is to be used. Color, whether it be hue, value or a combination of both, does not seem to relate well to genetic factors, or to soil behavior. For this reason, color is proposed for use only at the low categoric levels.

Key to Udox

9.31 Udox with an umbric epipedon, or with an ochric epipedon that has a moist color value of 3 or less and that has more than 2 percent organic carbon (3.5 percent organic matter) in the surface 10 cm. (4 inches) if virgin, and more than 3 percent organic matter (1.74 percent carbon) in the Ap if the soil is cultivated.

9.310 Soils of 9.31 with no plinthite that forms a continuous phase and that has not hardened within a depth of 2 meters from the surface; with 20 percent or more clay in the oxic horizon at a depth of 1 meter or less; with no horizon that is immediately below an A1 or Ap and that has enough bleached sand grains to have a higher color value than the next underlying horizon; with very few patchy clay skins or no clay skins on peds or in pores; with the oxic horizon extending to a depth of 1 meter or more.

9.32 Other Udox with an ochric epipedon.

9.320 The concept of the orthic subgroup is identical with that of 9.310, except for the difference in the epipedon.

Class 9.31

The soils of this class include primarily Udox of relatively cool, humid climates. Some have a short dry season; others have none. On the continents between the equator and 6° latitude, they are mostly at elevations somewhat above 1,300 to 1,600 meters (about 4,300 to 5,300 feet). At higher latitudes, or in oceanic climates, the elevations may be lower.

The mean annual temperatures at these elevations are less than about 19° to 21° C. (66° to 70° F.). Temperatures and elevations are not given precise limits, because many factors seem to influence the content of organic matter. But the limits suggested here may be useful to the reader in understanding the general climatic conditions.

The soils of class 9.31 may be moist at all times. Or, if the base saturation (by sum of cations) of the oxic horizon between depths of 50 and 125 cm. (20 and 50 inches) is less than 25 percent, they may have periods of less than 30 days during which some horizons are dry. They have, in addition, an umbric epipedon, or they have a surface horizon with a moist color value of 3 or less that has more than 2 percent organic carbon (3.5 percent organic matter) in the surface 10 cm. (4 inches) if virgin, and more than 3 percent organic matter (1.74 percent organic carbon) in the Ap if the soil is being cultivated. The oxic horizon has a negative charge to a depth of 125 cm. (50 inches) or more.

The distinction between the umbric and ochric epipedon is partly based on the color value, but for many Udox color value has little validity because it seems to be influenced more by the iron oxides than by the organic matter.

A tentative definition of the orthic subgroup is given in the key to Udox. Profile 28, page 93, is an example of the soils of class 9.31 that are never dry at any time. The profile probably is incomplete. The darker horizon at depths between 28 and 34 inches was interpreted in the field as a buried Al horizon, but the data do not substantiate this interpretation. The variegated colors are interpreted as resulting from the varying composition of the parent materials. This soil is believed to be relatively young and to represent soil formation in the present environment.

The presence of weatherable minerals or 2:1 lattice clays, except for traces of vermiculite, suggests a subgroup intergrading to the Inceptisols, either to the Umbrepts or to a great group of tropical Umbrepts that has not yet been defined.

The presence of clay skins in the oxic horizon, accompanied by an increase in content of clay with depth below an Al, might represent an intergrade to the Umbrults.

Mottles of low chromas might indicate an intergrade to the Aquox, class 9.12. Plinthite that has not hardened and that occurs less than about 125 cm. (50 inches) below the surface might indicate an intergrade toward the Aquox, class 9.11.

Profile 99, page 243, is a second example of a soil of class 9.31, but one that contains throughout the oxic horizon, and even in the C horizon, a few patchy clay-skins, the presence of which is confirmed by thin sections. X-ray analyses show small amounts of vermiculite. It is possible to use the presence of the clay skins and the vermiculite to define another great group. It would not seem reasonable to consider this soil an intergrade to the Ultisols. The silt content appears to be high, but thin sections reveal few silt-sized primary minerals. The silt appears to be partly aggregated clay or oxides, but primarily it is silt size crystals of kaolin.

Profile 99 also illustrates why some soils with ochric epipedons are included in class 9.31. The epipedon is umbric in this profile, but it would be ochric if the dark-red colors extended to the bedrock, a feature that is fairly common.

Class 9.32

This class includes the Udox with an ochric epipedon that has a moist color value of more than 3, or that has less than 2 percent organic carbon (3.5 percent organic matter) in the surface 10 cm. (4 inches) if virgin. If the soils are cultivated, the Ap contains less than 3 percent organic matter (1.74 percent organic carbon) or has a moist color value of more than 3.

The soils of class 9.32 are formed chiefly at lower elevations and in warmer climates than those of class 9.31. They are, however, either always moist or are dry in some horizons for only short periods. If there are short periods when some part of the solum is dry, the base saturation of the oxic horizon is less than 25 percent between depths of 50 and 125 cm. below the surface.

The definitions of the orthic and other subgroups should parallel those of class 9.31.

Profile 100, page 244, illustrates the central concept of this class. It will be noted that this profile is very much like profile 99. The silt content is partly the result of incomplete dispersion and partly silt size crystals of kaolin. Vermiculite is present in the upper horizons. However, profile 100 shows no clay skins in thin sections and has lighter color values in most horizons than profile 99. Its content of organic matter is probably high for this class.

USTOX (9.4)

The Ustox also include soils that have been called Latosols. They are found only in humid climates that have pronounced dry seasons. The soils are usually moist, as far as is known, and between depths of 50 and 125 cm. (20 and 50 inches) below the surface, have base saturation of less than 50 percent in the oxic horizon. They lack the evidences of wetness definitive of the Aquox, and have negative charges in the oxic horizon to depths of 125 cm. (50 inches) or more.

The native vegetation may be savannah or forest, but most of the forest is deciduous. Some of the savannah may be natural, but much of it is probably anthropic.

The Ustox generally are similar to the Udox in appearance. The Ustox tend to have a higher base saturation, but there is an overlap in the range of the base saturation for the two suborders.

It is believed that at least three great groups need recognition.

Key to Ustox

9.41 Ustox that have an umbric epipedon, and that have, in the oxic horizon, a subhorizon that is darker in color or has a lower chroma than the horizons above and below, and this darker horizon contains some clay skins and has in its mass or in its clay fraction a higher content of organic matter than the overlying and underlying parts of the oxic horizon.
9.42 Other Ustox with an umbric epipedon.
9.43 Other Ustox with an ochric epipedon.

Class 9.41

The soils of this class have been called Dark-Horizon Latosols. They are characterized by an umbric epipedon, and by a "dark horizon," the upper surface of which is 75 to 100 cm. (30 to 40 inches) below the surface. Few data on these soils are available. Profile 101, page 245, is an example of what probably should be the orthic subgroup. The soils, however, are unknown in the United States, and the definitions of the great group and the subgroups need to be developed by others.

Class 9.42

This class includes Ustox that have no "dark horizon" but that have an umbric epipedon. In appearance, many closely resemble the soils of class 931. The definitions of the orthic and other subgroups should parallel those of class 9.31.

Class 9.43

This class includes Ustox that have an ochric epipedon. In appearance, they closely resemble the soils of class 9.32. The definitions of the orthic and other subgroups should parallel those of class 9.32.

IDOX (9.5)

The Idox[1] include the Oxisols that are usually dry or that have prolonged dry seasons and have base saturation of 50 percent or more in the oxic horizon.

If they developed in their present climate, the genesis of most Idox is difficult to understand. Some, considering the landforms, are obviously very old soils, and the past climates are thought to have been more humid. Some soils that are thought to belong to this class have ca horizons that are weak but discernible. Plinthite is common and, on what are thought to be Idox, may form a desert pavement. If the assumptions about the formation and hardening of plinthite are correct as outlined in the discussion of Aquox, the plinthite could not have formed in the present environment.

Only one great group is being proposed for the Idox at this time, the Haplidox. These soils have been called Low-Humic Latosols. The orthic subgroup should have an oxic horizon that extends to at least 1 meter (40 inches) below the surface, and within this depth there should be no plinthite that has not hardened. The definition of this subgroup is very incomplete, but little more can be added at this time.

Profile 102, page 246, is an example of a Haplidox, probably an Orthic Haplidox. The content of clay and silt reported appears to be inaccurate. Thin sections reveal little silt. The sand consists largely of what appear to be iron-cemented aggregates. The base-exchange capacities of the oxic horizon are high for an Oxisol, and they may indicate the presence of some allophane. Thin sections show no clay skins. No 2:1 lattice clays have been identified. The presence of montmorillonite in the shells of boulders now weathering in comparable soils lends weight to the thought that the Idox have formed in a different environment or have formed from materials that were weathered in a different environment.

[1] Taken from the final formative element of the names of classes of Aridisols and the ending *ox*, from Oxisol. Pronounce *id*, as in idiom. The name is tentative.

Profile Descriptions for Chapter 16

(Colors for moist soil unless otherwise stated)

Profile No. 99

Area: Cibuco, Puerto Rico.
Vegetation: Unimproved pasture.
Parent material: Residuum from mixed andesitic and basaltic flows.
Topography: Convex slope, facing southeast; mountainous relief; elevation 1,575 feet.

Ap 0 to 6 inches, dark reddish-brown (5YR 3/4) clay; strong, fine to very fine, granular structure; firm, slightly sticky, slightly plastic; abrupt, smooth boundary.

B21 6 to 14 inches, dark-red (2.5YR 3/6) clay; few mottles of yellowish brown (10YR 5/4); weak, medium, subangular blocky, breaking to moderate, very fine, blocky structure; firm, slightly sticky, slightly plastic; thin, patchy, films of clay; few, fine pores; stringers of Ap horizon, intermixed with this horizon; gradual, smooth boundary.

B22 14 to 26 inches, dark-red (10R 3/6) clay; fine, distinct mottles of reddish brown (5YR 4/4); moderate, very fine, blocky structure; firm, slightly sticky, slightly plastic; patchy films of clay; few, fine pores; clear, smooth boundary.

B23 26 to 37 inches, weak-red (10R 4/4) to red (10YR 4/6) clay; weak, medium, subangular blocky, breaking to strong, very fine, angular blocky structure; firm, slightly sticky, slightly plastic; few, thin, patchy films of clay; gradual, smooth boundary.

B24 37 to 48 inches, red (10R 4/6) clay, in other features similar to B23 horizon.

B3 48 to 60 inches, dark-red (2.5YR 3/6) clay; weak, medium, subangular blocky, breaking to moderate, very fine, angular blocky structure; firm, slightly sticky, slightly plastic; few, thin patchy films of clay; clear, wavy boundary.

C1 60 to 71 inches, dominantly weak-red (10R 4/4) to red (10R 4/6) clay loam or silty clay loam; color is variable and ranges to strong brown (7.5YR 5/6); massive; friable, nonsticky, nonplastic.

C2 71 to 78 inches, dominantly yellowish-red (5YR 4/6) clay loam or silty clay loam; color is variable and ranges from red (10R 4/6) to strong brown (7.5YR 5/6); massive; firm, fine pores.

C3 117 to 128 inches, saprolite, similar to C2 horizon.

Climatic data (Cordzal, P. R.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	73	72	73	75	77	78	78	78	78	78	76	74	76
Mean precipitation, 1931-52 (inches)	5.3	3.9	3.1	5.6	9.1	5.5	7.7	9.0	6.8	7.0	8.2	5.7	76.8

Annual precipitation more than 61.8 and less than 91.8 inches during 9 years out of 10.

Depth, inches	Horizon	Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
		Particle size distribution (mm.) (%) Pipette and hexametaphosphate													
0-6	Ap	0.3	0.6	0.8	3.8	3.0	19.1	72.4	8.5	16.0	--	1.19	2.72	12	14.7
6-14	B21	.1	.2	.2	1.4	1.5	20.5	76.1	4.4	18.5	--	1.30	1.42	10	16.4
14-26	B22	<.1	<.1	.2	2.0	2.4	27.6	67.8	6.4	25.0	--	1.42	.66	12	16.2
26-37	B23	<.1	.1	.3	2.6	2.4	35.6	59.0	7.1	32.6	--	1.51	.24		12.2
37-48	B24	<.1	.1	.3	3.0	2.8	34.1	59.7	8.4	30.5	--	1.51	.22		13.5
48-60	B3	<.1	.1	.4	3.5	3.7	34.7	57.6	11.0	29.8	--	1.43	.26		12.5
60-71	C1	1.6	2.8	2.7	7.7	7.5	39.6	38.1	20.9	30.8	--	1.42	.16		11.8
71-78	C2	.4	1.3	2.5	9.7	9.4	41.8	34.9	24.5	32.6	--	1.30	.21		13.6
117-128	C3	.1	.5	2.0	10.5	10.2	44.3	32.4	27.2	34.1	--		.06		10.9

Cation exch. cap. b	Ca	Mg	H*	Na	K	Base sat. % s	pH H_2O 1:1	pH 1N KCl 1:1	Cation exch. cap. s	Moisture tensions 1/3 atmos. %	15 atmos. %
	Extractable cations, meq./100 gm.										
16.7	2.1	0.6	21.3	0.1	0.2	12	4.6	3.8	24.3	41.9	30.5
13.0	3.2	1.5	16.8	.1	.1	22	5.0	4.2	21.7	43.0	32.1
12.8	1.0	.8	16.7	<.1	.1	10	5.1	3.9	18.6	40.3	30.1
11.9	.5	.6	14.3	<.1	.1	8	4.9	3.8	15.5	36.8	26.5
11.7	.5	.9	15.1	<.1	.1	9	4.9	3.8	16.6	38.1	26.9
11.4	.6	.9	14.3	<.1	.1	10	4.9	3.7	15.9	39.6	27.0
10.4	.5	.8	11.8	<.1	.1	11	4.8	3.6	13.2	38.4	18.7
11.1	.5	.6	12.6	<.1	.1	9	4.8	3.6	13.8	41.7	19.7
12.0	1.2	.8	14.3	<.1	.1	13	4.8	3.5	16.4	48.2	21.4

*Exchange acidity.

Profile No. 100

Area: Cibuco, Puerto Rico
Vegetation: Unimproved pasture.
Parent Material: Residuum from mixed andesitic and basaltic flows.
Topography: 25 percent slope, facing west; intermountain; elevation 2,130 feet.

Ap 0 to 10 inches, brown to dark-brown (7.5YR 4/4) clay; weak, medium, subangular blocky, breaking to moderate, fine, granular structure; firm, slightly sticky, slightly plastic; abrupt, wavy boundary.

B11 10 to 14 inches, reddish-brown (5YR 5/4) clay; weak to moderate, medium, subangular blocky structure; firm, slightly sticky, slightly plastic; clear, smooth boundary.

B12 14 to 23 inches, yellowish-red (5YR 4/6) clay; few, medium mottles of yellowish brown 10YR 5/5); weak, coarse, prismatic, breaking to moderate, medium to fine, subangular and angular blocky structure; firm, slightly sticky, slightly plastic; clear, smooth boundary.

B21 23 to 31 inches, red (2.5YR 4/6) clay; strong, medium to fine, angular blocky structure; firm, slightly sticky, slightly plastic; gradual, smooth boundary.

B22 31 to 43 inches, similar to B21 horizon except strong tendency for structure to become slightly subangular.

B23 43 to 59 inches, red (2.5YR 4/6) clay; moderate, fine, subangular blocky structure; firm, slightly sticky, slightly plastic; gradual, smooth boundary.

B3 59 to 72 inches, red (2.5YR 4/6) to yellowish-red (5YR 4/6) clay; weak, medium to fine, subangular blocky structure; firm, slightly sticky, slightly plastic; few, small, angular fragments of parent rock; clear, smooth boundary.

C1 72 to 86 inches, yellowish-red (5YR 4/6) to red (2.5YR 4/8) clay loam; very fine mottles of strong brown (7.5YR 5/6) to reddish yellow (7.5YR 6/6); massive; some evidence of parent rock structure; friable, slightly sticky, slightly plastic; gradual, smooth boundary.

C2 86 to 90 inches, yellowish-red (5YR 4/6) loam, massive; friable, slightly sticky, slightly plastic; few, very fine pores; bedrock at depth of 90 inches.

Climatic data (Cordzal, P. R.)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1931-52 (deg. F.)	73	72	73	75	77	78	78	78	78	78	76	74	76
Mean precipitation, 1931-52 (inches)	5.3	3.9	3.1	5.6	9.1	5.5	7.7	9.0	6.8	7.0	8.2	5.7	76.8

Annual precipitation more than 61.8 and less than 91.8 inches during 9 years out of 10.

Depth, inches	Hori-zon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.) c	Organic matter C % w	C/N k	Free iron oxides Fe_2O_3 %
0-10	Ap	0.2	.3	0.3	0.6	1.1	26.1	71.4	4.4	23.2	---	1.05	3.45	15	11.4
10-14	B11	.4	.4	.2	.6	1.0	23.8	73.6	4.0	21.2	---	1.26	1.56	12	12.6
14-23	B12	.3	.2	.1	.6	.9	26.7	71.2	3.8	24.2	---	1.26	.88	9	14.2
23-31	B21	< .1	<.1	.1	.8	1.7	37.1	60.3	6.1	33.3	---	1.44	.60	11	15.5
31-43	B22	.1	.2	.3	1.9	3.1	43.0	51.4	9.6	37.8	---	1.42	.48		15.6
43-59	B23	< .1	.2	.7	3.6	5.2	47.5	42.8	15.0	40.1	---	1.30	.38		14.4
59-72	B3	.1	1.0	1.9	5.9	6.7	48.3	36.1	18.5	40.1	---	1.26	.32		14.1
72-86	C1	1.2	4.3	4.4	9.3	8.0	45.5	27.3	22.4	36.4	---	1.16	.26		12.6
86-90	C2	1.2	4.4	4.2	8.8	7.9	48.8	24.7	21.7	40.0	---	1.12	.22		13.7

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH H_2O 1:1	pH 1N KCl 1:1	Base sat. % s	Cation exch. cap. s	Moisture tensions: 1/3 atmos. %	15 atmos. %
19.2	0.9	1.0	28.7	0.1	0.2	4.5	3.4	7	30.9	45.9	31.7
13.8	.7	.8	21.7	.1	.1	4.8	3.5	7	23.4	46.2	32.6
13.2	.7	.6	19.2	.1	< .1	4.9	3.6	7	20.6	45.1	32.8
12.5	.5	.8	19.7	.1	<.1	4.8	3.5	7	21.1	41.7	30.1
11.8	.3	.7	17.1	.1	<.1	4.8	3.5	6	18.2	41.1	28.2
12.1	.3	.4	18.0	.1	<.1	4.7	3.5	4	18.8	41.7	27.2
12.1	.1	< .1	17.1	.1	<.1	4.7	3.5	1	17.3	43.7	24.6
10.9	.1	1.2	15.1	.1	.1	4.8	3.6	9	16.6	46.1	22.0
11.1	.1	.8	15.9	.1	.1	4.7	3.6	6	17.0	47.2	19.5

*Exchange acidity.

Profile No. 101
Area: At Rubona, Belgian Congo.
Vegetation: Cultivated; probably forested, long ago.
Parent material: Probably a mixture of colluvium from relatively basic rocks and possibly granite.
Topography: Rolling; elevation about 5,400 feet.

Ap 0 to 12 inches, dark reddish-gray (5YR 4/2, dry) sandy clay loam; granular structure; loose.
A12 12 to 22 inches, dark reddish-gray (5YR 4/2, dry) sandy clay loam; granular structure; very friable.
B1 22 to 40 inches, reddish-brown (5YR 4/3, dry) sandy clay loam; weak, subangular blocky, breaking to granular structure; friable.
B2 40 to 62 inches, nearly black sandy clay, very dark reddish brown (5YR 2/2) when dry; brown streaks and spots; horizon is 5 to 30 inches thick; tongues extend into the B3 horizon.
B3 62 to 75 inches, reddish-brown (5YR 4/4, dry) clay; mottles of dark brown, brown, and reddish yellow; massive, breaking to subangular blocky structure; firm.
C 75 to 80 inches +, reddish-yellow (5YR 6/6, dry) clay; mottles of brown and yellow; massive; firm.

Remarks: Roots penetrate to a depth of about 72 inches.

Climatic data (Rubona, Ruana-Urundi)	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1940-54 (deg. F.)	67	67	67	67	67	66	66	68	69	68	67	68	67
Mean precipitation, 1930-54 (inches)	4.2	4.5	5.5	7.0	6.4	1.0	0.3	1.0	2.4	4.0	4.4	3.3	44.0

Annual precipitation more than 32.7 and less than 55.3 inches during 9 years out of 10.

Depth, inches	Horizon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N
0-12	Ap	8.4	17.9	10.9	18.6	6.2	7.6	30.4		4.0			1.6	
12-22	A12	9.1	13.8	9.7	19.0	7.3	8.4	32.7		4.6			1.3	
22-40	B1	9.5	12.9	8.7	17.4	6.7	8.0	36.8		3.9			.7	
40-62	B2	7.0	11.6	7.3	13.6	5.7	6.1	48.7		3.2			1.8	
62-75	B3	7.4	7.9	5.6	12.1	5.6	6.1	55.3		3.2			.6	
75-80	C	9.0	7.4	4.5	9.4	4.4	4.3	61.0		3.4			.3	

Cation exch. cap. b	Extractable cations, meq./100 gm.: Ca	Mg	H*	Mn	K	Base sat. % b	pH 1:1
14.0	3.0	1.1	9.1	0.09	0.7	35	5.5
13.2	1.8	.6	8.9	.06	1.8	32	6.7
11.2	1.0	.4	8.8	.05	.9	21	5.0
27.1	2.3	.1	24.5	<.01	.2	10	4.7
13.9	2.4	.1	11.3	.01	.1	19	4.4
9.3	1.4	.1	7.7	<.01	.1	17	4.4

*Exchange acidity.

Profile No. 102
Area: Island of Molokai, Hawaii.
Vegetation: Pineapple.
Parent material: Residuum from basic igneous rock (mostly ultrabasaltic rock)
Topography: 6 percent slope, facing west; gentle, low slopes of Maunaloa; elevation 425 feet.

Ap1 0 to 7 inches, dusky red (10R 3/3), weak red (10R 4/3) when dry; cloddy, breaking to weak, very fine, granular structure; slightly hard, very friable, sticky, very plastic; many, very fine and fine interstitial pores; common, very fine, black pellets of manganese; abrupt, wavy boundary.

Ap2 7 to 12 inches, dusky red (10R 3/3), weak red (10R 4/3) when dry; weak, coarse, subangular blocky, breaking to weak, fine, granular structure; slightly hard, friable, sticky, very plastic; common, fine roots; many, very fine and fine, interstitial pores; common, very fine, black pellets of manganese; clear, wavy boundary.

B21 12 to 17 inches, dusky red (10R 3/4), weak red (10R 4/4) when dry, and crushes to dark red (2.5YR 3/6) when dry; weak, coarse, prismatic, breaking to weak, fine and medium, subangular, blocky structure; slightly hard, friable, sticky, very plastic; few, patchy, gelatinous films; common, fine roots; many, very fine and fine, tubular pores; few, fine, black coats of manganese on faces of peds; clear, wavy boundary.

B22 17 to 32 inches, dusky red (10R 3/4); weak, coarse, prismatic breaking to weak, fine, and medium, subangular blocky structure; slightly hard, friable, sticky, very plastic, compact in place; common, thick, gelatinous films on faces of peds; few roots; many, very fine and fine, tubular pores, few, fine, black pellets of manganese.

B23 32 to 53 inches, dusky red (10R 3/4); moderate, very fine and fine, subangular blocky structure; hard, friable, sticky, very plastic, compact in place; thin, continuous, gelatinous films; many, very fine and medium, tubular pores; common, black coats of manganese on faces of peds; gradual boundary.

B24 53 to 64 inches, dusky red (10R 3/4); crushed color is dark red (2.5YR 3/6); moderate, very fine and fine, subangular structure; hard, friable, sticky, very plastic, very compact in place; continuous, gelatinous films; many, fine and medium, tubular pores; common, black coats of manganese on faces of peds; gradual, wavy boundary.

C 64 to 72 inches +, dark reddish-brown (2.5YR 3/4); strong, very fine, subangular blocky structure; hard, friable, sticky, plastic, compact in place; continuous, gelatinous films; many, very fine and fine, tubular pores; few pockets of gray, very highly weathered fragments of rock.

Climatic data (Hoolehua, Hawaii)*	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean temperatures, 1919-52 (deg. F.)	69	69	69	70	72	74	75	76	76	75	72	70	72
Mean precipitation, 1931-52 (inches)	3.4	2.7	3.5	2.6	1.1	0.4	0.5	0.7	0.5	2.4	2.6	2.6	22.9

Annual precipitation more than 9.6 and less than 36.2 inches during 9 years out of 10.
*Temperature data from Kualapuu

Depth, inches	Hori-zon	Particle size distribution (mm.) (%) Pipette and hexametaphosphate: Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Silt 0.05-0.002	Clay <0.002	0.2-0.02	0.02-0.002	>2	B.D. (gm. per cc.)	Organic matter C % w	C/N m	Free iron oxides Fe_2O_3 %
0-7	Ap1	0.1	0.2	0.5	5.4	15.0	47.9	30.9	39.3	27.8	---		0.93	6	17.0
7-12	Ap2	.1	.2	.7	6.2	18.2	42.2	32.4	42.0	23.2	---		.60	5	18.6
12-17	B21	.0	.2	.5	4.8	12.8	45.3	36.4	33.9	27.9	---		.74	5	18.1
17-32	B22	.2	.9	1.3	7.9	10.6	33.3	36.8	41.4	17.6	---		.31	4	19.3
32-53	B23	1.4	2.3	3.0	11.6	17.1	32.6	32.0	40.2	17.8	---		.24		19.7
53-64	B24	5.2	5.7	4.9	10.9	12.2	28.0	33.1	30.4	16.4	---		.18		19.8
64-72+	C	9.6	8.9	6.8	10.4	10.2	24.3	29.8	25.0	15.2	---		.24		17.4

Cation exch. cap.	Extractable cations, meq./100 gm.: Ca	Mg	H*	Na	K	pH 1:1	pH 1N KCl 1:1	Base sat. % s	Moisture tensions 1/3 atmos. %	15 atmos. %	Elemental analyses** (mols/100 gm.) SiO_2 g	Al_2O_3 g	Fe_2O_3 g
21.7	4.6	3.2	11.3	0.51	2.08	6.3	6.0	48	25.4	19.9	0.5079	0.2723	0.1609
18.8	5.1	3.3	9.2	.42	.79	6.6	6.3	51	24.8	20.4	.4935	.2809	.1648
20.2	4.7	3.0	11.1	.35	1.09	6.1	5.7	45	24.3	20.4	.5118	.2785	.1524
18.8	4.8	5.5	7.4	.40	.76	6.9	6.9	61	25.4	20.5	.4985	.2731	.1703
19.8	4.5	4.9	8.4	.67	1.32	7.0	6.9	58	28.4	23.5	.4939	.2738	.1688
21.0	4.4	4.4	9.6	1.06	1.52	6.9	6.6	54	31.3	25.0	.4812	.2833	.1623
21.7	3.3	3.8	10.7	2.03	1.90	6.8	6.5	51	32.3	26.0	.4939	.2997	.1553

*Exchange acidity.
**Elemental analyses by Univ. Hawaii, Dept. Agronomy and Soil Science, Hawaii Agr. Expt. Sta.

Chapter 17. Histosols

The Histosols include the soils previously called Bog soils, or organic soils, and some Half-Bog soils. While there has been much discussion, there has been little agreement on the classification of the Histosols. Traditionally, in the United States, an attempt has been made to define the series of the Bog soils in large part on the botanic composition of the plants that formed the peat and on the presence or absence of identifiable plant remains. The main grouping within the Bog soils has been made on the presence or absence of a thin surface layer of muck. This has given muck and peat types within a few series. A few other types have been recognized on the basis of the presence or absence of a surface mineral layer.

In other countries, the Bog soils have been grouped either as oligotrophic, mesotrophic, and eutrophic peats, or as high and low moors. These have been the conventional bases for groupings of Bog soils.

Two bases have been proposed for the classification of the Histosols, in addition to the nutrient status, and the type of plant remains. These are the presence and nature of genetic horizons, and the sequence of depositional layers. The properties that can be used for classification of Histosols include physical and chemical properties, the presence of genetic horizons, the sequence of depositional layers that reflect the history of the bog, and the botanic composition of the plant remains. Among the physical properties we might list the thickness, bulk density, water-holding capacity, temperature, permeability, and irreversible drying. Among the chemical properties that we should consider are the presence or absence of carbonates, bog iron, sulfates and sulfides, carbon-nitrogen ratios, nature of the mineral fraction, pH, base saturation, and degree of decomposition. Among the horizons that can develop in organic soils we can list decomposition to form surface horizons with varying properties, and the formation of an illuvial humus horizon. The depositional layers include basal layers of sedimentary peat, diatomaceous earth, calcium carbonate, decomposed peat, fibrous and woody peats, and moss peats. The sequence of depositional layers indicates, among other things, the history of the bog including its hydrology.

The criteria that have been used for the classification of the soils of the other orders have been, with no apparent exception, properties of the soil. Kinds of horizons have been used as differentiae. The properties of layers that lie below the soil have not been used consciously. The presence of hard rock or permafrost below the soil has been used as a differentia in situations where, in effect, rock or permafrost truncate the soil and make it thin.

If the classification of Histosols is to be consistent with the rest of the system, the only properties that may be considered are those that are soil properties. The nature of the depositional layers at depths of several meters are not appropriate for use in any category of this system. They are, however, appropriate for the definition of phases, if they influence soil behavior. Histosols should be included in a single classification system with mineral soils, for there are many intergrades between the Histosols and several orders of mineral soils.

If one were to classify peats or bogs, the nature and sequence of the depositional layers would form a logical basis. But this is a classification of soils, not of peat deposits.

It has been emphasized that a soil does not necessarily have genetic horizons. The surface layers of the peat deposits are soils, within the meaning of the word as it is used here. The presence or absence of horizons in the soil forms one logical basis for classification of Histosols.

It has also been emphasized that relations of soils are concealed if the classification is changed by plowing and cultivating for a few years, or by a single fire. The Histosols are an exception to the effect of fire, because they can be completely destroyed by one fire. They must also be considered in a somewhat different light than the mineral soils, insofar as the effects of drainage and cultivation are concerned. A mineral soil may be cultivated for hundreds of years. If it is not subject to erosion, it may show only limited change because of the cultivation. In contrast, if the organic deposit is thin, the Histosols may disappear completely in a few decades. Under drainage or cultivation, their existence, at best, involves only a century or so. The soil morphologist must be reconciled to the fact that the Histosols do change, sometimes drastically, in a very few decades--a short time even in the life of one man. So, if a Histosol is cultivated, its properties and its classification are subject to change. This seems inescapable. Yet the less the classification has to be changed, the better it will show relations between the cultivated or drained soils and the undrained soils. This relationship is important, for it can be used as a basis for predictions about the behavior of Histosols that are to be developed for agriculture.

No definite proposals for the classification of Histosols are made at this time. Instead, we will outline, with their advantages and disadvantages, the two proposals that are being considered.

One proposal is to classify the Histosols in the higher categories on the nature of their genetic horizons and in the lower categories on the nature of their other properties.

The decomposition of the surface layers produces a dark-colored, finely divided muck of varying thickness. It is possible to define at least two such horizons, one that is comparable to the mollic epipedon in its properties, and the other comparable to the umbric epipedon. The first has a high base saturation, a pH of more than 5, and carbon-nitrogen ratios of less than 17. The second is more acid or has carbon-nitrogen ratios of more than 17. The thickness that is necessary for these horizons has not been determined, but it must be an arbitrary thickness. It probably should be somewhere between 15 and 30 cm. (6 and 12 inches).

One suborder of Histosols might be defined as having one or the other of these epipedons. This suborder could have three great groups, one with the "umbric" epipedon on peat, a second with the "umbric" epipedon on peat that contains an illuvial humus B horizon, and the third with the "mollic" epipedon.

The second suborder, without a "mollic" or "umbric" epipedon, would have several great groups.

One could be provided for the Histosols with an organic B. A second may be wanted for the Histosols with high N factors, comparable to the Hydraquents. A third might have permafrost, and a fourth might have no diagnostic horizons.

The subgroups would provide for orthic classes, for intergrades to the other Histosols, and for intergrades to a number of the classes of mineral soils, including Aquents, Aquepts, and Aquods.

The families might be defined on water-holding capacity and on the particle-size distribution of the mineral fraction if it is large, rather than texture; on the presence or absence of carbonates, sulfates, sulfides, and bog iron, instead of mineralogy; and on irreversible drying, rather than consistence. Series definitions would be based largely on other properties of the depositional layers within the soil; thus the plant remains would be treated as the parent material of the soil.

Such a classification would be entirely consistent with the classification of the mineral soils. Classes above the series category are defined in terms of properties that can be determined in any Histosol.

The second proposal being discussed has two suborders, one dominantly of unaltered or slightly altered organic materials, and the other dominantly of altered materials. The great groups are defined in very different terms from those of the first proposal. The unaltered peats have several great groups based on the kind of plant remains in the peat. Sphagnum moss peat, fibrous peat, woody peat, and mixed peats would constitute different great groups. The altered peats would have great groups for sedimentary peat, disintegrated peat, and muck. The subgroups provide for orthic classes and intergrades to other great groups of Histosols. Families provide for deep and shallow peats, for the presence of differing organic layers at the base of the soil, and for differences in the nature of the mineral substratum under shallow peats. Series are defined on the sequence of the different layers within the soil, the reaction, toxic materials, and other properties of the soil.

Considering change that takes place in Histosols, this second proposal provides a classification that may need change a little less quickly than the first. But the second proposal, as it stands, has one defect that seems very serious; that is, a definition of great groups based on an entirely artificial distinction between trees on the one hand, and forbs and grasses on the other. The properties of the peats themselves are not considered. If peats from other continents are to be related to those of North America, this classification is useless in showing relationships. The papyrus is a forb, but this is hardly an adequate basis for grouping the papyrus peats with those formed from sedges. The mangrove is a tree, but the mangrove-swamp peats can be much more like those formed from sedges in Illinois than those formed from larch (tamarack), spruce, and cedar.

This defect is one that can be corrected by analysis of the reasons for making distinctions between woody and herbaceous peats. The classes should be defined on the properties of the two kinds of peat that led to the original desire to distinguish them.

The distinction between sphagnum-moss peat and other peats can be justified on the basis of the peculiar structure of the sphagnum plant that gives the peat a high water-holding capacity. This, however, is a physical property that would also be appropriate at the family level.

The proposal to define the classes of the higher categories on the presence or absence of horizons has the advantage that it can be applied generally to all organic soils. The classification will probably change a little more rapidly as the peat changes under drainage and cultivation.

Neither of the proposals seems likely to be adopted without changes, perhaps drastic changes. At this writing it is impossible to foresee the nature of the classification that will finally be adopted.

Appendix I. Soil Survey Manual Terminology for Describing Soils

HORIZON BOUNDARIES

Horizon boundaries vary (1) in distinctness, and (2) in surface topography. Some boundaries are clear and sharp, as those between A_2 and B_2 horizons in most solodized-Solonetz and well-developed Podzols. Again they may be diffuse, with one horizon gradually merging into another, as between the A_1 and A_3 of Chernozem or the B_2 and B_3 of many Latosols. With these diffuse horizons, the location of the boundary requires time-consuming comparisons of small samples of soil from various parts of the profile until the midpoints are established. Small markers can be inserted until all horizons of the profile are worked out; then measurements can be taken; and finally the individual horizons can be described and sampled. Sampling can often begin with the lowest horizon to good advantage.

The distinction of the horizons to the observer depends partly upon the contrast between them—some adjacent ones are highly contrasting in several features—and partly upon the width of the boundary itself or the amount of the profile in the transition between one horizon and the next. The characteristic widths of boundaries between soil horizons may be described as (1) *abrupt*, if less than 1 inch wide; (2) *clear*, if about 1 to 2½ inches wide; (3) *gradual*, if 2½ to 5 inches wide; and (4) *diffuse*, if more than 5 inches wide.

The topography of different soil horizons varies, as well as their distinctness. Although observations of soil horizons are made in profiles or sections, and so photographed or sketched, we must continually recall that they are not "bands" (or literally "horizons" as that word is understood in everyday speech) but rather three-dimensional layers that may be smooth or exceedingly irregular. Horizon boundaries may thus be described as (1) *smooth*, if nearly a plane; (2) *wavy* or undulating, if pockets are wider than their depth; (3) *irregular*, if irregular pockets are deeper than their width; and (4) *broken*, if parts of the horizon are unconnected with other parts, as the B_2 in the limestone cracks of a truncated Terra Rossa.

COLOR PATTERNS

Nearly every soil profile consists of several horizons differing in color. For every soil examined and described in the field, the complete color profile should be presented. A single horizon may be uniform in color or it may be streaked, spotted, variegated, or mottled in many ways. Local accumulations of lime or organic matter may produce a spotted appearance. Streaks or tongues of color may result from the seeping downward of colloids, organic matter, or iron compounds from overlying horizons. Certain combinations of mottled colors, mainly the grays and browns, indicate impeded drainage. The word "mottled" means marked with spots of color. Some mottled colors occur unassociated with poor drainage, either past or present. A mottled or variegated pattern of colors occurs in many soil horizons and especially in parent materials that are not completely weathered.

Mottling in soils is described by noting: (1) The color of the matrix and the color, or colors, of the principal mottles, and (2) the pattern of the mottling. The color of the mottles may be defined by using the Munsell notation, as with other soil masses; but usually it is sufficient and even better to use the standard linguistic equivalents, since precise measurement of the color of the mottles is rarely significant. In fact, descriptions of soil horizons containing several Munsell notations are difficult to read rapidly.

The pattern of mottles can be conveniently described by three sets of notations: contrast, abundance, and size.[4]

Contrast.—Contrast may be described as *faint, distinct*, or *prominent* as follows:

Faint: Indistinct mottles are evident and recognizable only with close examination. Soil colors in both the matrix and mottles have closely related hues and chromas.

Distinct: Although not striking, the mottles are readily seen. The hue, value, and chroma of the matrix are easily distinguished from those of the mottles. They may vary as much as one or two hues or several units in chroma or value. The pattern may be one of a continuous matrix with mottles or one of mixtures of two or more colors.

Prominent: The conspicuous mottles are obvious and mottling is one of the outstanding features of the horizon. Hue, chroma, and value may be several units apart. The pattern may be one of a continuous matrix with contrasting mottles or one of mixtures of two or more colors.

Abundance.—Abundance of mottles can be indicated in three general classes as: *few, common*, and *many*, based upon the relative amount of mottled surface in the unit area of the exposed soil horizon, as follows:[5]

Few: Mottles occupy less than about 2 percent of the exposed surface.
Common: Mottles occupy about 2 to 20 percent of the exposed surface.
Many: Mottles occupy more than 20 percent of the exposed surface. This last class can be further subdivided according to whether (a) the mottles set in a definite matrix or (b) there is no clear matrix color.

Size.—Size refers to the approximate diameters of individual mottles. Three relative size classes can be used as follows:

Fine: Mottles less than 5 mm. in diameter along the greatest dimension.
Medium: Mottles range between 5 and 15 mm. in diameter along the greatest dimension.
Coarse: Mottles are greater than 15 mm. in diameter along the greatest dimension.

In the detailed examination of some soil horizons, it may be necessary to add still further notes on the mottling to indicate whether or not the boundaries of the mottles are sharp (knife-edge), clear (less than 2 mm. wide), or diffuse (more than 2 mm. wide). Although many mottles are roughly circular in cross-section, others are elongated and merge into streaks or tongues. Although, normally, mottling carries no inferences of differences in texture as compared to the matrix, many soils show mottling in a freshly exposed horizon because of the slicing of incipient concretions.

[4] This discussion is based on a recent paper: SIMONSON, R. W. DESCRIPTION OF MOTTLING IN SOILS. Soil Science. 7: 187–192. 1951.

[5] The suggested limits are tentative only. More research is needed to establish the most useful size classes and number of classes.

In soil descriptions the mottling can be most conveniently described by describing the mottles as to abundance, size, contrast, and color, such as, ". . . brown silt loam with few, fine, distinct reddish-brown and dark-gray mottles."

In verbal descriptions of soil mottling intended for the general reader, part of the detail needed in detailed soil morphology and correlation may be omitted. Thus, starting with the classes according to abundance, descriptions may be written as follows:

1. *Few:* ". . . brown silt loam, slightly mottled with red and yellow."
2. *Common:* ". . . brown silt loam, mottled with red and yellow."
3. *Many:*
   (a) If the matrix is clearly apparent: ". . . brown silt loam, highly mottled with red and yellow."
   (b) If no clear matrix exists: ". . . mottled red, yellow, and brown silt loam."

If contrast is not clearly shown by the color names, "faintly" or "prominently" may be added. Faint mottling can be implied as ". . . brown silt loam, mottled with shades."

If size is important "finely" or "coarsely" may be added, as ". . . coarsely mottled red and yellow clay", or ". . . brown silt loam finely and slightly mottled with reddish brown." Usually such distinctions are more confusing than helpful to the lay reader.

In the description of soil color, special notice should be taken of any relationships between the color pattern and structure or porosity. Structural aggregates in the soil must be broken to determine whether the color is uniform throughout. The black or dark-brown surface color of soil granules is often due to a thin coating, though the basic color of the soil material is brown or yellow. When such granules are crushed, the mass of soil is lighter in color than the original surfaces of the aggregates. Marked contrast between the color of the soil aggregates and the color of the soil when crushed is common. Coatings of red color often cover structural particles or sand grains; and a gray color may be due to a thin film of leached soil around darker aggregates.

EFFECTS OF MOISTURE

Soil color changes with the moisture content, very markedly in some soils and comparatively little in others. Between dry and moist, soil colors commonly are darker by ½ to 3 steps in value and may change from −½ to +2 steps in chroma. Seldom are they different in hue. Some of the largest differences in value between the dry and moist colors occur in gray and grayish-brown horizons having moderate to moderately low contents of organic matter.

Reproducible quantitative measurements of color are obtained at two moisture contents: (1) Air dry, and (2) field capacity. The latter may be obtained with sufficient accuracy for color measurements by moistening a sample and reading the color as soon as visible moisture films have disappeared. Both the dry and the moist colors are important. In most notes and soil descriptions, unless stated otherwise, colors are given for moist soils. Comparisons of color among widely separated soils are facilitated by using the color designation of freshly broken surfaces of air-dry samples. Official descriptions for technical use, such as series descriptions, should include the moist colors, and preferably, both dry and moist colors if significantly unlike.

DETERMINATION OF SOIL COLOR

Soil colors are most conveniently measured by comparison with a color chart. The one generally used with soil is a modification of the Munsell color chart and includes only that portion needed for soil colors, about one-fifth of the entire range of color.[6] It consists of some 175 different colored papers, or chips, systematically arranged, according to their Munsel notations, on cards carried in a loose-leaf notebook. The arrangement is by *hue, value,* and *chroma*—the three simple variables that combine to give all colors. *Hue* is the dominant spectral (rainbow) color; it is related to the dominant wavelength of the light. *Value* refers to the relative lightness of color and is a function (approximately the square root) of the total amount of light. *Chroma* (sometimes called saturation) is the relative purity or strength of the spectral color and increases with decreasing grayness.

In the soil color chart, all colors on a given card are of a constant hue, designated by the symbol in the upper right-hand corner of the card. Vertically, the colors become successively lighter by visually equal steps; their value increases. Horizontally, they increase in chroma to the right and become grayer to the left. The value and chroma of each color in the chart is printed immediately beneath the color. The first number is the value, and the second is the chroma. As arranged in the chart the colors form three scales: (1) Radial, or from one card to the next, in hue; (2) vertical in value; and (3) horizontal in chroma.

The nomenclature for soil color consists of two complementary systems: (1) Color names, and (2) the Munsell notation of color. Neither of these alone is adequate for all purposes. The color names are employed in all descriptions for publication and for general use. The Munsell notation is used to supplement the color names wherever greater precision is needed, as a convenient abbreviation in field descriptions, for expression of the specific relations between colors, and for statistical treatment of color data. The Munsell notation is especially useful for international correlation, since no translation of color names is needed. The names for soil colors are common terms now so defined as to obtain uniformity and yet accord, as nearly as possible, with past usage by soil scientists. Bizarre names like "rusty brown," "tan," "mouse gray," "lemon yellow," and "chocolate brown" should never be used.

The soil color names and their limits are given in the name-diagrams, figures 30 to 36.

The Munsell notation for color consists of separate notations for hue, value, and chroma, which are combined in that order to form the color designation. The symbol for hue is the letter abbreviation of the color of the rainbow (R for red, YR for yellow-red, or orange, Y for yellow) preceded by numbers from 0 to 10. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The middle of the letter range is at 5; the zero point coincides with the 10 point of the next redder hue. Thus 5YR is in the middle of the yellow-red hue, which extends from 10R (zero YR) to 10YR (zero Y).

The notation for value consists of numbers from 0, for absolute black, to 10, for absolute white. Thus a color of value 5/ is visually midway between absolute white and absolute black. One of value 6/ is slightly less dark, 60 percent of the way from black to white, and midway between values of 5/ and 7/.

The notation for chroma consists of numbers beginning at 0 for neutral grays and increasing at equal intervals to a maximum of about 20, which is never really approached in soil. For absolute achromatic colors (pure grays, white, and black), which have zero chroma and no hue, the letter N (neutral) takes the place of a hue designation.

In writing the Munsell notation, the order is hue, value, chroma, with a space between the hue letter and the succeeding value number, and a virgule between the two numbers for value and chroma. If expression beyond the whole numbers is desired, decimals are always used, never fractions. Thus the notation for a color of hue 5YR, value 5, chroma 6, is 5YR 5/6, a yellowish-red. The notation for a color midway between the 5YR 5/6 and 5YR 6/6 chips is 5YR 5.5/6; for one midway between 2.5YR 5/6 and 5YR 6/8, it is 3.75YR 5.5/7. The notation is decimal and capable of expressing any degree of refinement desired. Since color determinations cannot be made precisely in the field—generally no closer than half the interval between colors in the chart—expression of color should ordinarily be to the nearest color chip.

In using the color chart, accurate comparison is obtained by holding the soil sample above the color chips being compared. Rarely will the color of the sample be *perfectly* matched by any color in the chart. The probability of having a perfect matching of the sample color is less than one in one hundred. It should be evident, however, which colors the sample lies between, and which is the closest match. The principal difficulties encountered in using the soil color chart are (1) in selecting the appropriate hue card, (2) in determining colors that are intermediate between the hues

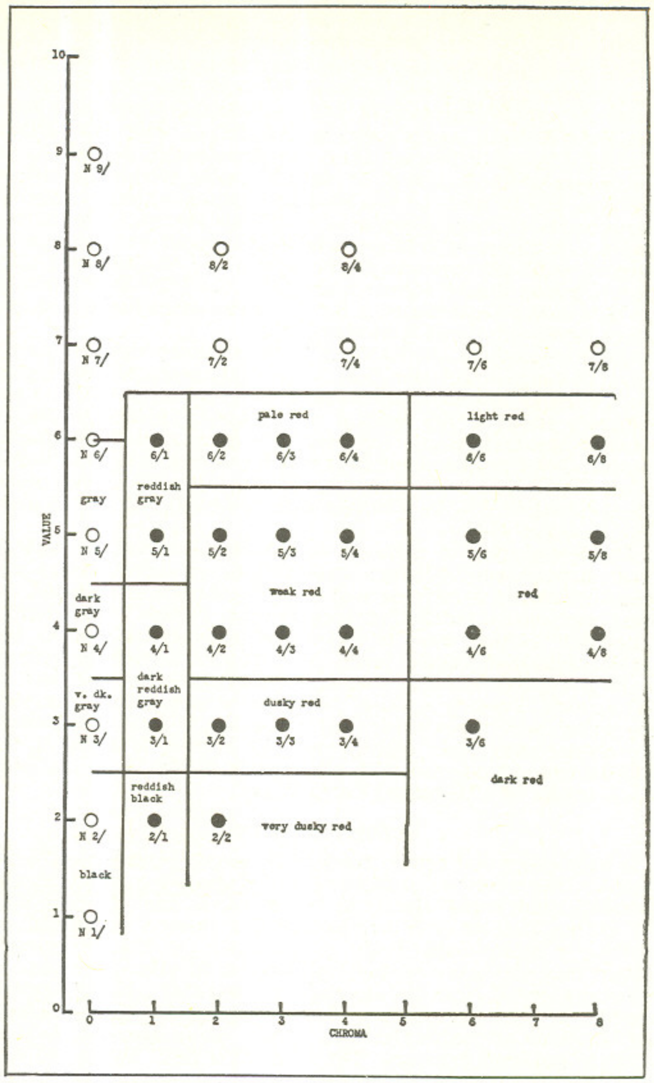

FIGURE 30.—Soil color names for several combinations of value and chroma and hue 10R.

in the chart, and (3) in distinguishing between value and chroma where chromas are strong. In addition, the chart does not include some extreme dark, strong (low value, high chroma) colors occasionally encountered in moist soils. With experience, these extreme colors lying outside the range of the chart can be estimated. Then too, the ability to sense color differences varies among people, even among those not regarded as color blind.

While important details should be given, long involved designations of color should generally be avoided, especially with variegated or mottled colors. In these, only the extreme or dominant colors need be stated. Similarly, in giving the color names and Munsell notations for both the dry and moist colors, an abbreviated form, such as "reddish brown (5YR 4/4; 3/4, moist)," simplifies the statement.

By attempting detail beyond the allowable accuracy of field observations and sample selection, one may easily make poorer soil descriptions than by expressing the dominant color simply. In all descriptions, terms other than the ones given on these charts should be used only in rare instances, and then only as supplemental expressions in parentheses where some different local usage is common.

SOIL TEXTURE, COARSE FRAGMENTS, STONINESS, AND ROCKINESS

Soil texture refers to the relative proportions of the various size groups of individual soil grains in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand below 2 millimeters in diameter.

The presence of coarse particles larger than very coarse sand

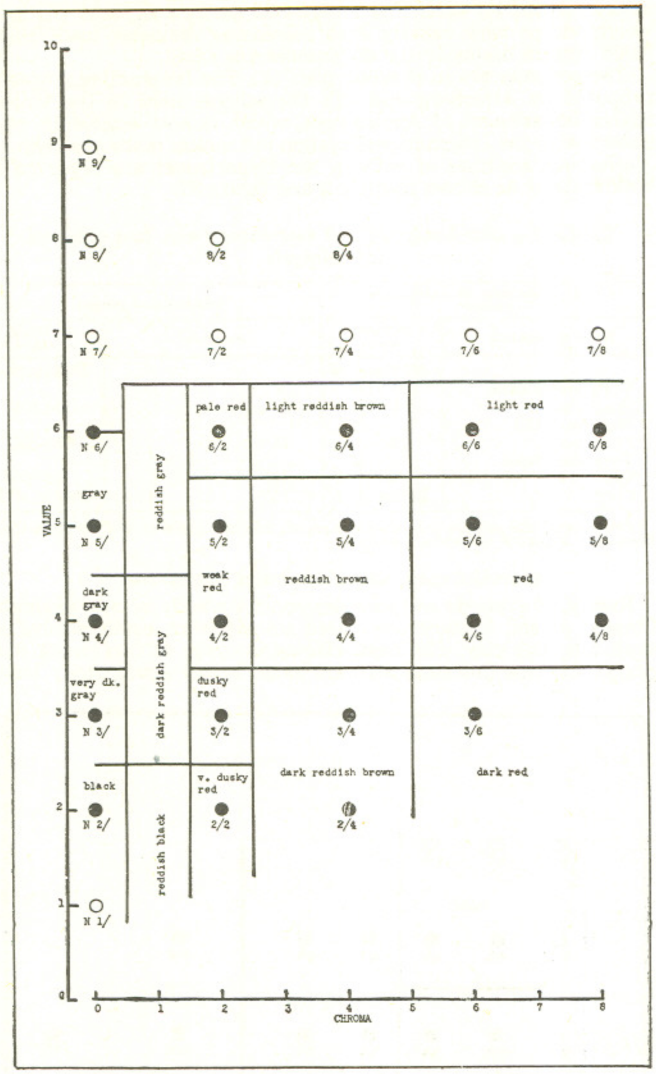

FIGURE 31.—Soil color names for several combinations of value and chroma and hue 2.5YR.

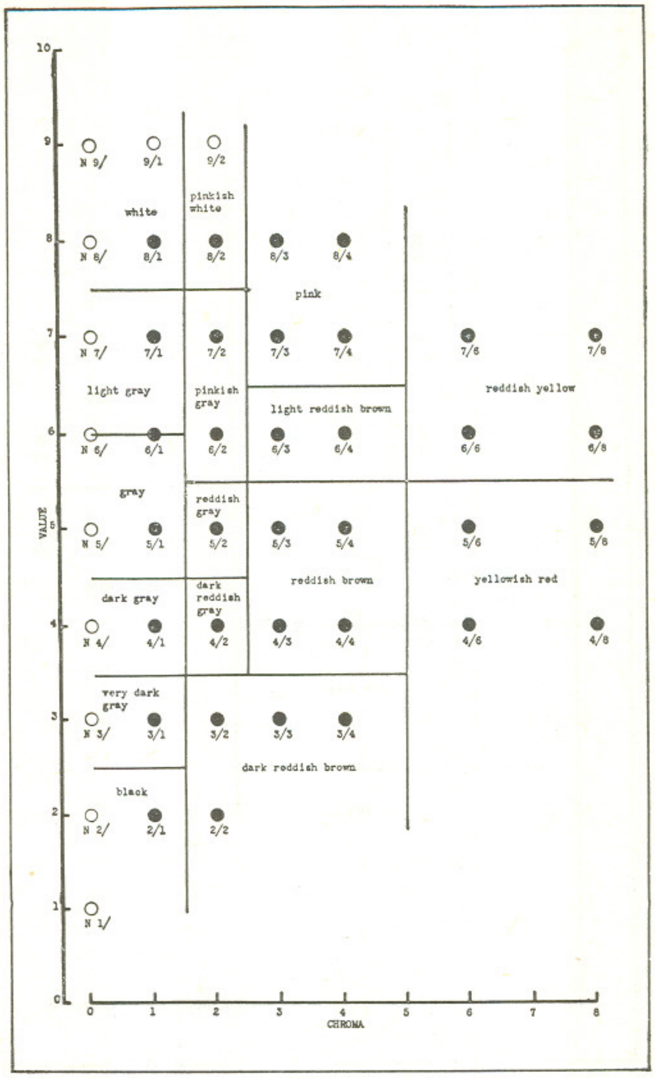

FIGURE 32.—Soil color names for several combinations of value and chroma and hue 5YR.

(or 2 mm.) and smaller than 10 inches is recognized by modifiers of textural class names, like *gravelly* sandy loam or *cobbly* loam.

General classes of still larger particles—stones or rock outcrops—are defined in terms of the influence they have on soil use, and in specific physical terms for individual soil series. Although distinctions within a type, series, family, or great soil group according to stoniness or rockiness are *phases*, these are indicated in soil types by an additional adjective added to the soil class name. Thus, Gloucester stony loam and Gloucester very stony loam are two phases of Gloucester loam which could be written more accurately and more clumsily Gloucester loam, stony phase, and Gloucester loam, very stony phase.

Actually, of course, sharp distinctions among the size groups of particles are more or less arbitrary. They have been arrived at after many, many trials in developing classes that can be used consistently and conveniently to define soil classificational and mapping units in such ways that they can be given the most specific interpretations.

The discussion of particle size is therefore presented under three principal headings: (1) The designation of soil textural class based primarily upon the proportion of clay, silt, and sand; (2) the definition of groups of coarse fragments having diameters less than 10 inches that may be regarded as a part of the soil mass and modify the textural class; and (3) the definition of classes of stoniness and rockiness for stones over 10 inches in diameter and for bedrock not considered a part of the soil mass.

SOIL TEXTURAL CLASS

The texture of a soil horizon is, perhaps, its most nearly permanent characteristic. Structure can be quickly modified by management. Often the texture of the plowed layer of an arable soil is modified, not by changes within the surface layer, but by the removal of surface horizons and the development of a new surface soil from a lower natural horizon of different texture, or by the addition of a new surface horizon, say of wind-blown sand or of silt loam settling out of muddy irrigation water. Soil blowing during drought may change soil texture by removing the fine particles from the exposed soil, leaving the surface soil richer in sand and coarse fragments than before.

Although texture is a seemingly simple basic concept in soil science, its consistent application has not been easy. Texture is so basic that terms like sand, clay, and loam are very old indeed. Since both consistence and structure are very important properties related partly to texture, the textural terms, as used earlier, had some connotations of these qualities as well as of texture. As long as their use was confined to soils in Britain and in the easterr part of the United States, the lack of correspondence between fielc designations of soil textural class and actual size distribution as shown by mechanical analysis was not obviously great. Yet structure and consistence depend on the kind and condition of the clay as well as on the amount of clay, on other soil constituents, and on the living tissue in the soil. As soil scientists began to deal with all soils, many of which are quite unlike the podzolized soils of the temperate forested regions, it became clear that structure, consistence, and texture had to be measured separately. Then too, early dispersion methods were so inadequate that fine granules of clay were actually reported as silt or sand.

Common sources of confusion and error are the agricultural connotations that were associated with the soil textural class names as formerly used. Clay soils were supposed to be sticky and easily puddled; sand soils were supposed to be loose, struc-

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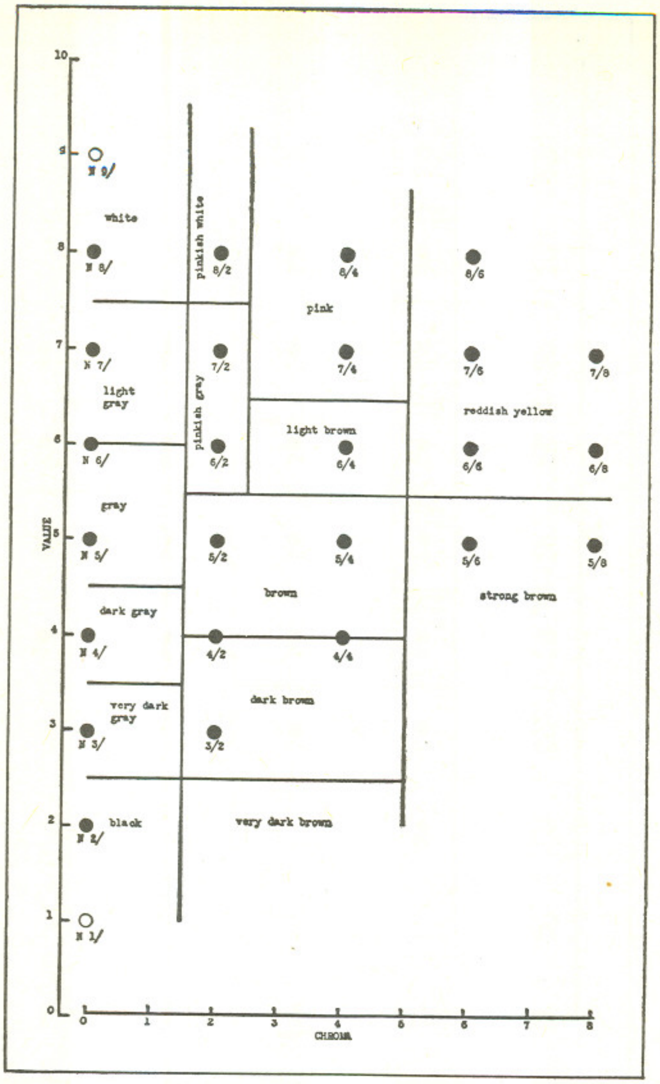

FIGURE 33.—Soil color names for several combinations of value and chroma and hue 7.5YR.

tureless, and droughty. Such connotations do not hold generally, however, and must be dissociated from general soil textural class names. Among some soil groups, clay soils are sticky and easily puddled, but among others they are not at all. Many sand soils are loose, structureless, and droughty, but some are not. As with each other soil characteristic, no direct relationship that can be applied generally to all soils exists between soil textural class and fertility, productivity, or other inferred qualities. To make such inferences we must also know the other important soil characteristics. Unfortunately, these erroneous correlations are well fixed in some textbooks and other books about soils for farmers and gardeners. Within the universe that the authors of these books actually consider, say Britain and the northeastern part of the United States, the correlations may be approximately correct for most soils; but the writers do not thus clearly limit their universe. As applied to the arctic, the tropics, and the desert they are often seriously wrong, even for the principal soils. Standardization of soil textural class names in terms of size distribution alone is clearly essential if soils of widely different genetic groups are to be compared.

SOIL SEPARATES

Soil separates are the individual size-groups of mineral particles. Sometimes the large sizes—coarse fragments—are included, but usually the groups of particles below 2 mm. in diameter are the only ones called soil separates. Since so many of the chemical and physical reactions in soils occur mainly on the surface of the grains, the fine part is most important. Only 4 pounds of dry clay particles having a diameter of 0.001 mm. have a total surface area of about an acre. The amount of surface exposed per unit weight drops very rapidly with increasing diameter until above 0.005 mm. in diameter the differences are small.

Two schemes are in common use: (1) The International system proposed by Atterberg and (2) the scheme used in the United States Department of Agriculture, which is now essentially consistent with the International system but makes more separations. Mechanical analyses of soils in the Department are reported in both systems as shown in table 2 and figure 37.

TABLE 2.—*Size limits of soil separates from two schemes of analysis*

U. S. Department of Agriculture scheme		International scheme	
Name of separate	Diameter (range)	Fraction	Diameter (range)
	Millimeters		*Millimeters*
Very coarse sand[1]	2.0 -1.0		
Coarse sand	1.0 - .5	I	2.0-0.2
Medium sand	.5 - .25		
Fine sand	.25- .10	II	.20-.02
Very fine sand	.10- .05		
Silt	.05- .002	III	.02-.002
Clay	Below .002	IV	Below .002

[1] Prior to 1947 this separate was called fine gravel. Now fine gravel is used for coarse fragments from 2 mm. to ½ inch in diameter.

TEXTURAL CLASS NAMES AND THEIR DEFINITIONS

Rarely, if ever, do soil samples consist wholly of one separate. Classes of soil texture are based on different combinations of sand, silt, and clay. The basic classes in order of increasing proportions of the fine separates are sand, loamy sand, sandy loam,

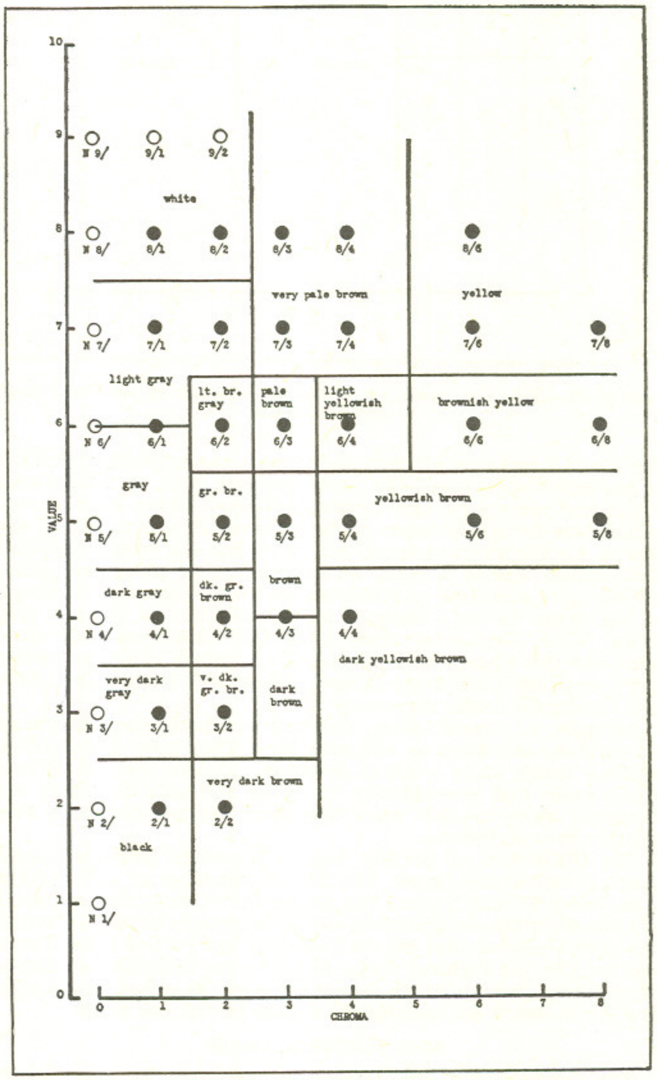

FIGURE 34.—Soil color names for several combinations of value and chroma and hue 10YR.

loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Those with the term "sand" in the name are modified for very fine, fine, coarse, or very coarse sand.[1] In these class names the word "loam" appears. This is an old English word formerly applied to crumbly soils rich in humus. It is still used by some in that sense. In soil classification, however, it is used only in soil textural class names.[2]

The basic soil textural class names in present use are defined in terms of *size distribution* as determined by mechanical analysis in the laboratory.[3]

The definitions of these classes developed since the earlier edition of this *Manual* have resulted from long experience and much special research to establish boundaries between classes so that they have the maximum general use for soil definitions and interpretations. Using the results of this research had the effect of some nearly drastic modifications in the old definitions of class names in terms of actual percentages of sand, silt, and clay as determined in the laboratory, and some modifications in field definitions based upon feel. Whereas laboratory data from mechanical analyses were formerly regarded as general guides only to soil textural class names, they are now regarded as absolute guides to soils of the mainland of the United States. At the same time one cannot say that the standards are yet perfect. Especially may further improvements be expected in the designations used for the textural class of Tundra soils and of Latosols in which the clays generally have different mineralogical compositions from those of soils in temperate regions. Textural class names must be defined wholly in terms of size distribution, however, and not used to express differences in consistence or structure; else the names will lose their fundamental significance.

Definitions of the basic classes are set forth in graphic form in figure 38, in terms of clay, below 0.002 mm; silt, 0.002 to 0.05 mm; and sand 0.05 to 2.0 mm. Although much improved over previous charts, this one is still tentative. Those frequently interpreting laboratory data into soil textural class names will find an enlarged copy of this triangle useful. Verbal definitions of the soil textural classes, defined according to size distribution of mineral particles less than 2 millimeters in diameter, are as follows:

Sands.—Soil material that contains 85 percent or more of sand; percentage of silt, plus 1½ times the percentage of clay, shall not exceed 15.

Coarse sand: 25 percent or more very coarse and coarse sand, and less than 50 percent any other one grade of sand.

Sand: 25 percent or more very coarse, coarse, and medium sand, and less than 50 percent fine or very fine sand.

Fine sand: 50 percent or more fine sand (or) less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.

Very fine sand: 50 percent or more very fine sand.

Loamy sands.—Soil material that contains at the upper limit 85 to 90 percent sand, and the percentage of silt plus 1½ times the percentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85 percent sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

[1] It will be noted that the terms "clay," "silt," "very fine sand," "fine sand," and "coarse sand" are used for both soil separates and for specific soil classes.

[2] Unfortunately, old and misleading names like "desert loams," "tropical red loams," and "brown loams" still persist as group names for soils varying widely from loam in texture.

[3] For accepted methods now in use see KILMER, V. J., and ALEXANDER, L. T. METHODS OF MAKING MECHANICAL ANALYSIS OF SOILS. Soil Sci. 68: 15–24. 1949.

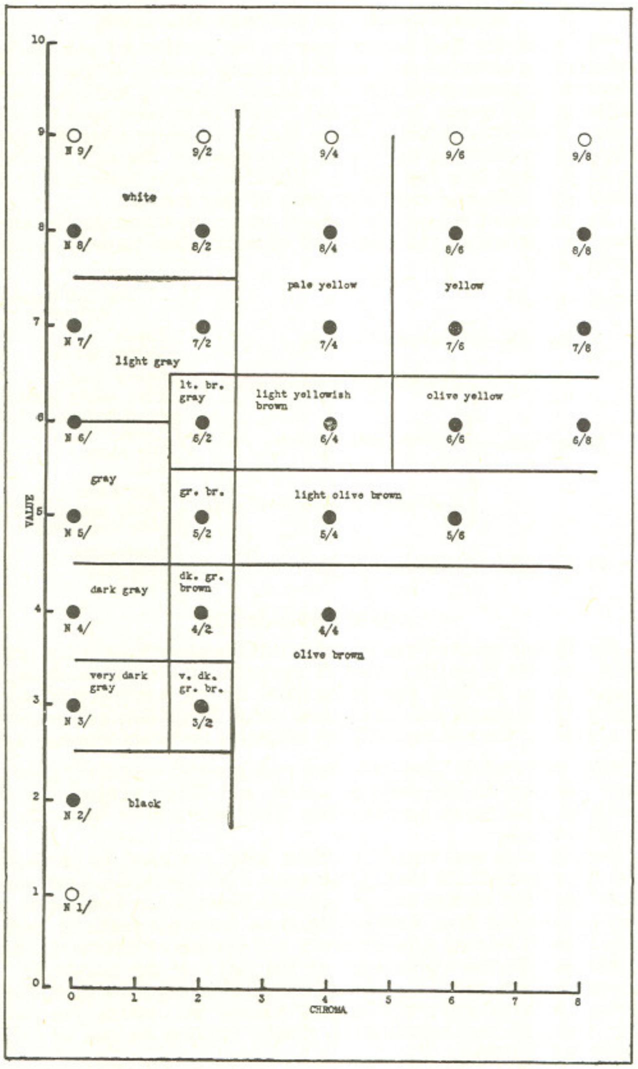

FIGURE 35.—Soil color names for several combinations of value and chroma and hue 2.5Y.

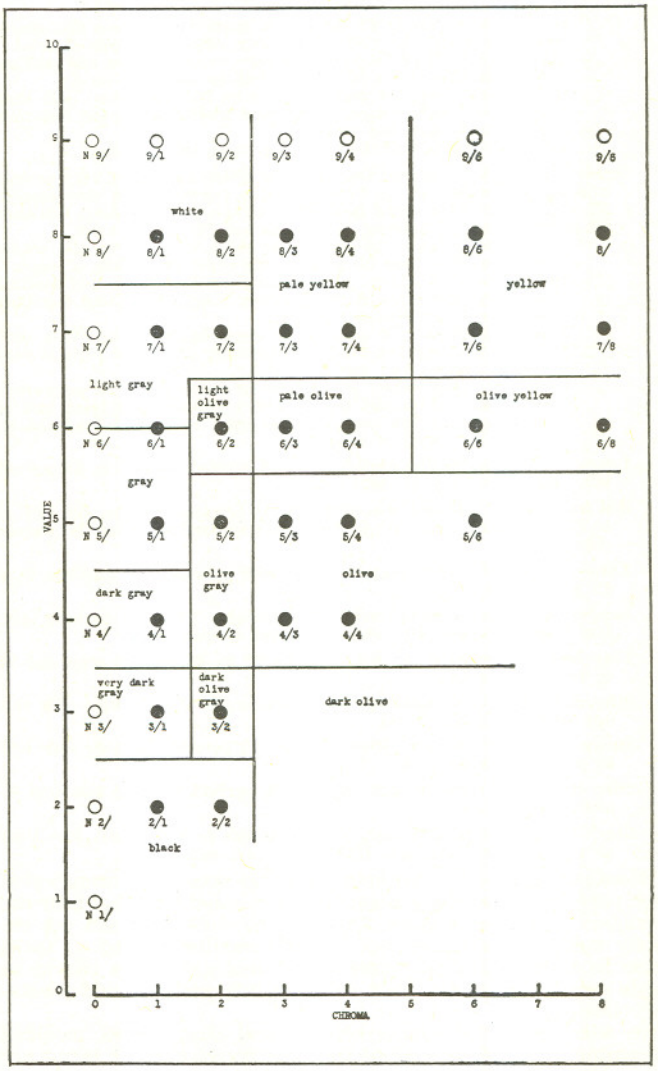

FIGURE 36.—Soil color names for several combinations of value and chroma and hue 5Y.

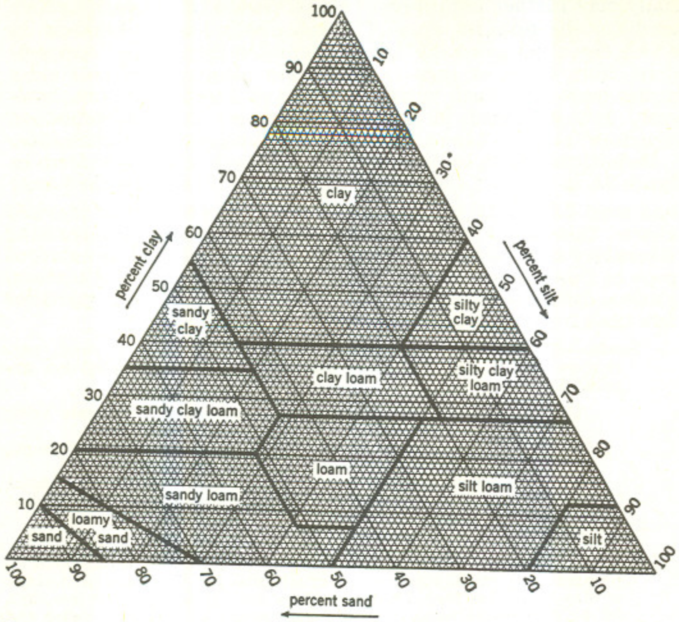

FIGURE 38.—Chart showing the percentages of clay (below 0.002 mm.), silt (0.002 to 0.05 mm.), and sand (0.05 to 2.0 mm.) in the basic soil textural classes.

Loamy coarse sand: 25 percent or more very coarse and coarse sand, and less than 50 percent any other one grade of sand.
Loamy sand: 25 percent or more very coarse, coarse, and medium sand, and less than 50 percent fine or very fine sand.
Loamy fine sand: 50 percent or more fine sand (or) less than 25 percent very coarse, coarse, and medium sand and less than 50 percent very fine sand.
Loamy very fine sand: 50 percent or more very fine sand.

Sandy loams.—Soil material that contains either 20 percent clay or less, and the percentage of silt plus twice the percentage of clay exceeds 30, and 52 percent or more sand; or less than 7 percent clay, less than 50 percent silt, and between 43 percent and 52 percent sand.
Coarse sandy loam: 25 percent or more very coarse and coarse sand and less than 50 percent any other one grade of sand.
Sandy loam: 30 percent or more very coarse, coarse, and medium sand, but less than 25 percent very coarse sand, and less than 30 percent very fine or fine sand.
Fine sandy loam: 30 percent or more fine sand and less than 30 percent very fine sand (or) between 15 and 30 percent very coarse, coarse, and medium sand.
Very fine sandy loam: 30 percent or more very fine sand (or) more than 40 percent fine and very fine sand, at least half of which is very fine sand and less than 15 percent very coarse, coarse, and medium sand.

Loam.—Soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

Silt loam.—Soil material that contains 50 percent or more silt and 12 to 27 percent clay (or) 50 to 80 percent silt and less than 12 percent clay.

Silt.—Soil material that contains 80 percent or more silt and less than 12 percent clay.

Sandy clay loam.—Soil material that contains 20 to 35 percent clay, less than 28 percent silt, and 45 percent or more sand.

Clay loam.—Soil material that contains 27 to 40 percent clay and 20 to 45 percent sand.

Silty clay loam.—Soil material that contains 27 to 40 percent clay and less than 20 percent sand.

Sandy clay.—Soil material that contains 35 percent or more clay and 45 percent or more sand.

Silty clay.—Soil material that contains 40 percent or more clay and 40 percent or more silt.

Clay.—Soil material that contains 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Necessarily these verbal definitions are somewhat complicated and, perhaps, not entirely adequate for unusual mixtures near the boundaries between classes. Some of the definitions are not entirely mutually exclusive, but the information needed to make them so is lacking. Departures from these definitions should be made only after careful joint research between field and laboratory scientists.

In addition to these basic soil textural class names, modified according to the size group of the sand fraction, other terms are also added as modifiers.

Muck, peat, mucky peat, and *peaty muck* are used in place of the textural class names in organic soils—muck for well-decomposed soil material, peat for raw undecomposed material, and peaty muck and mucky peat for intermediate materials. Former definitions have also specified a higher mineral content for muck than for peat. This cannot be followed, however, since many raw peats contain high amounts of mineral matter dropped from the air or washed in by water. The word "mucky" is used as an adjective on the textural class name for horizons of mineral soils, especially of Humic-Gley[4] soils that contain roughly 15 percent or more of partially decomposed organic matter. Horizons designated "mucky loam" or "mucky silt loam" are intergrades between muck and the soil textural class.

The terms for coarse fragments, outlined in the following section, are also added as adjectives to the soil class name and become a part of it. Thus a "gravelly sandy loam" has about 20 percent or more of gravel in the whole soil mass. The basic soil textural class name, however, is determined from the size distribution of the material below 2 mm. in diameter. That is, the percentages used for the standard soil class designations are net after the coarse fragments are excluded.

Phase names for stoniness and rockiness, although not a part of textural soil class names, are used to modify the soil-class part of a soil-type name, as for example, Gloucester *very stony* loam. In the descriptions of all soil horizons, particles larger than 10 inches are excluded from the soil textural class name. It needs to be recalled that classes of stoniness and rockiness are separate from soil class and have a separate place in soil descriptions.

Terms besides those herein defined, such as "wet," "ashy," "cindery," and the like, should be avoided in soil-class names or as modifiers of soil class in soil-type names.

[4] Tentative name for soils now included with Wiesenboden and for some included in Half Bog.

GENERAL GROUPING OF SOIL TEXTURAL CLASSES

The need for fine distinctions in the texture of soil horizons results in a large number of soil textural classes. Often it is convenient to speak generally of a broad group of textural classes. Although the terms "heavy" and "light" have been used for many years, they are confusing, since the terms arose from the power required in plowing, not the actual weight of the soil. According to local usage in a few places, "light" soils are those low in productivity, including especially ones of clay texture.

An outline of acceptable general terms, in three classes and in five, in relation to the basic soil textural class names, is shown as follows:

General terms:		*Basic soil textural class names*
Sandy soils.—*Coarse-textured soils*		Sands. Loamy sands.
Loamy soils.—	*Moderately coarse-textured soils*	Sandy loam. Fine sandy loam.
	Medium-textured soils	Very fine sandy loam. Loam. Silt loam. Silt.
	Moderately fine-textured soils	Clay loam. Sandy clay loam. Silty clay loam.
Clayey soils.—*Fine-textured soils*		Sandy clay. Silty clay. Clay.

COARSE FRAGMENTS

Significant proportions of fragments coarser than very coarse sand and less than 10 inches, if rounded, or 15 inches along the longer axis, if flat, are recognized by an appropriate adjective in the textural soil-class name. Such fragments are regarded as a part of the soil mass. They influence moisture storage, infiltration, and runoff. They influence root growth, especially through their dilution of the mass of active soil. They protect the fine particles from wash and blowing. They are moved with the soil mass in tillage.

Many names and standards have been proposed by geologists and soil scientists for these fragments. Fine distinctions are easily made (but not always easily mapped) because the fragments are easy to see; but finer distinctions than those set forth in table 3 have little or no real significance to soil genesis or behavior. Other variables, like the mineralogy of the clays or the nature of the organic matter, are far more important. The scientist must guard against making finer distinctions among the coarse fragments than those of real significance, simply because he can see them easily in the field.

The accepted adjectives to include in textural soil class names and the size limits of classes of coarse fragments are set forth in outline form in table 3. This table includes the probable maximum of detail required for detailed basic soil surveys. In situations where no useful purpose is served by developing separate mapping units to indicate the separate classes, the classes are grouped and a name given the soil type or soil phase that most clearly indicates the situation. Thus a cobbly loam or a stony phase may include other fragments also listed in the two right hand columns. In this section we shall concern ourselves only with fragments smaller than stones.

TABLE 3.—*Names used for coarse fragments in soils*[1]

Shape and kind of fragments	Size and name of fragments		
	Up to 3 inches in diameter	*3 to 10 inches in diameter*	*More than 10 inches in diameter*
Rounded and subrounded fragments (all kinds of rock).	Gravelly	Cobbly	Stony (or bouldery).[2]
Irregularly shaped angular fragments:			
Chert	Cherty	Coarse cherty.	Stony.
Other than chert	(Angular) gravelly.	Angular cobbly[3].	Do.
	Up to 6 inches in length	*6 to 15 inches in length*	*More than 15 inches in length*
Thin, flat fragments:			
Thin, flat sandstone, limestone, and schist.	Channery	Flaggy	Stony.
Slate	Slaty	do	Do.
Shale	Shaly	do	Do.

[1] The individual classes are not always differentiating characteristics of mapping units.
[2] Bouldery is sometimes used where stones are larger than 24 inches.
[3] Formerly called "stony."

The adjectives listed in the first two columns of table 3 are incorporated into the soil textural class designations of horizons when the soil mass contains significant proportions of the fragments, above 15 to 20 percent by volume, depending upon the other soil characteristics. These class names become parts of soil-type names. Where the coarse fragments make up 90 percent or more of the soil mass by volume in the upper 8 inches, the land is classified in the appropriate miscellaneous land type.[6] If necessary to make distinctions of clear significance, another subdivision can be made of the coarse fragments at about 50 percent to give, for example, gravelly loam (20 to 50 percent gravel) and very gravelly loam (50 to 90 percent gravel). The other defined fragments may be handled similarly.

The recommended terms to apply to soil containing above 15 to 20 percent coarse fragments smaller than stones, and less than 90 percent, are defined as follows:

Channery: Soils contain fragments of thin, flat sandstone, limestone, or schist up to 6 inches along the longer axis. A single piece is a *fragment*.

Cherty: Soils have angular fragments that are less than 3 inches in diameter, more than 75 percent of which are chert; *coarse cherty* soils have fragments of 3 to 10 inches (fig. 39). Unless the size distinction is significant to the use capability of the soil, the *cherty* soil includes the whole range up to 10 inches. Most cherty soils are developed from weathered cherty limestone. A single piece is a *chert fragment*.

Cobbly: Soils have rounded or partially rounded fragments of rock ranging from 3 to 10 inches in diameter. *Angular cobbly*, formerly included as stony, is similar to cobbly except that fragments are not rounded. A single piece of either is a *cobblestone* or *small stone*.

Flaggy: Soils contain relatively thin fragments 6 to 15 inches long of sandstone, limestone, slate, or shale, or, rarely, of schist. A single piece is a *flagstone*.

Gravelly: Soils have rounded or angular fragments, not prominently flattened, up to 3 inches in diameter. If 75 percent or more of the fragments is chert, the soils are called *cherty*. In descriptions, soils with pebbles mostly over 2 inches in diameter may be called *coarsely gravelly* soils, and those with pebbles mostly under one-half inch in diameter may be called *finely gravelly* soils. An individual piece is a *pebble*. The term "gravel" refers to a mass of pebbles.

Shaly: Soils have flattened fragments of shale less than 6 inches along the longer axis. A single piece is a *shale fragment*.

Slaty: Soils contain fragments of slate less than 6 inches along the longer axis. A single piece is a *slate fragment*.

Stony: Soils contain rock fragments larger than 10 inches in diameter, if rounded, and longer than 15 inches along the longer axis, if flat. Classes are outlined in the following section.

[6] Formerly, some soils having a high proportion of gravel or pebbles in the surface 8 inches were given a textural class name of "gravel," as in Rodman gravel. It is recommended that such soils be classified as gravelly loam, gravelly sandy loam, or gravelly sand, if they have less than 90 percent pebbles, or with the appropriate miscellaneous land type if they have more

STONINESS AND ROCKINESS

Stones larger than 10 inches in diameter and rock outcrops are not regarded as part of the soil mass as defined by soil textural classes. They have an important bearing on soil use, however, because of their interference with the use of agricultural machinery and their dilution of the soil mass. In fact, stoniness, rockiness, or both, are the differentiating criteria between classes of arable soil and between arable and nonarable soil in many places. In large part the soils developed from glacial till, for example, especially where the till is thin, have characteristics that make them highly responsive to management, except for stoniness. Soil scientists have sometimes neglected this factor, perhaps in part because it is a difficult problem to deal with in the field. Several otherwise useful published soil surveys have failed in their objectives because of the failure to establish meaningful classes of stoniness. Although detailed attention was given soil color, texture, parent material, slope, erosion, depth, and the like, stoniness was so carelessly evaluated that the maps cannot be used to distinguish between potential cropland, pasture land, and forest land, in descending order of intensity.

The suggestions that follow differentiate between loose stones and fixed stones and provide classes within each as required in detailed basic surveys. Admittedly the suggestions are especially aimed to deal with the most complicated situations—where both loose stones and fixed stones exist and influence soil-use capability differently and where the soils are otherwise suitable for intensive use. Generally, loose stones are scattered over the soil area, while rock ledges are more concentrated in strips with relatively rock-free soil between. Such situations are most common in glaciated regions with thin drift, as in New England and parts of the northern Lake States.

Outside the glaciated regions, loose stones are less abundant, although by no means uncommon. In some sections of the country, soils containing fixed stones (rocky soils as here defined), some loose fragments 3 to 10 inches in diameter, and some stones have been called stony for many years. Where no useful purpose is served by dividing into additional types and phases, it should not be done. Thus the classes proposed for stoniness and rockiness may be grouped in the definition of any individual mapping unit.

STONINESS

Stoniness refers to the relative proportion of stones over 10 inches in diameter in or on the soil. The significance of a given number or amount of stones depends upon the other soil characteristics. That is, if a soil is not suited to cultivated crops anyway, the presence of enough stones to interfere with cultivation is not significant and should not be used as a basis for a soil phase separation. If a soil is exceedingly responsive to management for improved pasture, let us say, differences between even high degrees of stoniness are significant and may separate mapping units, as for example, an extremely stony phase of a soil type from the miscellaneous land type, Stony land.

The limits of the classes of stoniness are defined broadly in absolute terms and more specifically in terms of soil use wherever the other soil characteristics are favorable for crops or improved pasture. The able soil classifier avoids fine distinctions according to stoniness where they are not significant as clearly as he recognizes them where they are significant. This means that in the descriptive soil legend and in the soil survey report, stony phases need to be defined *within* the soil series and types. The classes of stoniness are used in definitions of all units of soil classification and may become one criterion for soil series as well as the sole criterion for distinctions among phases within the soil series or soil types.

Classes of stoniness are outlined as follows:

Class 0: No stones or too few to interfere with tillage. Stones cover less than 0.01 percent of the area.

Class 1: Sufficient stones to interfere with tillage but not to make intertilled crops impracticable. (If stones are 1 foot in diameter and about 30 to 100 feet apart, they occupy about 0.01 to 0.1 percent of the surface, and there are about 0.15 to 1.5 cubic yards per acre-foot.) (See fig. 40.)

Class 2: Sufficient stones to make tillage of intertilled crops impracticable, but the soil can be worked for hay crops or improved pasture if other soil characteristics are favorable. (If stones are 1 foot in diameter and about 5 to 30 feet apart, they occupy about 0.1 to 3 percent of the surface, and there are about 1.5 to 50 cubic yards per acre-foot.) (See fig. 41.)

Class 3: Sufficient stones to make all use of machinery impracticable, except for very light machinery or hand tools where other soil characteristics are especially favorable for improved pasture. Soils with this class of stoniness may have some use for wild pasture or forests, depending on other soil characteristics. (If stones are 1 foot in diameter and about 2.5 to 5 feet apart, they occupy about 3 to 15 percent of the surface, and there are about 50 to 240 cubic yards per acre-foot)

Class 4: Sufficient stones to make all use of machinery impracticable; the land may have some value for poor pasture or for forestry. (If stones are 1 foot in diameter and are about 2.5 feet or less apart, they occupy 15 to 90 percent of the surface, and there are more than about 240 cubic yards per acre-foot.)

Class 5: Land essentially paved with stones that occupy more than 90 percent of the exposed surface (Rubble).

It should be emphasized that these classes are for general application in soil descriptions. They may or may not be used as phase distinctions. In other words a mapping unit may be defined in terms of more than one class of stoniness. Some individual soils may be defined in terms of classes of stoniness, classes of rockiness, and classes of coarse fragments. Stoniness is not a part of the soil textural class. The terms "stony," very stony," or "exceedingly stony" may modify the soil textural class name in the soil type; but this is simply a brief way of designating stony phases.[7] Soil series descriptions need to include the range of stoniness in terms of classes 0, 1, 2, and 3.

ROCKINESS

Rockiness refers to the relative proportion of bedrock exposures, either rock outcrops or patches of soil too thin over bedrock for use, in a soil area. "Rocky" is used, perhaps arbitrarily, for soils having fixed rock (bedrock), and "stony" for soils having loose detached fragments of rock.

The classes of rockiness, as of stoniness, are given broad definitions in absolute terms and more specific definitions in terms of soil use for those soils otherwise suitable for crops or improved pasture. Soil areas having the same definitions in terms of area of bedrock exposure may vary widely in the depth of soils between the rock outcrops. Such distinctions need to be made within the soil series definitions. As with stoniness, the classes of rockiness are used in soil series descriptions and can become one criterion for series distinctions or the sole criterion for phase distinctions. Two or more classes may be combined in one mapping unit. Some mapping units may also have classes of stoniness and of coarse fragments.

The relationships to soil use suggested in the definitions of the classes apply mainly to areas of soil in humid regions that are otherwise responsive to management. The definitions of actual soil phases must take account of the alternative management practices that can be used for seeding, harvesting, weed control, and the like.

In each descriptive legend and soil survey report, rocky phases need to be defined specifically within each soil series or type.

The classes of rockiness are as follows:

Class 0: No bedrock exposures or too few to interfere with tillage. Less than 2 percent bedrock exposed.

Class 1: Sufficient bedrock exposures to interfere with tillage but not to make intertilled crops impracticable. Depending upon how the pattern affects tillage, rock exposures are roughly 100 to 300 feet apart and cover about 2 to 10 percent of the surface.

Class 2: Sufficient bedrock exposures to make tillage of intertilled crops impracticable, but soil can be worked for hay crops or improved pasture if the other soil characteristics are favorable. Rock exposures are roughly 30 to 100 feet apart and cover about 10 to 25 percent of the surface, depending upon the pattern (fig. 42).

Class 3: Sufficient rock outcrop to make all use of machinery impracticable, except for light machinery where other soil characteristics are especially favorable for improved pasture. May have some use for wild pasture or forests, depending on the other soil characteristics. Rock exposures, or patches of soil too thin over rock for use, are roughly 10 to 30 feet apart and cover about 25 to 50 percent of the surface, depending upon the pattern.

Class 4: Sufficient rock outcrop (or of very thin soil over rock) to make all use of machinery impracticable. The land may have some value for poor pasture or for forestry. Rock outcrops are about 10 feet apart or less and cover some 50 to 90 percent of the area.

Class 5: Land for which over 90 percent of the surface is exposed bedrock (Rock outcrop).

SOIL STRUCTURE

Soil structure refers to the aggregation of primary soil particles into compound particles, or clusters of primary particles, which are separated from adjoining aggregates by surfaces of weakness. The exteriors of some aggregates have thin, often dark-colored, surface films which perhaps help to keep them apart. Other aggregates have surfaces and interiors of like color, and the forces holding the aggregates together appear to be wholly internal.

An individual natural soil aggregate is called a *ped*, in contrast to (1) a *clod*, caused by disturbance, such as plowing or digging, that molds the soil to a transient mass that slakes with repeated wetting and drying, (2) a *fragment* caused by rupture of the soil mass across natural surfaces of weakness, or (3) a *concretion* caused by local concentrations of compounds that irreversibly cement the soil grains together.

The importance of soil structure in soil classification and in influencing soil productivity can scarcely be overemphasized. The capability of any soil for the growth of plants and its response to management depends as much on its structure as on its fertility. Generally, in the United States, soils with aggregates of spheroidal shape have much pore space between aggregates, have more rapid permeability, and are more productive than soils of comparable fertility that are massive or even coarsely blocky or prismatic. In other parts of the world, some soils are overgranulated. Some Latosols have such well-developed spheroidal peds that the moisture-holding capacity is low, too few contacts exist between roots and soil, and the soils are relatively unproductive.

Field descriptions of soil structure note (1) the shape and arrangement, (2) the size, and (3) the distinctness and durability of the visible aggregates or peds. Field terminology for structure consists of separate sets of terms designating each of these three qualities, which by combination form the names for structure. Shape and arrangement of peds is designated as *type* of soil structure; size of peds, as *class;* and degree of distinctness, as *grades*.[1] The structural pattern of a soil horizon also includes the shapes and sizes of pore spaces as well as those of the peds themselves.

There are four primary types of structure: (1) Platy, with particles arranged around a plane, generally horizontal; (2) prismlike, with particles arranged around a vertical line and bounded by relatively flat vertical surfaces; (3) blocklike or polyhedral, with particles arranged around a point and bounded by flat or rounded surfaces which are casts of the molds formed by the faces of surrounding peds; and (4) spheroidal or polyhedral, with particles arranged around a point and bounded by curved or very irregular surfaces that are not accommodated to the adjoining aggregates. Each of the last three have two subtypes. Under prismlike the subtypes are *prismatic*, without rounded upper ends, and *columnar*, with rounded caps. The subtypes of blocklike are *angular blocky*, bounded by planes intersecting at relatively sharp angles, and *subangular blocky*, having mixed rounded and plane faces with vertices mostly rounded. If the term "blocky" is used alone, angular blocky is understood. Spheroidal is subdivided into *granular*, relatively nonporous, and *crumb*, very porous. Each type of structure includes peds that vary in shape, and detailed soil descriptions may require supplemental statements about the shape of the individual peds (figs. 43 and 44).

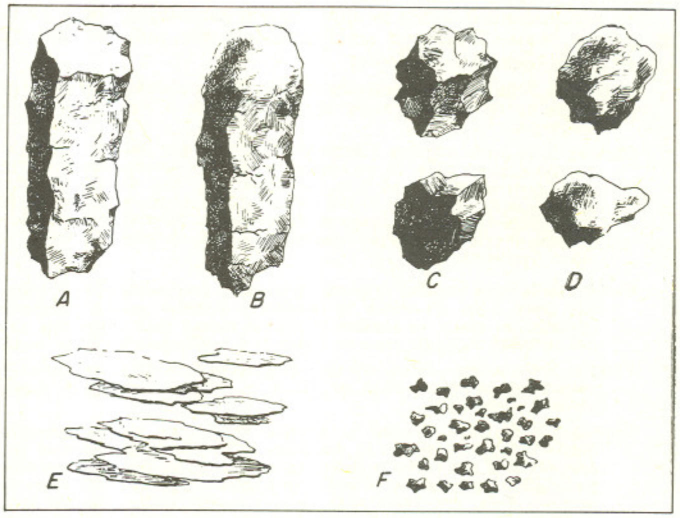

FIGURE 44.—Drawings illustrating some of the types of soil structure: *A*, prismatic; *B*, columnar; *C*, angular blocky; *D*, subangular blocky; *E*, platy; and F, granular.

The names in the preceding paragraph placed in italics are the terms most used in descriptions of soil horizons. *Nut* has been used for blocklike peds, but is not recommended; *nuciform* has been an optional alternative for subangular blocky, but *subangular blocky* is recommended. It is difficult for many to dissociate a size connotation from terms like *nut* and *nuciform*. For this reason some confuse very fine blocky with granular. Terms

[1] For a useful background discussion of these concepts, see NIKIFOROFF, C. C. MORPHOLOGICAL CLASSIFICATION OF SOIL STRUCTURE. Soil Sci. 52: 193–212, illus. 1941.

TABLE 6.—*Types and classes of soil structure*

Class	TYPE (Shape and arrangement of peds)						
	Platelike with one dimension (the vertical) limited and greatly less than the other two; arranged around a horizontal plane; faces mostly horizontal.	Prismlike with two dimensions (the horizontal) limited and considerably less than the vertical; arranged around a vertical line; vertical faces well defined; vertices angular.		Blocklike; polyhedronlike, or spheroidal, with three dimensions of the same order of magnitude, arranged around a point.			
				Blocklike; blocks or polyhedrons having plane or curved surfaces that are casts of the molds formed by the faces of the surrounding peds.		Spheroids or polyhedrons having plane or curved surfaces which have slight or no accommodation to the faces of surrounding peds.	
		Without rounded caps.	With rounded caps.	Faces flattened; most vertices sharply angular.	Mixed rounded and flattened faces with many rounded vertices.	Relatively nonporous peds.	Porous peds.
	Platy	Prismatic	Columnar	(Angular) Blocky [1]	Subangular blocky [2]	Granular	Crumb
Very fine or very thin.	Very thin platy; <1 mm.	Very fine prismatic; <10 mm.	Very fine columnar; <10 mm.	Very fine angular blocky; <5 mm.	Very fine subangular blocky; <5 mm.	Very fine granular; <1 mm.	Very fine crumb; <1 mm.
Fine or thin	Thin platy; 1 to 2 mm.	Fine prismatic; 10 to 20 mm.	Fine columnar; 10 to 20 mm.	Fine angular blocky; 5 to 10 mm.	Fine subangular blocky; 5 to 10 mm.	Fine granular; 1 to 2 mm.	Fine crumb; 1 to 2 mm.
Medium	Medium platy; 2 to 5 mm.	Medium prismatic; 20 to 50 mm.	Medium columnar; 20 to 50 mm.	Medium angular blocky; 10 to 20 mm.	Medium subangular blocky; 10 to 20 mm.	Medium granular; 2 to 5 mm.	Medium crumb; 2 to 5 mm.
Coarse or thick.	Thick platy; 5 to 10 mm.	Coarse prismatic; 50 to 100 mm.	Coarse columnar; 50 to 100 mm.	Coarse angular blocky; 20 to 50 mm.	Coarse subangular blocky; 20 to 50 mm.	Coarse granular; 5 to 10 mm.	
Very coarse or very thick.	Very thick platy; >10 mm.	Very coarse prismatic; >100 mm.	Very coarse columnar; >100 mm.	Very coarse angular blocky; >50 mm.	Very coarse subangular blocky; >50 mm.	Very coarse granular; >10 mm.	

[1] (a) Sometimes called *nut*. (b) The word "angular" in the name can ordinarily be omitted.
[2] Sometimes called *nuciform*, *nut*, or *subangular nut*. Since the size connotation of these terms is a source of great confusion to many, they are not recommended.

used to designate types of soil structure refer *only* to shape and arrangement and do not specify size.

Five size classes are recognized in each of the primary types. The names of these and their size limits, which vary with the four primary types for shape and arrangement, are given in table 6.

Grade of structure is the degree of aggregation and expresses the differential between cohesion within aggregates and adhesion between aggregates. In field practice, grade of structure is determined mainly by noting the durability of the aggregates and the proportions between aggregated and unaggregated material that result when the aggregates are displaced or gently crushed. Grade of structure varies with the moistening of the soil and should be described at the most important moisture contents of the soil horizon. The principal description of the structure of a soil horizon should refer to its normal moisture content, although attention should be called to any striking contrasts in structure under other moisture conditions to which the soil is subject. If grade is designated at an unstated moisture content, it is assumed that the soil is nearly dry or only very slightly moist, which is commonly that part of the range in soil moisture in which soil structure is most strongly expressed.

With exposure, structure may become much altered, often much stronger. Old road cuts are not suitable places to determine the grade of structure, but they often afford a clue to the type of structure present where the grade is so weak that it cannot be identified in the undisturbed soil.

Terms for grade of structure are as follows:

0. *Structureless*.—That condition in which there is no observable aggregation or no definite orderly arrangement of natural lines of weakness. *Massive* if coherent; *single grain* if noncoherent.
1. *Weak*.—That degree of aggregation characterized by poorly formed indistinct peds that are barely observable in place. When disturbed, soil material that has this grade of structure breaks into a mixture of few entire peds, many broken peds, and much unaggregated material. If necessary for comparison, this grade may be subdivided into *very weak* and *moderately weak*.
2. *Moderate*.—That grade of structure characterized by well-formed distinct peds that are moderately durable and evident but not distinct in undisturbed soil. Soil material of this grade, when disturbed, breaks down into a mixture of many distinct entire peds, some broken peds, and little unaggregated material. Examples are the loam A horizons of typical Chestnut soils in the granular type, and clayey B horizons of such Red-Yellow Podzolic soils as the Boswell in the blocky type.
3. *Strong*.—That grade of structure characterized by durable peds that are quite evident in undisplaced soil, that adhere weakly to one another, and that withstand displacement and become separated when the soil is disturbed. When removed from the profile, soil material of this grade of structure consists very largely of entire peds and includes few broken peds and little or no unaggregated material. If necessary for comparison, this grade may be subdivided into *moderately strong* and *very strong*. Examples of strong grade of structure are in the granular-type A horizons of the typical Chernozem and in the columnar-type B horizons of the typical solodized-Solonetz.

The sequence followed in combining the three terms to form the compound name of the structure is (1) grade (distinctness), (2) class (size), and (3) type (shape). For example, the designation for the soil structure in which the peds are loosely packed and roundish but not extremely porous, dominantly between 1 and 2 mm. in diameter, and quite distinct is *strong fine granular*. The designation of structure by grade, class, and type can be modified with any other appropriate terms wherever necessary to describe other characteristics of the peds.

Many soil horizons have compound structure consisting of one or more sets of smaller peds held together as larger peds. Compound structures are so described: for example, *compound moderate very coarse prismatic and moderate medium granular*. Soil that has one structural form when in place may assume some other form when disturbed. When removed, the larger peds may fall into smaller peds, such as large prisms into medium blocks.

With increasing disturbance or pressure any aggregate breaks into smaller particles. These finer particles may or may not be peds, depending on whether their form and size are determined by surfaces of weakness between natural aggregates or by the place and direction of the pressures applied. Mere breakage into fragments larger than the soil grains without some orderly shape and size should not be confused with soil structure. Massive soil horizons, without structure, can be shattered into fragments—so can glass. Such fragments are not peds.

SOIL CONSISTENCE

Soil consistence comprises the attributes of soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation or rupture. Every soil material has consistence irrespective of whether the mass be large or small, in a natural condition or greatly disturbed, aggregated or structureless, moist or dry. Although consistence and structure are interrelated, structure deals with the shape, size, and definition of natural aggregates that result from variations in the forces of attraction within a soil mass, whereas consistence deals with the strength and nature of such forces themselves.

The terminology for consistence includes separate terms for description at three standard moisture contents (dry, moist, and wet). If moisture conditions are not stated in using any consistence term, the moisture condition is that under which the particular term is defined. Thus *friable* used without statement of the moisture content specifies *friable when moist;* likewise, *hard* used alone means *hard when dry,* and *plastic* means *plastic when wet.* If a term is used to describe consistence at some moisture content *other* than the standard condition under which the term is defined, *a statement of the moisture condition is essential.* Usually it is unnecessary to describe consistence at all three standard moisture conditions. The consistence when moist is commonly the most significant, and a soil description with this omitted can hardly be regarded as complete; the consistence when dry is generally useful but may be irrelevant in descriptions of soil materials that are never dry; and the consistence when wet is unessential in the description of many soils but extremely important in some.

Although evaluation of consistence involves some disturbance, unless otherwise stated, descriptions of consistence customarily refer to that of soil from undisturbed horizons. In addition, descriptions of consistence under moist or wet conditions carry an implication that disturbance causes little modification of consistence or that the original consistence can be almost restored by pressing the material together. Where such an implication is misleading, as in compacted layers, the consistence both before and after disturbance may require separate description. Then, too, compound consistences occur, as in a loose mass of hard granules. In a detailed description of soils having compound structure, the consistence of the mass as a whole and of its parts should be stated.

A number of terms, including *brittle, crumbly, dense, elastic, fluffy,*[1] *mealy, mellow, soft, spongy, stiff, tight, tough,* and some others, which have often been used in descriptions of consistence, are not here defined. These are all common words of well-known meanings. Some are indispensable for describing unusual conditions not covered by other terms. They are useful in nontechnical descriptions where a little accuracy may be sacrificed to use a term familiar to lay readers. Whenever needed, these or other terms for consistence not defined in this *Manual* should be employed with meanings as given in standard dictionaries.

The terms used in soil descriptions for consistence follow:

[1] As used in describing soils, *fluffy* denotes a combination of loose to very friable consistence and low bulk density.

I. CONSISTENCE WHEN WET

Consistence when wet is determined at or slightly above field capacity.

A. **Stickiness.**—Stickiness is the quality of adhesion to other objects. For field evaluation of stickiness, soil material is pressed between thumb and finger and its adherence noted. Degrees of stickiness are described as follows:

0. *Nonsticky:* After release of pressure, practically no soil material adheres to thumb or finger.
1. *Slightly sticky:* After pressure, soil material adheres to both thumb and finger but comes off one or the other rather cleanly. It is not appreciably stretched when the digits are separated.
2. *Sticky:* After pressure, soil material adheres to both thumb and finger and tends to stretch somewhat and pull apart rather than pulling free from either digit.
3. *Very sticky:* After pressure, soil material adheres strongly to both thumb and forefinger and is decidedly stretched when they are separated.

B. **Plasticity.**—Plasticity is the ability to change shape continuously under the influence of an applied stress and to retain the impressed shape on removal of the stress. For field determination of plasticity, roll the soil material between thumb and finger and observe whether or not a wire or thin rod of soil can be formed. If helpful to the reader of particular descriptions, state the range of moisture content within which plasticity continues, as plastic when slightly moist or wetter, plastic when moderately moist or wetter, and plastic only when wet, or as plastic within a wide, medium, or narrow range of moisture content. Express degree of resistance to deformation at or slightly above field capacity as follows:

0. *Nonplastic:* No wire is formable.
1. *Slightly plastic:* Wire formable but soil mass easily deformable.
2. *Plastic:* Wire formable and moderate pressure required for deformation of the soil mass.
3. *Very plastic:* Wire formable and much pressure required for deformation of the soil mass.

II. CONSISTENCE WHEN MOIST

Consistence when moist is determined at a moisture content approximately midway between air dry and field capacity. At this moisture content most soil materials exhibit a form of consistence characterized by (a) tendency to break into smaller masses rather than into powder, (b) some deformation prior to rupture, (c) absence of brittleness, and (d) ability of the material after disturbance to cohere again when pressed together. The resistance decreases with moisture content, and accuracy of field descriptions of this consistence is limited by the accuracy of estimating moisture content. To evaluate this consistence, select and attempt to crush in the hand a mass that appears slightly moist.

0. *Loose:* Noncoherent.
1. *Very friable:* Soil material crushes under very gentle pressure but coheres when pressed together.
2. *Friable:* Soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.
3. *Firm:* Soil material crushes under moderate pressure between thumb and forefinger but resistance is distinctly noticeable.
4. *Very firm:* Soil material crushes under strong pressure; barely crushable between thumb and forefinger.
5. *Extremely firm:* Soil material crushes only under very strong pressure; cannot be crushed between thumb and forefinger and must be broken apart bit by bit.

The term *compact* denotes a combination of firm consistence and close packing or arrangement of particles and should be used only in this sense. It can be given degrees by use of "very" and "extremely."

III. CONSISTENCE WHEN DRY

The consistence of soil materials when dry is characterized by rigidity, brittleness, maximum resistance to pressure, more or less tendency to crush to a powder or to fragments with rather sharp edges, and inability of crushed material to cohere again when pressed together. To evaluate, select an air-dry mass and break in the hand.

0. *Loose:* Noncoherent.
1. *Soft:* Soil mass is very weakly coherent and fragile; breaks to powder or individual grains under very slight pressure.
2. *Slightly hard:* Weakly resistant to pressure; easily broken between thumb and forefinger.
3. *Hard:* Moderately resistant to pressure; can be broken in the hands without difficulty but is barely breakable between thumb and forefinger.
4. *Very hard:* Very resistant to pressure; can be broken in the hands only with difficulty; not breakable between thumb and forefinger.
5. *Extremely hard:* Extremely resistant to pressure; cannot be broken in the hands.

IV. CEMENTATION

Cementation of soil material refers to a brittle hard consistence caused by some cementing substance other than clay minerals, such as calcium carbonate, silica, or oxides or salts of iron and aluminum. Typically the cementation is altered little if any by moistening; the hardness and brittleness persist in the wet condition. Semireversible cements, which generally resist moistening but soften under prolonged wetting, occur in some soils and give rise to soil layers having a cementation that is pronounced when dry but very weak when wet. Some layers cemented with calcium carbonate soften somewhat with wetting. Unless stated to the contrary, descriptions of cementation imply that the condition is altered little if any by wetting. If the cementation is greatly altered by moistening, it should be so stated. Cementation may be either continuous or discontinuous within a given horizon.

1. *Weakly cemented:* Cemented mass is brittle and hard but can be broken in the hands.
2. *Strongly cemented:* Cemented mass is brittle and harder than can be broken in the hand but is easily broken with a hammer.
3. *Indurated:* Very strongly cemented; brittle, does not soften under prolonged wetting, and is so extremely hard that for breakage a sharp blow with a hammer is required; hammer generally rings as a result of the blow.

Appendix II. Identification of Profiles Index

Soil survey numbers, laboratory numbers and soil series names are given for the profiles used. The series names are those by which the profiles were identified when the samples were taken and the descriptions were written. The names may be incorrect in some cases and the proper identification will require further study and comparison with other profiles within the series or related series. Names are absent from a number of the profiles which were not identified according to any established series. Both soil survey numbers and laboratory numbers are included for all profiles for which they are available.

The list is as follows:

Profile Number	Soil Survey Number	Laboratory Number	Soil Series Names	Area
1	S53ND9-5	1785-1791	Bearden	Cass Co., N. D.
2	S57Neb89-11	6326-6331	Sharpsburg	Washington Co., Neb.
3	S56SD33-10	4433-4440	Eakin	Hand Co., S. D.
4	ND53-P-10		Exline	Dickey Co., N. D.
5	S58Wash5-1	58151-58158	Quillayute	Clallam Co., Wash.
6		55150-55155	Bladen	Craven Co., N. C.
7	S55Oreg5-1	3409-3415	Aiken	Columbia Co., Oreg.
8	S55Oreg7-1	55140-55150	Odin	Crook Co., Oreg.
9	4544072-1	45540-45546	Windthorst	Erath Co., Tex.
10		9854-9858		Pola, Yugoslavia
11	S56Ind42-1	5489-5495	Alford	Knox Co., Ind.
12	S47Miss59-6	4838-4845	Shubuta	Prentiss Co., Miss.
13		6424-6429	Morley	Allen Co., Ohio
14		4578-4586		Van Wert Co., Ohio
15	S54ND53-1	2315-2321	Williams	Williams Co., N. D.
16		E5248-5253		Union Co., Ohio
17	S54SD53-1	2616-2623	Rhoades	Perkins Co., S. D.
18	S56ND41-7	4487-4494	Exline	Sargent Co., N. D.
19	S56ND41-10	4509-4516	Tetonka	Sargent Co., N. D.
20	S49Wn17-1	49739-49745	Klaus	King County, Wash.
21	S53Ga13-10	53320-53328	Leon	Brantley Co., Ga.
22	S48Minn56-4	49652-49658	Nebish	Ottertail Co., Minn.
23	S51Neb40-13	963-970	Fillmore	Hall Co., Neb.
24	S54NY55-2	55508-55520	Marlin	Tompkins Co., N. Y.
25	S56Nev2-4	5653-5658	McCarran	Clark Co., Nev.

Profile Number	Soil Survey Number	Laboratory Number	Soil Series Names	Area
26	S55Ca136-3	5517-5525	Lahontan	San Bernadino Co.,Calif.
27	S57PR8-1	7442-7448	Nipe	Puerto Rico
28	S58PR11-1	9838-9844	Los Guineos	Puerto Rico
29	S56NH9-2	561171-561178	Scituate	Strafford Co., N. H.
30	S56NH9-4	561186-561194	Ridgebury	Strafford Co., N. H.
31	S4557-5	S4557-5-1 to S4557-5-6	Redding	Tehama Co., Calif.
32	S56Maine2-4	561223-561229	Caribou	Aroostook Co., Maine
33	S45Minn22-1	451543-451551	Clarion	Faribault Co., Minn.
34	S58WVa13-3	10496-10499	Teas	Greenbrier Co., W. Va.
35	S58Alas3-2	9561-9565	Tanana	Alaska
36	S57Alas5-18	9552-9556	Kalifonsky	Alaska
37	S57SC15-11	57565-57568		Colleton Co., S. C.
38	S53Va68-17	54760-54761	Wehadkee	Nottoway Co., Va.
39	S53Fla58-1	531059-531064	Lakewood	Sarasota Co., Fla.
40	S55SC40-1	551540-551547	Lakeland	Richland Co., S. C.
41 1/			Redfield	Beryl-Enterprise Area, Utah
42	S56Tex178-3	5032-5039	Victoria	Nueces Co., Texas
43	S56Tex61-1	4996-5001		Denton Co., Texas
44	S58Miss48-1	8200-8207	Eutaw	Monroe Co., Miss.
45	S56Ariz13-7	561040-561047		Yavapia Co., Ariz.
46	S56Ariz13-6	561033-561039		Yavapia Co., Ariz.
47		1256-1262A		Ashtabula Co., Ohio
48	S58NY55-2	59316-59322	Erie	Tompkins Co., N. Y.
49	S58Mass8-5	10404-10407	Whitman	Hampshire Co., Mass.
50	S46Alas61-2	47366-47369		Adak Island, Alaska
52	S58HA1-3	59521-59526	Waimea	Hawaii Island, Hawaii
53	S58HA1-1	59495-59503	Hilo	Hawaii Island, Hawaii
54	46Alas1-1			Point Barrow, Alaska
55	S53Tenn5-29	53377-53381	Burton	Blount Co., Tenn.
56	S56Ore26-2	5410-5415	Powell	Multnomah Co., Ore.
57	2221/A-1	P.S.No.1 101-107	Mimbres	Luna Co., N. M.
58	S56Nev14-14	56410-56414	Blackhawk	Pershing Co., Nev.
59	S51Utah11-16		Escalante	Beryl-Enterprise Area, Utah

Profile Number	Soil Survey Number	Laboratory Number	Soil Series Names	Area
60	S56Nev2-4	5653-5658	McCarran	Clark Co., Nev.
61	S58Utah6-2	58136-58142	Saltair	Davis Co., Utah
62	S59Ariz7-3	5938-5945	Mohave	Maricopa Co., Ariz.
63 2/	S51Utah11-15	3093-3097	Uvada Uvada	Beryl-Enterprise Area, Utah
64	S58Calif10-1	58245-58250	Fresno	Fresno Co., Calif.
65	P-16		Edina	Wayne Co., Iowa
66	S56ND41-3	4456-4464	Tetonka	Sargent Co., N. D.
67	S54Minn81-113B	55105-55112	Webster	Waseca Co., Minn.
68	S56ND41-2	4449-4455	Barnes	Sargent Co., N. D.
69	S49SD58-1	1279-1285		Spink Co., S. D.
70	S50ND38-4		Hamerly	Renville Co., N. D.
71		59309-59315		Yugoslavia
72	S56Iowa1-6	5748-5755	Shelby	Adair Co., Ia.
73	S58ND17-1	8617-8624	Morton	Golden Valley Co., N. D.
74	S57Neb53-1	5795-5802	Kieth	Kimball Co., Mo.
75	33L2K/A	281-289	Mansker	Quay Co., N. M.
76	S58ND51-3	8707-8715	New Mexico	Ward Co., N. D.
77		59295-59300		Bardufoss, Norway
78		59301-59307		Bardufoss, Norway
79	S57La1-4	7159-7167	Wrightsville	Acadia Parish, La.
80	S58Wash21-1	58159-58167	Lacamas	Lewis Co., Wash.
81	W1-1toW1-10	531552-531561	Bethel	Wayne Co., Ind.
82		3059-3069	Clermont	Clinton Co., Ohio
83	S58Ill38-1	9726-9732	Huey	Jasper Co., Ill.
84	S56Ind42-2	5515-5523	Hosmer	Knox Co., Ind.
84a	S58NY6-1	59323-59330	Lansing	Cayuga Co., N. Y.
85	S54Wash6-2	551664-551672	Gee	Clark Co., Wash.
86	S4557-10		Redding	Sacramento Co., Calif.
87	S56Calif37-1	56206-56213	Carlsbad	San Diego Co., Calif.
88	S4557-6		Red Bluff	Sacramento Co., Calif.
89	S4557-11		Corning	Sacramento Co., Calif.
91	S58PR9-1	9831-9837	Sabana Seca	San Juan SCD, Puerto Rico
92	S47Ga82-1		Leaf	Jenkins Co., Ga.
94	S58Md16-1	58651-58660	Leonardtown	Prince George's Co., Md.

Profile Number	Soil Survey Number	Laboratory Number	Soil Series Names	Area
95	S55Oreg2-2	3443-3449	Aiken	Benton Co., Oreg.
96	45Ala35-1		Cahaba	Houston Co., Ala.
97	S56Miss16-1	8979-8986	Ora	Covington Co., Miss.
98	S49Ill91-1	17561-17570	Hosmer	Union Co., Ill.
99	S58PR4-3	9791-9799	Catalina	Cibuco SCD, Puerto Rico
100	S58PR4-8	9817-9825	Cialitos	Cibuco SCD, Puerto Rico
101		48766-48771	Rubona	Costermansville, Belgian Congo
102	S58HA5-1	59560-59566	Molokai	Molokai Island, Hawaii

1/ Data of Profile No. 41, representing the Redfield series, are from SSSAP20:570-574.

2/ The data from two almost identical profiles a short distance apart are represented in Profile No. 63. Mechanical analyses, pH, and $CaCO_3$ equivalent are from the profile with soil survey number S51Utah11-15. The remainder of the laboratory data are from the profile with laboratory numbers 3093 to 3097.

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(Numbers marked by an asterisk* indicate references to principal definitions or explanations)

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