A More Quantitative Approach to Soil Morphology

George Jule Buntley

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A MORE QUANTITATIVE APPROACH TO SOIL MORPHOLOGY

BY

GEORGE JULE BUNTLEY

A thesis submitted
in partial fulfillment of the requirements for the
degree Doctor of Philosophy, Department
of Agronomy, South Dakota State
College of Agriculture and
Mechanic Arts

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.
A MORE QUANTITATIVE APPROACH TO SOIL MORPHOLOGY

Abstract

GEORGE J. BUNTLEY

Under the supervision of Professor Fred C. Westin

As a means of developing a more quantitative approach to the study of soil morphology, quantitative standards for the consistent observation and characterization of the morphologic features were developed. The development of quantitative values for the features of soil morphology also was undertaken, first, to provide a means through which the results of detailed soil morphology studies made using the quantitative standards could be presented graphically, and secondly, as a pilot study pointed toward the possibility of the field determination of certain soil properties, common to both the field and laboratory study of soils, with a degree of quantitateness presently only obtainable through laboratory methods. A symbolization system and a description card for recording the field observations of soil morphology made using the quantitative standards were also developed.

The quantitative standards, values and recording methods developed and tested in the study, were applied to a climosequence of six soil profiles in eastern South Dakota as a means of testing the sensitivity of the methods developed to bring out and quantitatively present the subtle developmental progression in the genetic morphology of closely related soils. The profiles were also characterized in the laboratory.
It is concluded from this study that: (a) The quantitative standards and recording methods developed appear to be well adapted to the consistent field observation and characterization of the morphologic features of the soil. (b) The quantitative standards and values developed appear to be sensitive to, and capable of showing, the micro as well as the macro changes in the developmental progressions of the genetic morphology of soils. (c) The quantitative standards and values developed are useful in locating natural discontinuities in the continua of individual morphologic entities, thus providing a basis within the soil itself for the quantitative differentiation and characterization of classificational units. (d) The use of the quantitative standards and values developed makes possible the graphic portrayal of all morphologic features of the soil for which values can be developed. (e) A graphic presentation of the morphologic features of the soil facilitates the recognition and characterization of the evolutionary nature of the morphologic and genetic transitions between adjacent profiles in the continuum of soils. (f) The use of the quantitative standards and values developed appears to make possible the field determination of certain soil properties with a degree of quantitateness presently only obtainable through laboratory analysis.

Conclusions also were drawn from the results of this study relative to the classification of the profiles investigated.
ACKNOWLEDGMENTS

The author wishes to extend his most sincere appreciation to Professor Fred C. Westin for his kind guidance, assistance, and encouragement throughout the pursuance of this problem and the preparation of this thesis.

Appreciation also is extended to Mr. C. A. Nogen, Senior Soil Correlator, Soil Conservation Service, for initiating the challenge, many years ago, which ultimately led the author to undertake this study. The author is grateful to the Laboratory Staff, Soil Survey Laboratory, Lincoln, Nebraska, for furnishing the laboratory data for three of the profiles used in this study.

To my wife, Bernice, and to my children, Hal and Carla, for their thoughtful understanding and unselfish consideration throughout the prolonged pursuance of this problem, I wish to express my deepest appreciation.

OJB
One of the basic concepts in my philosophy of soil classification deals primarily with my beliefs as to the definition of, the true purpose of, and the value to be derived from any classification scheme. Classification for the sake of classification per se is unproductive and defeats what I believe to be the true purpose of classification—the acquisition of knowledge about the entities being classified. Therefore, in the broad sense, my definition of classification is that of a learning process and should not, under any condition, be an arbitrary, unyielding, and unchanging set of rules. This learning process involves the tentative organization of the existing knowledge about the entities being classified, but even more importantly, the periodic but continuing reorganization of this knowledge as new facts bearing on the classification of the entities are uncovered. Each such reorganization should result in a refinement in the classification, and each refinement should reflect the progress made in the acquisition of knowledge.

Thus classification must be a dynamic medium, which through imperfection in its framework at any particular point in time, highlights the voids in our knowledge of the entities of which the classification is being attempted. This, it seems to me, is as it should be, for as soon as a classification becomes static and unchanging it is no longer compatible with the foundational precepts underlying scientific study. Moreover, a static classification implies a finality associated with completeness, and one can only presuppose that in a completed classification everything pertaining to the entities being classified is
known. If the latter is truly the case, then the classification in itself can serve no purpose, other than perhaps as a headstone for a dead science.

In order that classification satisfy the philosophical approach of science and assume its rightful place as a useful scientific tool, its development must come about through the use of the inductive method. In other words, a classification must be constructed. This makes the entity individuals the building blocks of classification, and the categorical levels above the individual can be only as sound as are the building blocks from which they must be constructed.

At this point it would be difficult and probably illogical to continue the discussion of my philosophy of soil classification without also introducing some of my philosophy of soil genesis and morphology. My apparent hesitancy to conceive of these as individual, unrelated philosophies appears justifiable, since it is both the morphologic and genetic characteristics of the soils which must form the criteria on which soil classification is based.

My first statement in this vein must be to the effect that I do not consider soil morphology and soil genesis to be mutually exclusive discrete entities. Without genesis there could be no morphology, and conversely, without morphology there could be no genetic points of reference. My concept of soil morphology is that it is the expression of soil genesis. I believe, therefore, that a morphologic classification is by necessity also a genetic classification.
A soil classification must classify the soils, not the factors responsible for their formation, nor the practical use to which the soils may be put. The morphologic characteristics, being the expression of soil genesis and being the only observable reflection in the soil profile of the interaction of the soil forming factors, must be the basis for the classification of soils. These morphologic features comprise the historical record of past genesis, are diagnostic of the present genesis and collectively are the prognostication of the direction of future genesis.

I strongly adhere to the concept that the soil individual is not in static equilibrium with its environment, but rather that the equilibrium that does exist is of a dynamic nature. I further consider that the dynamics involved are the slow but constant unidirectional changes leading toward the next higher stage of development than that already attained at any given point in time. Also involved is the concept that no soil individual is exclusively the product of just one genetic soil forming process. All soils, according to my philosophy of genetic relationships, are polygenic, being intergradational, inter-extragradational or extragradasional to a greater or lesser degree. The greater the degree of dominance of a particular genetic process however, the less adept we are at recognizing the existence of polygenesis with our present techniques of observation, sampling and analysis.

Resultant of the above stated concepts, and further because I believe that each individual soil forming factor is a continuum, that
the interaction of these factors is a continuum, and that the genetic processes are a continuum, I must also conceive of the soil population as a continuum.

The above concepts strongly influence my philosophical approach to classificational detail. I am firmly convinced that more emphasis should be placed on intergrade and extragrade classifications at all categorical levels in the classification system. The shades of intergradation, inter-extrgradation and extrgradation, along with their directional aspects, are recognizable in the micromorphological characteristics of the soil profile. The factor or combination of factors responsible for setting the dynamics of intergradation in motion are also exposed in the micromorphologic record. As techniques for the observation, sampling and analysis become more realistic, objective and quantitative, the story of the intergrading genetic conditions involved in soil formation will become more apparent and can be more precisely measured. As measurements become more precise, knowledge will become more complete and the classification more highly refined until ultimately it evolves into a three-dimensional ordinal system. The discontinuities in the rates of changes in the progression lines of different factor continuums, as reflected by the morphologic details embodied within the fabric of the soil profiles themselves, will set the limits of what comprises any particular categorical unit. Thus the limits will have been dictated from within the soils in which they exist and will no longer exist only as illusive figments in the minds of men.
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INTRODUCTION

Soil classification is based, directly or indirectly, on the morphology and genesis of the soil. Soil morphology must be the expression of soil genesis, since it is in terms of the morphological features of the soil that the genetic processes are identified, described, and defined. It would appear therefore, that the concepts of soil genesis and the concepts of soil classification can be no better than is the conceptional framework governing the observations of soil morphology and the terminology used to express these observations.

Concepts are expressed with terminology; consequently, concepts can be no more dependable than is the terminology with which they are given expression. So long as there are doubts as to the meanings of terms it is impossible to think clear thoughts, for all thinking on a theoretical level is implemented primarily, if not wholly, by words, and if the implements are faulty, so are the thoughts and concepts born of these thoughts likely to be faulty.

The problems of meaning and definition of terminology are acute in the morphological phases of soil study. Although problems of meaning admittedly are essentially philosophical problems, in that the answer is not a statement of fact but rather an interpretation of words or statements, they must somehow be resolved before it will be possible to deal objectively with the facts.

With this line of reasoning in mind, the following objectives were undertaken by this study: (a) To develop quantitative standards
for the consistent observation and characterization of the morphological features of the soil, (b) To develop quantitative numerical values for the quantitative standards to allow graphic presentation of the features of soil morphology as well as provide a basis for making quantitative field estimates of certain soil properties otherwise requiring laboratory characterization, (c) To develop a system of symbolization and other methods of recording to facilitate the use of the quantitative standards by the field morphologist, and (d) To assay the capacity and usefulness of the methods developed in (a), (b) and (c) above, as tools in the study of soil genesis and classification problems, and as a basis for the quantitative characterization of the classificational units, through the application of these methods of quantitative morphologic study to six soil profiles in eastern South Dakota.
Dokuchaiev in Russia, as reported by Afanasiev (1) and by Glinka (19), and Coffee (13) in the United States, both came to the realization around the beginning of the 20th century that the soil was an independent, natural body. This, then revolutionary concept of soil, although slow to gain acceptance, furnished the initial stimulus to the study of soil morphology.

The procession of soil classification schemes developed since 1900 also have served to stimulate increasingly more detailed study of the morphology of the soil by placing an ever-increasing burden of proof on the morphologic features of the soil as the differentiating criteria of soil classification.

In 1921, Warbut (33) listed the features of the soil profile that he regarded at that time as being significant and in constant use as bases for classificational differentiation. Included in this list were: (a) Number of horizons in the soil profile, (b) Color of the various horizons, with special emphasis on the surface one or two, (c) Texture of the horizons, (d) Structure of the horizons, (e) Relative arrangement of the horizons, (f) Chemical composition of the horizons, (g) Thickness of the horizons, and (h) Geology of the soil materials.

Warbut (34) relied in part on the morphologic features of the soils themselves as criteria for differentiating the classes in the scheme of soil classification that he presented to the First International Congress of Soil Science in 1927.
Nikiforoff (42), in discussing the description of soils and their morphology in a paper written in 1936, summed up the state of the knowledge pertaining to standards for the observation and characterization of the morphologic features of the soil at that time.

The general technique of soil description, however, still remains one of the weakest points of our discipline. It is still believed by many that a good description of the soil is a subject of art rather than of a technical record of exactly defined facts. . . . The difficulties in this particular case derive from both a primitiveness of the means available for the description and the nature of the subject to be described. . . . It is coupled with a rather primitive, and in many instances confusing terminology used for connotation of various facts, as well as conflicting interpretations and uses of certain terms by different writers.

Nikiforoff (42), in this same paper, set up standards, some of which with slight modifications are still in use today, for the observation and description of the following features of the morphology of the soil: (a) Depth and thickness of the soil horizons, (b) Character of the boundary between two adjoining horizons, (c) Color, (d) Consistency, (e) Texture, (f) Structure, (g) Carbonates and (h) Porosity.

In 1937 Kellogg (28) authored the first of several "Soil Survey Manuals." This manual was a standard work and was intended for the use of soil surveyors in the field, especially those engaged on projects of, or cooperative work with, the Bureau of Chemistry and Soils of the United States Department of Agriculture. In referring to the manual itself, Kellogg made the following statement.

Its present form and content reflects the development of the work over the last 38 years and the ideas and labor of hundreds of soil scientists working in the field during this period.
This publication (28), being an official publication of the Bureau of Chemistry and Soils of the United States Department of Agriculture, set the standards for the observation and characterization of the features of soil morphology that at least in part were to be the criteria for the differentiation of soils in the scheme of soil classification proposed one year later in the 1938 Yearbook of Agriculture.

The soil classification scheme presently in use, as outlined in "Soils and Men," the 1938 Yearbook of Agriculture (66), and as modified by Thorpe and Smith (64), Riecken and Smith (54) and others in 1949, places even greater emphasis on the soil characteristics themselves as criteria of differentiation within the classification than did Marbut's classification, even though, like in that of Marbut's, forces outside the soil profile per se appear to be the actual differentiae in many instances.

Standards for the quantitative observation, description and classification of soil colors received considerably more attention, and at a much earlier date, than did standards for the other features of soil morphology. Most of this early work was primarily the contribution of the "Committee on Soil Color Standards" of the American Soil Survey Association.

Hutton et al. (22), in the 1923 report of this committee, considered whirling Maxwell discs for color matching of soils, but this idea was temporarily abandoned for lack of standard color discs. At the 1925 meeting of this same committee, Hutton et al. (23) reported
the use of Munsell standard color discs for measuring and recording the colors of soils. By 1927 a set of four standard Munsell color discs, spectrophotometered by the U.S. National Bureau of Standards, was available for measuring soil colors (41). These discs were the basis of the standard color measurements proposed in the 1937 "Soil Survey Manual" (28); however, no attempt was made in this publication to correlate the laboratory measurements of the colors with a standard color nomenclature. Charts, carrying 56 different color chips, were published as the "Soil Color Name Charts" which accompanied Rice et al.'s, "Preliminary Color Standards and Color Names for Soils" (52).

A more recent committee of the U.S. Soil Survey, under the chairmanship of E. H. Tempkin, replaced the earlier charts with a much wider selection of colors (61, 41). This compact set of standard color charts and the accompanying standard color nomenclature (40) was authorized by the U.S. Soil Survey in 1948, and with minor revisions has been used widely as the standard reference for soil colors since that time. The "Munsell Soil Color Charts" (40) are the standard color reference appearing in the current "Soil Survey Manual" (53) which was issued in 1951 as a revision and enlargement of the "Soil Survey Manual" published earlier.

Although the "Munsell Soil Color Charts" provided a quantitative color standard, the conditions under which this standard was applied were critical to the ultimate quantitiveness of the actual color determinations made using the standard. Pendleton and Nickerson (48) set down certain standards with respect to light conditions
best suited to the use of the color standard. These standards however, appear to be somewhat contradictory. They suggest that as far as possible the charts should be used in the field when the soils are being described, although they also note that it is difficult to get a satisfactory match in bright sunlight or out in the open. These workers state that in the northern hemisphere, north light, preferably that from a light or moderately overcast sky, is best suited to reading soil colors.

Clarke (12), in discussing color description, reported the following.

The angle at which light illuminates the soil may cause apparent colour changes due to reflection and absorption. The length of the shadows cast by the soil particles in the texture and structure of the soil mass also produces peculiar effects. Red soils tend to look redder in the afternoon than in the morning . . . .

No reference is made in either the 1937 or 1951 "Soil Survey Manuals" (28, 58) to a standard light condition under which the soil color standard should be applied in making quantitative color determinations of the soil.

Because of the change in soil color with changing moisture content, Pendleton and Nickerson (48) and the current "Soil Survey Manual" (58) advocate reading and reporting the color of the soil at two moisture contents—air dry and field capacity.

The standard color of a horizon appears to be an undefined characteristic. Pendleton and Nickerson (48) imply that the standard horizon color is that color read on the freshly broken surface of a clod, although they do not define a clod relative to the natural unit
of structure.

Although the "Soil Survey Manual" (58) states that—

In the description of soil color, special notice should be taken of any relationships between 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 material is brown or yellow. When such granules are crushed, the mass of the 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 is common.

---it does not establish or identify a standard orientation within the horizon for the quantitative measurement of the standard horizon color or colors.

The incidence of color coatings on the faces of structure ped is a feature of color common in most soils, as indicated in the quotation above, and is frequently reported in soil descriptions; however, standards for the observation and quantitative characterization of color coatings have not been reported in the literature.

Conrey (14) emphasized the importance of mottled colors in soils. Simonson (56) devised and reported semi-quantitative standards for the observation and description of mottling in soils based on the contrast, abundance and size of the mottles per se. He also indicated that the description of the shape and boundary characteristics of the mottles might be necessary to the complete characterization of mottled patterns in some horizons. The standards for color mottling developed by Simonson also appear as the standards for color mottling in the current "Soil Survey Manual" (58).
The earliest standards for the observation and characterization of soil structure were those evolved by the Russian pedologist, Zakharov (69). These standards confined the description of the structure strictly to the size and shape of the aggregates, the consistence or the tenacity of the aggregates being described as a separate item. In Zakharov's system there were three types of structural elements classified according to the main shape of the aggregates. These types were then further divided into nine kinds according to the clarity of definition of the faces and edges of the elements, and then these were further subdivided into numerous varieties according to the size of the elements for which there were quantitative dimensional class limits.

In the United States, the first published standards of consequence for the observation and characterization of soil structure appeared in 1936 in Mikiforoff's paper, "Methods of Recording Soil Data" (42). In this paper he characterized soil structure as to its type, size and grade. The types of structure listed were columnar, platy, blocky and granular. Five size classes and five grade classes were suggested; however, no class limits were reported either for the size classes or the grade classes. The grade element of structure was defined in terms of consistence in this paper.

In 1937, Mikiforoff (43) revised the structure standards that he had proposed the previous year. Although he continued to characterize soil structure relative to its type, size and grade, he altered the number of classes within some of these elements. The types of structure were listed as platy, prismatic, lumpy and granular.
Three size classes and five grade classes were suggested. The most important change appeared to be in his concept of structure grade. The interaction between the aggregate cohesion and the interaggregate cohesion was substituted for consistence in determining the structure grade classes.

Standards for the observation and characterization of soil structure also appeared in the 1937 "Soil Survey Manual" (28). The manual stated that although there are no precise single-value expressions for soil structure in the field, there are several fairly well established morphological types of structure which vary in themselves as regards hardness and consistence. Consistence terms were used in describing the structure types and appeared to be a part of the definition of these types. The structure types listed were prismatic, nutlike, columnar, platy, crumb, granular, fragmental and phylliform. Although size was used as a modifier in describing the structure, size classes per se were not reported. The grade element of structure was not recognized as such but was included within the definitions of the structure types through the use of consistence terms as modifiers. These standards apparently were used by the Federal Soil Survey until the new "Soil Survey Manual" was issued in 1951.

Bradfield and Jamison (5) attempted a quantitative characterization of the type, size and grade of structure utilizing pore space and moisture tension measurement methods in the laboratory. The results of this investigation were concluded not to be applicable to the field characterization of the elements of soil structure.
In 1924, Nikiforoff (44) revised, refined and enlarged his standards for the field characterization of soil structure. Four principal types of soil structure—platy, prismatic, blocky, and granular—were recognized on the basis of the general shape of the aggregates. Five classes were recognized according to the average size of the most numerous and conspicuous aggregates and these classes were defined with quantitative dimensional limits. Five grades of soil structure were distinguished and each grade was characterized by a particular combination of durability of the aggregates and degree of their adhesion to one another. Quantitative limits were not reported for the structure grade classes.

Clarke (12) outlines what he terms the "Oxford System" of soil structure classification which, in its essentials, is very similar in all aspects to Zakharov’s (69) system.

The structure standards published in the 1951 revision of the "Soil Survey Manual" (58) are very similar to those advocated by Nikiforoff in 1941. The primary structure types and subtypes are, (a) platy, (b) prismatic (prismatic and columnar), (c) blocklike (angular blocky and subangular blocky), and (d) spherical or polyhedral (granular and crumb). Quantitative definitions of these types are not reported. Five size classes are used that are similar in nomenclature and quantitative dimensional limits to those proposed by Nikiforoff (44). Five classes of structure grade are provided but quantitative definitions are not reported for these classes.
Although numerous national and regional committees have worked on the overall problem of the field characterization of the different elements of soil structure since 1951, the standards included in the 1951 revision of the "Soil Survey Manual" (53) are still the current published official standard of the Federal Soil Survey.

Clay skins are relatively new to the morphologic characterization of the soil in the field, although their occurrence had been noted in thin section studies much earlier. In 1939, Johnston (27) in utilizing the thin section technique of soils investigation, as outlined by Kubiena (32), made the following statement in describing the characteristics of the thin section of the B2 horizon in a Marshall profile.

A light yellowish-brown, birefringent, and pleochroic mineral is quite abundant in this horizon; large particles of it occur around small cracks, fissures, and root channels. Between crossed nicols this mineral can be seen to occur in an intricate network which indicates that it may be one of the clay minerals.

Although Johnston made no other reference to this condition in the paper, this would appear to be the first mention in the published literature of the entity now known as clay skins.

Illuviated clay size particles on deposition become oriented and under suitable conditions produce bands and coatings of optically oriented materials. More recently such coatings have been observed in thin sections of soils by numerous workers (17, 10, 36, 6, 9).

The clay skin entity, although not recognized as such, appears to have been observed in the field by some morphologists as early as 1950 (33). Soil profile descriptions including such statements as: "the ped surfaces glisten," or "the surfaces of the peds have a
varnished appearance," were written in the early 1950's (38). The current "Soil Survey Manual" (58) includes no reference to the clay skin entity. Standards for the field observation and characterization of clay skins are not reported in the published literature, although a number of soil morphologists with whom the author is personally acquainted have devised and used standards of varying detail for the field characterization of clay skins (38, 61).

The new classification scheme presently being proposed (59), places considerable emphasis on the clay skin entity as a criterion of certain of the diagnostic horizons used in the system.

The first standards published in the United States dealing with the field characterization of soil consistence appear to be those proposed by Nikiforoff (42) in 1936. Terminology was developed for four consistence classes for the dry soil and four classes for the wet soil. These classes were defined only in terms of their relationship to the texture and moisture content of the soil material involved.

In 1937, Nikiforoff (43) enlarged upon and refined the standards for the field characterization of soil consistence that he had proposed the year previously. Two consistence terms were added to describe the consistence of clay-textured soils at two additional levels of moisture between those already established for dry and wet soil material. In addition, three classes of cementation were introduced. Adequate descriptive definitions were included for the consistence classes proposed but the class limits were not quantitatively defined. The part of the soil fabric on which the consistence determination should be
made was not mentioned.

Kellogg (28), in the 1937 "Soil Survey Manual," listed what he referred to as "self-explanatory terms commonly used for defining soil consistence." The terminology presented in this manual was identical to that proposed by Nikiforoff (43); however, the consistence classes presented in the manual were not defined.

The 1951 revision of the "Soil Survey Manual" (58) extensively revised the standards for the field characterization of soil consistence. Six consistence classes for the dry soil and six consistence classes for the moist soil were developed, named and descriptively defined. The standards for determining wet consistence were enlarged. Four classes of stickiness (defined as the degree of adhesion to other objects), and four classes of plasticity (defined as the change in shape under stress and the retention of that shape when the stress is removed) were developed, named and descriptively defined. Three classes of cementation also were developed, named and descriptively defined.

In addition, the standards state that consistence should be described at all three moisture levels and that the consistence of the soil mass as a whole, and of its parts, should be described in horizons having compound structure.

Clarke (12) followed the standards for the field characterization of soil consistence presented in the 1951 "Soil Survey Manual" (58).

Nikiforoff (42), in 1936, published the results of one of the first attempts made in the United States of the field characterization
of soil porosity. He described three major kinds of porosity as occurring in soils in situ. **Primary** soil porosity was defined as that element of the total porosity of the soil that is a function of the texture and consistence of the soil. **Ordinary** soil porosity was defined as that element of the total porosity of the soil that is a function of the soil structure and other cracking. **Specific** soil porosity was subdivided into biologic porosity and physical porosity. Biologic porosity was defined as that element of the total soil porosity that is a function of the root channels and the channels caused by the activities of insects, worms and small animals. Physical porosity was defined as that element of the total porosity that is a function of vesicules and tubular pores. Standards for the field observation and quantitative characterization of the different elements of the total porosity were not reported.

The 1937 "Soil Survey Manual" (28) did little more than mention that field descriptions of the soil profile should include some notes regarding any observable features of soil porosity, such as tubular pores, fissures and the activities of the soil fauna.

Clarke (12) reported a system for the field characterization of soil porosity in 1957 that was similar in many respects to that proposed earlier by Nikiforoff (42). Clarke described the porosity within the aggregates and the porosity resulting from the nature of the spaces between the aggregates. Both types of porosity were characterized as to the size, shape and distribution of the pores. The size classes were quantitatively defined.
The most recent and by far the most comprehensive standards for the field observation and characterization of soil pores was proposed in 1960 by Johnson et al. (26). This paper presents a tentative classification of soil pores and a descriptive nomenclature related to that classification. Quantitatively defined abundance classes and size classes are developed along with classes characterizing the continuity and orientation of the pores. Standards defining the various cross sectional and transverse sectional shapes of the individual pores also are reported.

Nikiforoff (42) briefly discussed the field observation and characterization of the form and distribution of calcium carbonate in the soil profile in his 1936 paper. He proposed that the upper and lower limits of effervescence and the zone of greatest concentration in the profile be noted. He also states that the form in which the carbonates occur and other characteristics of their occurrence should be included in the profile description. No standards were suggested for the field observation and characterization of these features. No reference was made to salts other than calcium carbonate.

Kellogg (28), in the 1937 "Soil Survey Manual," states that the depth of occurrence, degree of concentration and the forms of free calcium carbonate and other salts should be carefully studied and described. A differentiation was drawn between the calcium carbonate uniformly distributed through the mass and that which occurred in concentrated forms. The concentrated forms of calcium carbonate and of other salts were classified as pseudomycelium, nodules or nests, and
surface films. Standards were not given for the field observation and characterization of these features.

The 1951 "Soil Survey Manual" (58) developed limited standards for the field observation and characterization of the free calcium carbonate occurring in soils. Three classes of effervescence were proposed to classify the free carbonates present as indicated by field testing with 10 percent hydrochloric acid, but these classes were not defined. Although no classes or definitions of other forms of calcium carbonate were proposed, the manual states that it should be noted in the description if the effervescence is due primarily to forms of calcium carbonate other than that uniformly distributed through the mass of the soil material. It also states that the exact boundaries of effervescent material in relationship to structural aggregates and to depth are important. The manual did not mention the observation and characterization of salts other than calcium carbonate.

Clarke (12) reported the use of audio and visual methods for estimating the percent calcium carbonate in soil material, although he did not establish classes.

Standards dealing with the field observation and characterization of the mineral population in soils are not reported in the literature.

Khan (29) in 1960 reported the distribution of the sand minerals in profiles representing several Great Soil Groups. The sand separates obtained through mechanical analysis were examined microscopically in the laboratory. The mineral grains occurring in the different sand
size fractions in the major horizons of the profiles were characterized as to their size, shape and degree of rounding. Counts of minerals having different weathering indices also were made.

Standards per se for the field observation and characterization of the morphologic features of the soil that are directly related to the activities of the soil fauna are not reported in the literature. Nikiforoff (42) called attention to the mechanical reworking of soil material by insects, worms and rodents and advocated its notation in the soil description. Kellogg (28) and the 1951 "Soil Survey Manual" (58) noted the occurrence of krotovinas in soils. Thorpe (63) enumerated the effects that certain animals living in the soil have on the morphologic characteristics of the soil. In 1960, Buntley and Papendick (8), using unpublished standards for the observation and characterization of morphologic features resulting from worm-working, reported the morphologic changes in soils resulting from intensive worm-working.

Standards for the field observation and characterization of horizon boundaries were proposed by Nikiforoff (42) in 1936. The boundaries were defined with respect to the clearness and general shape of the boundary per se. Four clearness classes were established that were quantitatively defined on the basis of the thickness of the zone of transition between the horizons. Four quantitatively defined shape classes also were proposed.

Standards for horizon boundary characteristics were not included in the 1937 "Soil Survey Manual" (28). The standards reported in the
1951 "Soil Survey Manual" (58) for the field observation and characterization of horizon boundaries are identical to those reported earlier by Nikiforoff (42).

Methods of recording the field observations and characterizations of the morphologic features of the soil are not reported frequently in the literature.

Nikiforoff (42) presented a field notebook form for recording what at that time were thought to be the basic morphologic features that should be included in the description of the soil profile. Symbols were developed and used for recording some, but not all, of the field observations made. The 1937 "Soil Survey Manual" (28) made no reference to a field notebook form on which the field observations of the morphologic features could be recorded.

Gardner et al. (18) in 1946, presented a somewhat more detailed field notebook form on which the morphologic features, considered at that time to be pertinent to a complete soil profile description, could be recorded. The description form was accompanied by a complete set of symbols that were to be used in recording the morphologic information of the profile description forms. In addition, space was provided for recording the cultural features, the site characteristics and any special features meriting description.

The 1951 "Soil Survey Manual" (58) included a field notebook form for soil profile description that was similar in most respects to that presented by Gardner et al. (18). Letter abbreviations were used in place of the symbols developed by Gardner (18).
Pomerening and Knox (51) in 1962, reported for the first time in the literature the use of quantitatively measured morphologic properties. These properties were utilized as parameters in statistically testing for natural soil groups within a catena population. Of the nine properties reported, five were morphologic features and four were properties usually characterized by laboratory analysis. Of the five morphologic features reported, three were directly involved with soil color, one with the boundary characteristic and one with the depth in the profile to evidence of impeded drainage.

The 7th approximation of a "Comprehensive System of Soil Classification" (59) was presented by American pedologists to the 7th International Congress of Soil Science in the summer of 1960. Definitions of the classes in all categories in this system are expressed in terms of observable or measurable properties. An effort to achieve more quantitative definitions than have been devised in earlier classification systems is basic to this scheme.

The emphasis placed on quantitateness by the 7th approximation (59), the degree of quantitateness necessary to allow statistical treatment of the morphologic characteristics of the soil (51), and the degree of quantitateness required for ordinal approaches to soil classification, as undertaken by Hole and Hironaka (20), accent the need for a more quantitative approach to the study of soil morphology per se.
FIELD AND LABORATORY METHODS

Field Methods

Development of Quantitative Standards for the Observations of Soil Morphology

The quantitative standards for the observations of soil morphology were developed through field studies of soil profiles over a period of seven years. The development of these standards proceeded through a series of approximations in which each succeeding approximation was a revision resulting from the refinement of the preceding one.

During this period of development, detailed field studies were made of the morphology of several hundred complete soil profiles. Detailed field studies also were made of one or more of the individual features of soil morphology in several hundred additional soil profiles during this phase of the field investigations.

Soil profiles, in which the extremes of one or more of the morphologic features were expressed, were sought out. The characteristics of these extreme expressions were observed and studied and were used as the basis for characterizing and establishing the upper and lower limits in the observable range of each of the individual morphologic features. The various degrees of expression between the established upper and lower limits of each of the morphologic features comprised a continuum, the members of which were variously represented and portrayed within the morphologic fabric of the large number of soil profiles studied. Although the bulk of the soil profiles utilized in
this phase of the study were those of South Dakota soils, observations
and notes from profiles comprising 13 zonal, six intrazonal and three
azonal Great Soil Groups, extending across 13 states, were incorporated
into the development of the standards. This was done in an attempt to
include as large a portion of the soil universe as possible in the
study, thus extending the range of its application and usefulness.

The expression continuum of each of the individual entities of
morphology was divided into classes having observable, quantitatively-
defined class limits. The class intervals were dependent in part on
the capabilities of the observer as well as on the observational and
measuring aids utilized. The number of classes used was influenced by
the interval detail required to show quantitatively the micro as well
as the macro changes in the developmental progression in the genetic
morphology as it might relate to more accurate classificational detail.

Development of Quantitative Numerical Values for the Quantitative
Standards

Quantitative numerical values were developed in conjunction
with the quantitative standards and their development by necessity pro-
ceeded through the same series of revisional approximations as did the
quantitative standards. The development of numerical values however,
was not attempted for all the features of soil morphology covered by
the quantitative standards. Numerical values were developed for only
the more commonly observed morphologic features.

For the most part the numerical values were derived from the
quantitative measurements defining the classes within the quantitative
standards. In these instances the quantitative measurement figures representing the class means were used as the numerical values of the classes. In cases in which more than one characteristic was involved in the characterization of a morphologic entity, the product of the numerical values of the individual characteristics was used as the numerical value of the complete entity being characterized.

In the case of free calcium carbonate however, a somewhat different approach was utilized for deriving the quantitative numerical values. In this instance the detailed observations of the free calcium carbonate feature on large numbers of samples were compared with the results of laboratory analyses of calcium carbonate equivalent on these same samples. The comparisons were analyzed and appropriate numerical values were assigned on the basis of these comparisons to the various forms and amounts of free calcium carbonate observable under field conditions through the use of the quantitative standards.

The development of quantitative numerical values was undertaken; first, to provide a means through which the results of detailed soil morphology studies made using the quantitative observational standards could be presented graphically; and secondly, as a pilot study pointed toward the possibility of the field determination of certain soil properties with a degree of quantitativeness presently obtainable only through laboratory methods.
Development of a Symbolization System and a Description Card for Recording the Field Observations of Soil Morphology Made Using the Quantitative Standards

The symbolization system was developed as a shorthand for recording the field observations of soil morphology made using the quantitative standards. The symbols used in the system were designed to be as connotative of the characteristic being symbolized as possible to facilitate their rapid recall by the observer.

The profile description card was developed to accommodate the use of the symbolization system for field recording the observations of soil morphology made using the quantitative standards. The forms comprising the description card were printed on flat-finish, blue stock to reduce the constant glare produced by the reflection of direct sunlight off the surface of a white card under field conditions.

Testing of the Quantitative Standards, Numerical Values and Recording Methods

The primary method utilized in testing the quantitative standards, numerical values and recording methods was the continuing application of these quantitative standards, numerical values and recording methods to the field study of soil profiles across a large and diverse soil population. This aspect of the testing was carried on simultaneously with, and as a planned part of, the developmental aspects of the study and it was this aspect of the testing that gave rise to the series of approximations through which the developmental phases progressed.
This method of testing also was used in correlating the ranges of each of the morphological characteristics as they exist across the soil universe, with the ranges in the quantitative standards developed for the characterization of these morphological characteristics.

The class interval detail within the quantitative standards, required to show the macro and micro changes in the developmental progression of the genetic morphology, also was tested by the use of this method.

Additional methods of testing the quantitative standards and numerical values were used in several instances.

The quantitative standards and numerical values for the thickness of clay skins were tested through the use of thin sections and a petrographic microscope.

The quantitative standards for the shape, condition and condition abundance of the quartz and dark minerals were tested by comparing the field determinations made of these characteristics with determinations made with a binocular microscope on the sand fractions obtained from mechanical analysis of the same material used for the field determinations.

The quantitative standards and numerical values used in the field determinations of calcium carbonate equivalent were tested by making laboratory analyses of calcium carbonate equivalent of the same materials on which the field determinations of calcium carbonate equivalent had been made.
Application of the Quantitative Standards, Numerical Values and Recording Methods Developed and Tested to Six Soil Profiles in Eastern South Dakota

The application of the quantitative standards, numerical values and recording methods developed and tested to six soil profiles in eastern South Dakota was designed to serve as a means of testing the sensitivity of the methods developed to bring out and quantitatively present the subtle developmental progression in the genetic morphology of closely related soils.

Selection of Profiles

The six soil profiles used in this phase of the study were selected in order to obtain a sample that would be stratified with respect to parent materials, but that also would be representative of the climatic variation existing in eastern South Dakota. The geographic locations of the soil profiles selected are shown in Figure I.

To accomplish stratification with respect to parent material, three profiles developed in loess were selected. In addition to the three loess profiles, three profiles developed in glacial till also were selected. The till profiles selected had been described previously by the author as county correlation samples, and laboratory characterizations of these profiles were made at that time by the Soil Survey Laboratory at Lincoln, Nebraska or the Soil Survey Laboratory formerly located at Mandan, North Dakota.

The profiles developed in loess that were selected to be used in this study are:
Figure I. Geographic location of the six profile sites studied
T-1, Moody silty clay loam; Union County
T-2, Moody silty clay loam; Brookings County
T-3, Agar silt loam; Potter County

The profiles developed in glacial till that were selected to be used in this study are:

T-4, Vienna loam; Codington County
T-5, Houdek loam; Spink County
T-6, Williams loam; Hand County

Within the framework of the parent material stratification, profiles were selected that were developing under various climatic environments in eastern South Dakota. The orientation of the six profile sites selected with respect to the continuums of some of the elements of the macroclimate is shown in Figures II, III, IV, V, VI, and VII.

Uniform local site characteristics were maintained as nearly as was practical for the six profile sites. The site characteristics selected were those of a well drained east or west-facing, 2 to 3 percent, convex interfluve slope. These particular profile site characteristics were selected because they were believed to be those on which the influence of the macroclimate on soil development is most nearly expressed.

Methods of Sampling and Description

The pit method of sampling was used in sampling all the profiles studied. The soil profiles were sampled by horizons. Samples for laboratory characterization were placed in plastic bags for transporting
Figure II. Relationship of the six profile sites studied to the mean annual precipitation
Figure III. Relationship of the six profile sites studied to the mean annual temperature
Figure IV. Relationship of the six profile sites studied to the number of weeks ground is not frozen.
Figure V. Relationship of the six profile sites studied to the mean precipitation for the period of unfrozen ground
Figure VI. Relationship of the six profile sites studied to the mean temperature for the period of unfrozen ground.
Figure VII. Relationship of the six profile sites studied to the precipitation effectiveness for the period of unfrozen ground.
and storage.

The profile descriptions were written at the pit sites using the quantitative standards and recording methods developed in earlier phases of the field studies. Full five foot profile slices were removed from the pit and laid out to facilitate examination and study of the morphology of the profile. Intact sections of each horizon were collected and sacked in plastic for later reference. All color readings reported in the profile descriptions were read in the laboratory under controlled lighting conditions from these sample sections of the horizons taken at the time of sampling.

Inasmuch as laboratory data from earlier investigations were available for the three till profiles selected; T-4, T-5 and T-6, these profiles were not sampled again for laboratory characterization. The pit sites of the profiles on which the laboratory data were available were revisited, excavated and the soil profiles redescribed however, using the quantitative standards and recording methods developed by the study and used in describing the three loess profiles; T-1, T-2 and T-3, to assure uniform treatment of the morphology for the six profiles investigated.

**Laboratory Methods**

The laboratory analyses made on the three loess profiles were done by the author as a part of this study. The laboratory analyses of the three till profiles used in the study were made by the Soil Survey Laboratories at Lincoln, Nebraska or Mandan, North Dakota as a part of the cooperative Soil Survey operations in South Dakota.
Sample Preparation

Prior to laboratory analysis, all samples were air dried, placed on a plastic sheet and carefully crushed with a rolling pin. The crushed material was passed through a 2-millimeter, round-hole sieve with the aid of a rubber pestle. The less than 2-millimeter materials were mixed and quartered to assure reasonable uniformity in the samples used for analysis. The greater than 2-millimeter materials were recorded as percent greater than 2-millimeter, based on the total weight of the sample, and unless otherwise noted, all laboratory analyses were made using the materials passing the 2-millimeter sieve.

Methods of Analysis

The particle size distribution determinations reported for the loess profiles were made on a 10-gram sample of the air-dry soil. The organic matter was destroyed with hydrogen peroxide. Dissolved mineral matter and salts were removed by successive suspensions of the sample in water and ethanol followed by centrifugation and decantation. The samples were oven dried at 110°C, cooled, weighed, transferred to quart milk bottles and placed on a reciprocating shaker for 24 hours with sodium hexametaphosphate as the dispersing agent (65). The less than 2-micron fraction was determined with a 25-milliliter pipette at a 10-centimeter depth at the appropriate time interval (30, 31, 60). The greater than 50-micron fraction was determined by sedimentation, decantation and screening. The percent 2 to 50-micron fraction was obtained by subtracting the sum of the percent less than 2-micron fraction and the percent greater than 50-micron fraction from 100.
The particle size distribution determinations reported for the glacial till profiles were made by the pipette method following the procedures described by Kilmer and Alexander (30), Kilmer and Mullins (31) and Olmstead, et al. (46).

The total nitrogen determinations reported for the loess profiles were made using the Kjeldahl method as modified by Bal (3). The water treated samples were subjected to sulfuric acid, KCl-pack digestion. Distillation of the ammonia was carried out using sodium hydroxide and the addition of sodium thiosulfate for reduction of the mercuric compounds. The ammonia was distilled into boric acid and back titrated to brom cresol green-methyl red endpoint with sulfuric acid.

The total nitrogen determinations reported for the glacial till profiles were made using the Association of Official Agricultural Chemists method (2), with minor modifications.

The organic carbon data reported for the loess profiles was determined using the Walkley-Black wet combustion method (67). Oxidation of the organic matter was accomplished by the chromic acid method based on spontaneous heating by dilution of sulfuric acid. The adjusted solution was back titrated with acid ferrous sulfate solution using diphenylamine indicator.

The organic carbon determinations reported for the glacial till soils were made by a modification of the Walkley-Black wet combustion method as described by Feech, et al. (47).
For the samples from the loess profiles, the extractable cations were extracted and prepared for determination by a centrifuge extraction procedure as outlined by Bower, et al. (4). Samples were extracted three times using neutral ammonium acetate as the extractant.

Extractable hydrogen reported for the loess profiles was determined following the method described by Brown (7). For the samples from the glacial till soils, the extractable hydrogen determinations were made by the triethanolamine method outlined by Peech, et al. (47).

The extractable calcium and magnesium determinations reported for the loess soils were determined by the versenate method as described by Cheng and Bray (11). For the glacial till profiles, the extractable calcium and magnesium reported was determined as calcium oxalate and magnesium ammonium phosphate respectively, using the methods outlined by Peech, et al. (47).

The extractable sodium and potassium reported for the loess profiles was determined on the extracts with a Perkin-Elmer flame photometer, using the internal standard method described by Jackson (25) and Richards (53). The extractable sodium and potassium reported for the glacial till profiles was determined on the saturation extracts with a Beckman DU flame spectrophotometer.

The cation exchange capacity determinations reported for the loess profiles were made following the method described by Bower, et al. (4). The samples remaining in the centrifuge tubes following the ammonium acetate extraction of the cations were saturated with sodium acetate, washed with ethanol, and the adsorbed sodium extracted
with ammonium acetate using centrifugations. The decantate from the ammonium acetate extraction was collected, made to volume and the replaced sodium determined with the flame photometer, using the methods described earlier for the determinations of extractable sodium and potassium. Cation exchange capacity figures reported for the glacial till profiles were determined by the direct distillation of adsorbed ammonia as outlined by Fosch, et al. (47).

For the loess profiles the saturation extract soluble cations were extracted from the sample and prepared for determination by the method described by Richards (53). This same method was used for extraction of the saturation extract soluble cations for the samples from the glacial till soils.

The saturation extract soluble calcium and magnesium reported for the loess profiles was determined by the versenate method (11). For the glacial till profiles, the saturation extract soluble calcium and magnesium also was determined by the versenate method (11).

Saturation extract soluble sodium and potassium reported for the loess profiles was determined on the saturation extracts with a Perkin-Elmer flame photometer using the internal standard method (25, 53). For the glacial till profiles the saturation extract soluble sodium and potassium was determined on the saturation extracts with the Beckman DU flame spectrophotometer.

The calcium carbonate equivalent determinations reported for the loess soils were obtained by gasometric determination of calcium carbonate equivalent of the samples by measurement of the volume of
carbon dioxide evolved when the samples were treated with concentrated hydrochloric acid. The method described by Horton and Newsom (21) and by Pierce and Huenisch (50) was used with minor modifications. A similar method was used in determining the calcium carbonate equivalent of samples for the glacial till profiles.

Gypsum was determined on the loess and glacial till profiles following methods described by Richards (53), in which gypsum was determined by precipitation with acetone. Quantitative determinations were made only on samples showing the presence of gypsum, as based on qualitative testing.

The pH measurements were made with a glass-electrode pH meter. The measurements were made on 1:1, 1:5 and 1:10 soil-water ratios. The suspensions were stirred following the addition of water and allowed to stand. Just prior to 30 minutes after the addition of the water, the suspensions were again stirred and the pH was determined 30 minutes after the addition of water.

The electrical conductivity of the saturation extract was determined as outlined by Richards (53), using a conductivity bridge and a small conductance cell requiring only a few milliliters of solution.
RESULTS AND DISCUSSIONS OF FIELD
AND LABORATORY STUDIES

Field Studies

Development of Quantitative Standards for the Observation, Characterization and Recording of the Features of Soil Morphology and the Development and Application of Quantitative Numerical Values for Certain of These Features

One of the principal undertakings of this study involved the development of quantitative standards to be used in the observation and characterization of the morphologic features of a soil in its natural state. If the standards per se were to be quantitative, it was essential to formulate definite class limits within the standards considered for each of the commonly observed morphologic features of a soil. The development of a symbolization system and methods of recording were necessary companion studies to the development of the standards to facilitate the use of these standards in soil studies.

The development of quantitative numerical values and their application to certain of the standards developed was the next logical direction for this study to pursue. This portion of the study was undertaken, not only to provide numerical values for morphologic features that would allow for their graphic characterization and presentation, but also to explore the possibilities that they might offer the field morphologist to duplicate or closely approximate, through the use of quantitative morphology, the aspect of quantitatively associated with laboratory analysis of certain of the soil properties common to both the field and laboratory study of soils.
The following are the developmental results of these phases of the field study.

Quantitative Standards and Numerical Values

These standards, and the accompanying numerical values where included, were developed by this study unless otherwise indicated, and are the basis of all the observational data and calculated values for the morphologic aspects presented for the soil profiles studied in the later phases of the field studies.

Standards for the characterization of soil color. Color is one of the most easily observed morphologic features of a soil; yet, in many respects, it is one of the most informative to the soil morphologist, and especially so when it is considered in combination with the other observable features of the soil profile. For this reason, the color profile of a soil should be observed, described and presented as completely and as quantitatively as possible. The features of soil color that presently appear to merit consideration are the color or colors of the interiors of peds, the color coats or coatings on the natural faces of peds, and the color condition called mottling.

The following standards, covering each of the above features of soil color, as well as the conditions under which color determinations are made, are presented as a means of defining and characterizing these color features.

General color standards. The general color standards deal with the color reference standard and the standard external conditions
under which soil colors are determined. The general standards also
deine methods for using the color reference and set down specific
standards relative to what color readings are made for a horizon of
a soil profile and where in the horizon these colors are read.
(a) The general color standards developed and used in this study are
as follows:

All soil colors are read using the Munsell system of color
notations (40).

All soil colors are read under controlled lighting con-
ditions using a daylight-type fluorescent bulb.

Soil colors that fall between the printed color chips on
the Munsell soil color charts are interpolated using the decimal
system for recording the interpolated color notation. Interpo-
lations are made within any of the three components of color—
Hue, Value and Chroma, as defined in the Munsell system.

Soil colors are read of both the moist and the dry soil.

Soil colors are read in accordance with their orientation
on the peds, where peds are present. Color readings are made of
the natural faces of the peds and of the interiors of the peds.

Soil colors of the ped interiors are read on a broken or
fractured surface, not on a natural ped face, where the ped class
is conducive to this procedure or where the soil material is both
massive and motilled. Under conditions other than those described
above, the interior colors are read and reported as crushed or
rubbed colors.
Colors involved in the mottled condition common to many soils are read following the standards concerned with mottling.

Colors of tongued materials, worm casts, and channel fill materials, as well as stains, segregations, and concretions, not considered a part of the mottling, also are read as a part of the color profile.

Standards for color coats. Color coats are defined by these standards as only those coatings of color that occur on the natural faces of peds; that are included within and as a part of the discrete ped; and that are of a different color than that of the interiors of the peds. This excludes the loose adherence to the ped surfaces of tongued materials foreign to the horizon with respect to ped development.

Color coats are read as a separate entity from other kinds of coatings, as for example, clay skins or blanched silt or fine sand coatings, even though the clay skins or blanched silt or fine sand may be the cause of the observed differences in color that result in the color coats.

Color coatings or coats do not occur in the same abundance, in the same pattern, with the same thickness or with the same orientation with respect to peds from one horizon to the next in the same profile or from one soil profile to another. Therefore, terminology having quantitative definition was developed that would describe and define these observable differences.
Quantitative numerical values were developed to accompany the standards for thickness and abundance of color coats in combination with their orientation on the peds as a means of graphing and quantitatively representing the differences in the color coat feature between horizons and between profiles.

The standards as developed and used in this study for the quantitative observation, characterization and presentation of color coats are as follows:

(a) Standards for the abundance and pattern of color coats:

Extremely patchy: Color coats are present but cover less than 10 percent of the ped face. Coatings occur as isolated patches which do not merge to form a connected matrix.

Very patchy: Color coats cover 10 to 25 percent of the ped face. Coatings occur as isolated patches which do not merge to form a connected matrix.

Moderately patchy: Color coats cover 25 to 50 percent of the ped face. Coatings occur primarily as isolated patches which do not merge to form a completely connected matrix, although some patches may coalesce to form matrix connections.

Slightly patchy: Color coats cover 50 to 75 percent of the ped face. Coatings occur primarily as coalescent patches which form a nearly completely connected matrix, although some isolated, disconnected patches still occur.
Nearly continuous: Color coats cover 75 to 90 percent of the ped face. Coatings occur primarily as patches which have merged to form a completely connected matrix, with only a few uncoated voids present.

Continuous: Color coats cover over 90 percent of the ped face. Coatings occur as a continuous matrix with only a very few, if any, uncoated voids present.

(b) Standards for the thickness of color coats:

Thin: Less than 1/32 inch (0.75 mm) in thickness

Moderately thick: From 1/32 to 1/8 inch (0.75 - 3 mm) in thickness

Thick: From 1/8 to 1/4 inch (3 - 6 mm) in thickness

Very thick: Greater than 1/4 inch (6 mm) in thickness

(c) Standards for the orientation of color coats:

Color coats oriented on the vertical faces of the primary or secondary ped

Color coats oriented on the horizontal faces of the primary or secondary ped

(d) Standards for obtaining quantitative numerical values for color coats:

The numerical values assigned to the abundance classes in Table 1 are based on the percent of the area covered, used as the class limits in the observational standards for the abundance of color coats. The numerical values assigned to the thickness classes in Table 1 are based on the class limits used in the
observational standards for the thickness of color coats. The values given in Table 1 are obtained by multiplying the thickness values by the abundance values.

The orientation of the color coats on the peds is brought into the calculations in the following manner.

The appropriate value is taken from Table 1 for the abundance and thickness of the color coats on the vertical faces of the primary peds, the horizontal faces of the primary peds, the vertical faces of the secondary peds and the horizontal faces of the secondary peds.

The color coat values obtained for the primary peds are added to those obtained for the secondary peds to arrive at the total color coat value for the horizon.

Table 1. Quantitative Values for Thickness
Times Abundance of Color Coats

<table>
<thead>
<tr>
<th>Values of abundance classes</th>
<th>Thin 0.10</th>
<th>Mod. thick 0.30</th>
<th>Thick 0.60</th>
<th>Very thick 0.70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely patchy</td>
<td>0.05</td>
<td>0.005</td>
<td>0.020</td>
<td>0.030</td>
</tr>
<tr>
<td>Very patchy</td>
<td>0.17</td>
<td>0.017</td>
<td>0.068</td>
<td>0.102</td>
</tr>
<tr>
<td>Moderately patchy</td>
<td>0.37</td>
<td>0.037</td>
<td>0.148</td>
<td>0.222</td>
</tr>
<tr>
<td>Slightly patchy</td>
<td>0.62</td>
<td>0.062</td>
<td>0.248</td>
<td>0.372</td>
</tr>
<tr>
<td>Nearly continuous</td>
<td>0.82</td>
<td>0.082</td>
<td>0.328</td>
<td>0.492</td>
</tr>
<tr>
<td>Continuous</td>
<td>0.95</td>
<td>0.095</td>
<td>0.380</td>
<td>0.570</td>
</tr>
</tbody>
</table>

Example: The example horizon has thin, moderately patchy color coats on the vertical faces of the primary peds; thin, extremely patchy color coats on the horizontal faces of the primary peds; and thin, extremely patchy color coats on both the vertical
and horizontal faces of the secondary peds.

Color coat value of the vertical faces of the primary peds: 0.037
Color coat value of the horizontal faces of the primary peds: 0.005
Value of the color coats on the primary peds: 0.042

Color coat value of the vertical faces of the secondary peds: 0.005
Color coat value of the horizontal faces of the secondary peds: 0.005
Value of the color coats on the secondary peds: 0.010

Value of the color coats for the horizon: 0.042 + 0.010 = 0.052

(e) Color coats may be the result of any one of a number of different causative agents. Among these agents are organic matter, clay skins, iron, manganese, calcium and magnesium carbonates, gypsum, blanched silt and fine sand, oxidation, reduction or combinations of any several of these. The causative agent or agents are noted and recorded as a part of the characterization of color coats.

Standards for mottled colors. Mottling, or mottled colors, are defined by these standards as the complex association of two or more colors in a spotted or variegated pattern in which the individual colors in the pattern do not have the orientational relationships to each other that exist between the color coatings on the faces of peds and the interior color of the peds. Features that merit individual observational standards, such as segregated and concretionary carbonates, salts, iron and manganese concretions and worm casts and filled worm channel materials are not considered a part of the mottling as defined in these standards.
In mottled patterns, the proportion of one color to the other, or others, may vary considerably. In some patterns a matrix color is clearly evident, while in others, a matrix color only can be arbitrarily selected. Therefore, standards were derived to define a matrix color in mottled patterns.

Mottles vary in abundance, size, contrast and boundary characteristics from horizon to horizon and from one profile to another. Terminology having quantitative definition, where not already available, was developed that would describe and define these observable characteristics of mottling or mottled patterns.

Quantitative numerical values have not been developed to accompany these standards at this time.

The standards as developed and used in this study for the quantitative observation of mottling are as follows.

(a) Standards for the determination of a matrix color:

Any color that comprises greater than 50 percent of the area of the exposed surface is considered the matrix color.

If no color comprises greater than 50 percent of the area of the surface examined, no matrix color is recognized.

(b) Standards for the abundance of mottles: After Simonson (56, 58)

Few: Mottles occupy less than 2 percent of the exposed surface.

Common: Mottles occupy from 2 to 20 percent of the exposed surface.

Many: Mottles occupy more than 20 percent of the exposed surface.
(c) Standards for the size of mottles: After Simonson (56, 58)

Fine: Mottles are 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.

(d) Standards for the contrast of mottles:

The contrast of mottles is based on the degree of difference in the color of the mottle being characterized and the matrix color, or if no matrix color is present, the difference between the color of the mottle being characterized and the color of the most contrasting other mottle or mottles in the pattern.

Very faint: The existing contrast is:

1. Less than 1 hue; and, less than 1 unit of chroma; and, less than 1 unit of value; or,
2. One or more, but less than 2 hues; or,
3. One or more, but less than 2 units of chroma; or,
4. One or more, but less than 2 units of value.

Faint: The existing contrast is:

1. One or more, but less than 2 hues; and, 1 or more, but less than 2 units of chroma; and, 1 or more, but less than 2 units of value; or,
2. Two or more, but less than 3 hues; or,
3. Two or more, but less than 3 units of chroma; or
4. Two or more, but less than 3 units of value.

Distinct: The existing contrast is:

1. Two or more, but less than 3 hues; and, 2 or more, but less than 3 units of chroma; and, 2 or more, but less than 3 units of value; or,

2. Three or more, but less than 4 hues; or,

3. Three or more, but less than 4 units of chroma; or,

4. Three or more, but less than 4 units of value.

Prominent: The existing contrast is:

1. Three or more, but less than 4 hues; and, 3 or more, but less than 4 units of chroma; and, 3 or more, but less than 4 units of value; or,

2. Four or more, but less than 5 hues; or,

3. Four or more, but less than 5 units of chroma; or,

4. Four or more, but less than 5 units of value.

Very prominent: The existing contrast is:

1. Four or more hues; and, 4 or more units of chroma; and, 4 or more units of value; or,

2. Five or more hues; or,

3. Five or more units of chroma; or,

4. Five or more units of value.

(e) Standards for the boundary characteristic of mottles:

The boundary characteristic of mottles is based on the distance over which the color transition takes place between the mottle being characterized and the matrix, or, if no matrix color
is present, between the mottle being characterized and the adjacent mottles in the pattern.

Abrupt: The transition distance is less than one-eighth the diameter of the mottle measured along the shortest dimension of the mottle.

Sharp: The transition distance ranges between one-eighth and one-fourth the diameter of the mottle measured along the shortest dimension of the mottle.

Clear: The transition distance ranges between one-fourth and one-half the diameter of the mottle measured along the shortest dimension of the mottle.

Diffuse: The transition distance is greater than one-half the diameter of the mottle measured along the shortest dimension of the mottle.

(f) The causative agent or agents responsible for the colors of the mottles are appropriately noted and recorded.

Standards for obtaining quantitative numerical values for genetic color development: Color development is defined by these standards as the amount of increase in redness of hue and in strength of chroma in the genetic horizons over the inherent hue and chroma of the parent materials in which the soil profile is developing.

The unrelated use of hue alone or chroma alone does not appear to give a representative picture of the genetic color development of a soil; however, when hue and chroma are used in combination, the quantity and pattern of genetic color development appears to be well
represented.

The quantitative numerical values assigned to the 10YR, 1.25Y, 2.5Y and 5Y hues of the Munsell color charts are in accordance with the differences in the decreasing amounts of red and increasing amounts of yellow present in each of the hues from 10YR through 5Y. The quantitative numerical values used to represent the chromas are the quantitative notations of chroma given on the Munsell color charts, or, in the case of between printed chip colors, the decimal notations between the chroma notations given on the chart are used.

(a) Quantitative numerical values assigned to hues:

<table>
<thead>
<tr>
<th>Color</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10YR</td>
<td>3.0</td>
</tr>
<tr>
<td>1.25Y</td>
<td>2.5</td>
</tr>
<tr>
<td>2.5Y</td>
<td>2.0</td>
</tr>
<tr>
<td>5Y</td>
<td>1.0</td>
</tr>
</tbody>
</table>

(b) Methods of obtaining quantitative numerical values for color development:

In accordance with the general color standards, dry and moist color readings are made of the ped faces and of the interiors of the peds. This results in four individual color readings if color coats occur, and two individual color readings if color coats are absent. The chroma of the color reading is multiplied by the assigned value for the hue of the color reading to obtain the color development value of each color reading. The sum of the individual color development values is the total color development value of the horizon. This value, divided by the number of
individual color readings making up the total, is the average color development value of the horizon and is the quantitative numerical value used in making the color development comparisons between horizons and between profiles.

Example: In the example horizon the color coats on the ped faces have a Munsell notation of 10YR 3/1 moist and 10YR 4/1.5 dry. The interiors of the peds have a Munsell notation of 10YR 4/2.5 moist and 1.25Y 5/3 dry.

Color development value of the moist color coat: 3 x 1, or 3.0
Color development value of the dry color coat: 3 x 1.5, or 4.5
Color development value of the moist ped interior: 3 x 2.5, or 7.5
Color development value of the dry ped interior: 2.5 x 3, or 7.4
Total color development value of the horizon: 22.5
Average color development value of the horizon: 5.62

Total and average color development values may be obtained individually for the color coats or for the ped interiors if comparisons of the color development between the faces and the interiors of the peds are desired.

Standards for the characterization of soil structure. Soil structure, although readily apparent to the observer in its gross form, is one of the most difficult of the morphologic features to consistently describe and quantitatively define in detail consistent with its importance to soil classification.

The individual natural soil aggregate, or unit of structure, is called a ped and it is with the characteristics of the peds resulting from soil development, that the standards for soil structure must deal. The type, class and grade of peds are essential to the
characterization and classification of soil structure.

The following standards, covering each of the above mentioned features of soil structure, are presented and used in this study as a means of more quantitatively defining and measuring these features.

Standards for structure type. The type or kind of structure is defined by these standards as the shape and orientation of the peds in their natural occurrence in the horizon of the soil profile.

(a) Definitions of the basic structure types:

Prismatic: Peds that have a vertically oriented axis that is at least twice as long as the horizontally oriented axis, and that do not have rounded tops.

Short vertical axis prismatic: Peds that have a vertically oriented axis that is noticeably and consistently longer, but is less than twice as long as the horizontally oriented axis, and that do not have rounded tops. This is a subtype within the basic prismatic type.

Columnar: Peds that have a vertically oriented axis that is at least twice as long as the horizontally oriented axis, and that have rounded tops.

Short vertical axis columnar: Peds that have a vertically oriented axis that is noticeably and consistently longer, but is less than twice as long as the horizontally oriented axis and that have rounded tops. This is a subtype within the basic columnar type.
Blocky: Peds that have a vertically oriented axis and a horizontally oriented axis that consistently closely approximate each other in length, and that are bounded by faces that fit together with, or accommodate the shape of, the faces of the adjacent peds in much the same manner as do the pieces of a jigsaw puzzle.

Granular: Peds that have a vertically oriented axis and a horizontally oriented axis that consistently closely approximate each other in length, and that are bounded by faces that do not fit together with, or accommodate the shape of, the faces of the adjacent peds.

Flaty: Peds that have a horizontally oriented axis that is at least twice as long as the vertically oriented axis.

Platelet: Peds that have a horizontally oriented axis that is noticeably and consistently longer, but is less than twice as long as the vertically oriented axis. This is a sub-type within the basic platy type.

(b) Definitions of modifications of the basic structure types:

Angular: The angles formed by the intersection of the bounding faces of the individual peds are consistently 90 degrees or less. Used only for the prismatic, columnar and blocky structure types.

Subangular: The angles formed by the intersection of the bounding faces of the individual peds are consistently greater than 90 degrees. Used only for the prismatic,
columnar and blocky structure types.

Subangular-angular: The angles formed by the intersection of the bounding faces of the individual ped are not consistent, some being 90 degrees or less and others greater than 90 degrees. Used only with the prismatic, columnar and blocky structure types.

Oriented subangular-angular: The angles formed by the intersections of the vertical faces of the individual ped with the horizontal faces of the individual ped are consistently 90 degrees, but the angles formed by the intersections of the vertical faces with other vertical faces on the same individual ped are consistently greater than 90 degrees.

Unoriented subangular-angular: The angles formed by the intersections of the vertical faces of the individual ped with other vertical faces of the same individual ped are not consistently either greater than 90 degrees or less than 90 degrees, and the angles formed by the intersections of the vertical faces and the horizontal faces on the same ped also are not consistently either greater than 90 degrees or less than 90 degrees.

Smooth-surface: In vertically-oriented structure types (prismatic and columnar), the deviations in the surfaces of the vertical ped faces from the planes of the vertical ped faces are less than one-tenth the length of the
shorter horizontal dimension of the ped, in a distance greater than one-half the length of the longer vertical dimension of the ped.

In horizontally-oriented structure types (platy), the deviations in the surfaces of the horizontal ped faces from the planes of the horizontal ped faces are less than one-tenth the length of the shorter vertical dimension of the ped in a distance greater than one-half the length of the longer horizontal dimension of the ped.

In structure types of nearly equal dimensions relative to directional orientation (blocky and granular), the deviations in the surfaces of the ped faces from the planes of the ped faces are less than one-tenth the length of the shorter dimension of the ped in a distance of greater than one-half the length of the longer dimension of the ped.

Irregular-surface: In vertically-oriented structure types, the deviations in the surfaces of the vertical ped faces from the planes of the vertical ped faces are:

1. Less than one-tenth the length of the shorter horizontal dimension of the ped in a distance of less than one-half the length of the longer vertical dimension of the ped, or,

2. One-tenth to one-fourth the length of the shorter horizontal dimension of the ped, in
a distance of one-fourth to one-half the
length of the longer vertical dimension of
the ped, or.

3. Greater than one-fourth the length of the
shorter horizontal dimension of the ped, in
a distance of greater than one-fourth the
length of the longer vertical dimension of
the ped.

In horizontally-oriented structure types, the
deviations in the surfaces of the horizontal ped faces
from the planes of the horizontal ped faces are:

1. Less than one-tenth the length of the shorter
vertical dimension of the ped, in a distance
of less than one-half the length of the longer
horizontal dimension of the ped, or,

2. One-tenth to one-fourth the length of the
shorter vertical dimension of the ped, in a
distance of one-fourth to one-half the length
of the longer horizontal dimension of the ped,
or,

3. Greater than one-fourth the length of the
shorter vertical dimension of the ped, in a
distance of greater than one-fourth the length
of the longer horizontal dimension of the ped.
In structure types of nearly equal dimensions relative to directional orientation, the deviations in the surfaces of the ped faces from the planes of the ped faces are:

1. Less than one-tenth the length of the shorter dimension of the ped, in a distance of less than one-half the length of the longer dimension of the ped, or,

2. One-tenth to one-fourth the length of the shorter dimension of the ped, in a distance of one-fourth to one-half the length of the longer dimension of the ped, or,

3. Greater than one-fourth the length of the shorter dimension of the ped, in a distance of greater than one-fourth the length of the longer dimension of the ped.

Rough-surface: In vertically-oriented structure types, the deviations in the surfaces of the vertical ped faces from the planes of the vertical ped faces are greater than one-fourth the length of the shorter horizontal dimension of the ped, in a distance of less than one-fourth the length of the longer vertical dimension of the ped.

In horizontally-oriented structure types, the deviations in the surfaces of the horizontal ped faces from the planes of the horizontal ped faces are greater than
one-fourth the length of the shorter vertical dimension of the ped, in a distance of less than one-fourth the length of the longer horizontal dimension of the ped.

In structure types of nearly equal dimensions relative to directional orientation, the deviations in the surfaces of the ped faces from the planes of the ped faces are greater than one-fourth the length of the shorter dimension of the ped, in a distance of less than one-fourth the length of the longer dimension of the ped.

Standards for structure class. The class of the structure peds is defined as the size of the peds in their natural occurrence in the horizons of the profile. The following standards for structure class are after those used in the Soil Survey Manual (55).

(a) Structure class standards for prisms and columns:

Very fine: Less than 10 mm in horizontal dimension
Fine: From 10 to 20 mm in horizontal dimension
Medium: From 20 to 50 mm in horizontal dimension
Coarse: From 50 to 100 mm in horizontal dimension
Very coarse: Greater than 100 mm in horizontal dimension

(b) Structure class standards for blocks:

Very fine: Less than 5 mm in cross-section
Fine: From 5 to 10 mm in cross-section
Medium: From 10 to 20 mm in cross-section
Coarse: From 20 to 50 mm in cross-section
Very coarse: Greater than 50 mm in cross-section
(c) **Structure class standards for plates:**

- **Very thin:** Less than 1 mm in vertical thickness
- **Thin:** From 1 to 2 mm in vertical thickness
- **Medium:** From 2 to 5 mm in vertical thickness
- **Thick:** From 5 to 10 mm in vertical thickness
- **Very thick:** Greater than 10 mm in vertical thickness

(d) **Structure class standards for granules:**

- **Very fine:** Less than 1 mm in diameter
- **Fine:** From 1 to 2 mm in diameter
- **Medium:** From 2 to 5 mm in diameter
- **Coarse:** From 5 to 10 mm in diameter
- **Very coarse:** Greater than 10 mm in diameter

(e) **Standards developed by this study for obtaining quantitative numerical values for structure class:**

The quantitative numerical values assigned to the structure size classes are based on the class means of the structure size classes. The values given for the structure size classes in Table 2 were obtained by converting the class means from

<table>
<thead>
<tr>
<th>Structure class</th>
<th>Values for structure classes by type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prisms and columns</td>
</tr>
<tr>
<td>Very fine</td>
<td>0.20</td>
</tr>
<tr>
<td>Fine</td>
<td>0.60</td>
</tr>
<tr>
<td>Medium</td>
<td>1.40</td>
</tr>
<tr>
<td>Coarse</td>
<td>3.00</td>
</tr>
<tr>
<td>Very coarse</td>
<td>4.20</td>
</tr>
</tbody>
</table>
millimeters to inches. The quantitative values are therefore the inch-equivalents of the class means.

Examples: The example horizon has coarse primary prisms, medium and fine subprimary prisms, and medium and coarse secondary blocks.

Structure class value of primary prisms: 3.00
Structure class value of subprimary prisms: \(1.4 + 0.6 = 2.0/2 = 1.00\)
Structure class value of secondary blocks: \(0.6 + 1.4 = 2.0/2 = 1.00\)
Total structure class value of horizon: 5.00
Mean structure class value of horizon: 1.67

Standards for structure grade. The structure grade as defined by these standards involves a combination of: the degree of distinctness or individuality of the peds of a particular type; their degree of conformity to that type; and the degree to which they are dominant or subdominant over other types, where compound structure exists, or over unaggregated material, where a single structure type occurs.

The above characteristics associated with structure grade are influenced and reflected by: the thickness and abundance of clay skins on the faces of the peds; the degree to which irregularities occur on the faces of the peds; the durability of the peds; and the total degree of aggregation relative to that aggregated within the peds being graded. The standards developed and used in this study for the determination of structure grade are centered around these four characteristics or factors of structure grade.

The simple whole number values given for each of the classes within each of the four factors are the values used to represent that
class in the structure grade determination.

(a) Factor 1. Clay skin value standards and numerical values, as used for determining structure grade:

Clay skin value from 0.001 to 0.065: structure grade value of 1.0
Clay skin value from 0.065 to 0.239: structure grade value of 2.0
Clay skin value from 0.239 to 0.589: structure grade value of 3.0
Clay skin value from 0.589 to 0.939: structure grade value of 4.0
Clay skin value from 0.939 to 1.113: structure grade value of 5.0
Clay skin value from 1.113 to 1.178: structure grade value of 6.0

Standards for the quantitative determination of clay skins are given in the section of the overall standards devoted to clay skins.

(b) Factor 2. Ped surface irregularity standards and numerical values, as used for determining structure grade:

Rough-surface peds, strong irregularities: structure grade value of 1.0

Irregular-surface peds, moderate irregularities: structure grade value of 2.0

Smooth-surface peds, slight irregularities: structure grade value of 3.0

Standards for determination of ped surface irregularity are given earlier in this section of structure standards.

(c) Factor 3. Standards and numerical values for the determination of the percentage of the total material in the horizon that is incorporated in the peds being graded, as used for determining structure grade:
Less than 40 percent of the total material in the horizon is incorporated in the peds being graded; structure grade value of 1.0

From 40 to 60 percent of the total material in the horizon is incorporated in the peds being graded; structure grade value of 2.0

From 60 to 80 percent of the total material in the horizon is incorporated in the peds being graded; structure grade value of 3.0

From 80 to 90 percent of the total material in the horizon is incorporated in the peds being graded; structure grade value of 4.0

Greater than 90 percent of the total material in the horizon is incorporated in the peds being graded; structure grade value of 5.0

(d) Factor 4. Standards and numerical values for the durability of peds, as used for determining structure grade:

Ped form cannot be maintained if handled; structure grade value of 1.0

Ped form can be maintained if handled carefully; structure grade value of 2.0

Ped form can be maintained without special handling; structure grade value of 3.0

Ped form is maintained if dropped to the ground from a height of 3 feet; structure grade value of 4.0
(e) Standards for obtaining numerical values for structure grade:

The structure grade value for a ped is the sum of the appropriate numerical values for each of the four factors of structure grade.

Example: The example peds have a clay skin value of 0.106; have irregular surfaces; have 70 percent of the total material in the horizon incorporated within them; and their form can be maintained without special handling.

The structure grade value for clay skins is: 2.0
The structure grade value for ped surface irregularity is: 2.0
The structure grade value for percent of total material incorporated in the peds is: 3.0
The structure grade value for ped durability is: 3.0
The structure grade value for the peds is the sum of the individual factor values.

Table 3. Terminologies Associated with the Numerical Values for Structure Grade

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Massive or</td>
<td>0</td>
</tr>
<tr>
<td>1 single</td>
<td>1 single grain</td>
<td>1 single</td>
</tr>
<tr>
<td>grain</td>
<td>2</td>
<td>grain</td>
</tr>
<tr>
<td>3</td>
<td>Low very weak</td>
<td>3</td>
</tr>
<tr>
<td>4 Ortho</td>
<td>Very weak</td>
<td>4</td>
</tr>
<tr>
<td>very weak</td>
<td>5</td>
<td>Very weak</td>
</tr>
<tr>
<td>6</td>
<td>Low weak</td>
<td>6</td>
</tr>
<tr>
<td>7 Ortho</td>
<td>Weak</td>
<td>7</td>
</tr>
<tr>
<td>weak</td>
<td>8</td>
<td>Weak to moderate</td>
</tr>
<tr>
<td>9 Low</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>moderate</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>11 Ortho</td>
<td>Moderate</td>
<td>11</td>
</tr>
<tr>
<td>moderate</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>13 Low</td>
<td>Moderate to strong</td>
<td>13</td>
</tr>
<tr>
<td>strong</td>
<td>14</td>
<td>14 Strong</td>
</tr>
<tr>
<td>15 High</td>
<td>Strong</td>
<td>15</td>
</tr>
<tr>
<td>strong</td>
<td>16</td>
<td>16 Strong</td>
</tr>
<tr>
<td>17 Ortho</td>
<td>Strong to very strong</td>
<td>17</td>
</tr>
<tr>
<td>very strong</td>
<td>18</td>
<td>18 Very strong</td>
</tr>
</tbody>
</table>
(f) Standards for the terminology accompanying the numerical values for structure grade:

In Table 3, three separate terminologies have been developed for different arrays of the structure grade values from 0 to 18. The first, and most detailed breakdown of the array is probably best suited to research studies. The second, and somewhat less detailed breakdown within the array is probably best suited to field characterization of soils for correlation. The third, and least detailed breakdown within the array is probably satisfactory for day to day field mapping.

Standards for a general classification of peds. A general classification of peds is useful as a general reference in describing and discussing soil structure. These standards have classified the peds in their natural occurrence in the horizons of a soil into four general groups—primary peds, subprimary peds, secondary peds and subsecondary peds. These groups are based on the sequence of separation or breakdown relative to the sizes and types of peds within the individual horizons of the soil profile.

(a) Definitions of the groups in the general classification of peds:

Primary peds: A group of peds which, by virtue of their combined class and type, have a greater volume per individual ped than that of an individual representative of any other group of peds present in the horizon. The primary peds include within their volume all other groups of peds present in the horizon.
Subprimary peds: A group of peds having the same basic structure type as that of the primary peds but whose combined class and type engender to it a smaller volume per individual ped than that of an individual primary ped, yet a greater volume per individual ped than that of an individual ped representative of any other group of peds present in the horizon, with the exception of that of the primary group. The subprimary peds, if present, include within their volume all other groups of peds present in the horizon that have smaller individual ped volumes.

Secondary peds: A group of peds having a different basic structure type than that of the primary and subprimary peds and whose combined class and type result in a smaller volume per individual ped than that of an individual primary or subprimary ped, yet a greater volume per individual ped than that of an individual ped representative of any other group of peds present in the horizon excepting that of the primary and subprimary groups. The secondary peds, if present, include within their volume all other groups of peds present in the horizon that have smaller individual ped volumes.

Subsecondary peds: A group of peds having the same basic structure type as that of the secondary peds but whose combined class and type produce a smaller volume per
individual ped than that of an individual secondary ped, yet a greater volume per individual ped than that of an individual ped representative of any other group of peds present in the horizon, with the exclusion of the preceding groups. The sub-secondary peds, if present, include within their volume all other groups of peds present in the horizon that have smaller individual ped volumes. On rare occasions the need arises for sub-subprimary, sub-subsecondary, or tertiary groups; however, because of the rarity of situations requiring their use and because of the obviousness as to their place in the foregoing definitional pattern, they are not included and defined here.

Standards for the characterization of clay skins. Clay skins, as defined by these standards, are comparatively thin, usually somewhat laminated layers of water-translocated clay particles which when deposited are oriented with their long axes parallel to the surfaces receiving the deposit. The primary surfaces of deposition for these skins or coatings of oriented clay are the faces of peds and the walls of tubular pores and root channels.

The development of terminology, having quantitative definition that would describe and define the differences observed in the clay skin features, was made necessary by the increasing importance attached to the presence and characteristics of clay skins in the field identification of genetic clay illuviation and their use in these standards as a factor in the determination of structure grade.
Quantitative numerical values also were developed to accompany the standards for thickness and abundance of clay skins in combination with their orientation or placement on the peds as a means of graphing and quantitatively representing the differences in the clay skin characteristic throughout the soil profile.

The standards as developed and used in this study for the quantitative observation and representation of clay skins are as follows.

**Standards for the thickness, abundance and placement of clay skins.** Clay skins vary in thickness, abundance and placement on the various depositional surfaces from ped type to ped type within a horizon, from horizon to horizon, and from profile to profile. The following are the standards for these characteristics.

(a) **Standards for the thickness of clay skins:**

Very thin: (Less than 0.05 mm in thickness) Very thin clay skins form a nearly continuous, weakly light-reflecting surface film which does not accommodate most of the irregularities on the micro-surface of the ped. Very thin clay skins may bridge up onto, but do not bridge over, very fine sand (0.05 to 0.10 mm) on the micro-surface of the ped. Very fine tubular pores (less than 0.2 mm in diameter), if present, are open through the clay skin to the surface of the ped and the edges of the pore openings are sharp. Very thin clay skins are not observable if obstructed by the adherence of loose coarse silt and fine sand grains to the film surface. Very thin clay
skins usually occur only in the slightly concave areas on the surface of the ped and/or as linings in the vertical tubular pores and root channels, and seldom, if ever, have abundance patterns exceeding moderately patchy. Very thin clay skins are observable with fair reliability in medium and moderately fine-textured materials, but with very low reliability in fine-textured materials. Very thin clay skins can be observed only with the aid of a 10x or stronger hand lens and the general reliability of observation is somewhat less than in the following thickness classes.

Thin: (0.05 to 0.10 mm in thickness) Thin clay skins form a nearly continuous, light-reflecting surface film that accommodates most of the irregularities on the micro-surface of the ped. Thin clay skins bridge over the very fine sand and bridge up onto, but not over, the fine sand (0.10 to 0.25 mm) on the micro-surface of the ped. Very fine tubular pores are open through the clay skin to the vertical surface of the ped and the edges of these pore openings are sharp to only very slightly rounded. Some of the finer of the very fine vertical tubular pores may be clay-filled although the development of collars around the peripheries of the larger vertical tubular pore openings in the lower horizontal ped surfaces is very weak if present at all. Thin clay skins may occur in any of
the abundance patterns but are most commonly found as moderately patchy, slightly patchy or nearly continuous patterns. Thin clay skins are observable with good reliability in medium and moderately fine-textured materials and with somewhat less reliability in coarser and finer-textured materials. Thin clay skins are not usually identifiable as such without the aid of a 10x or stronger hand lens although the presence of clay skins in this and thicker classes can usually be detected with the unaided eye.

Moderately thick: (0.10 to 0.25 mm in thickness) Moderately thick clay skins bridge over very fine and fine sand and bridge up onto, but not over, medium sand (0.25 to 0.5 mm) on the micro-surface of the ped. Most of the very fine and many of the fine (0.2 to 0.5 mm in diameter) tubular pores do not open through the clay skin to the vertical surface of the ped, while tubular pores of the larger classes usually remain open through the clay skin to the vertical surface of the ped and the edges of these pore openings are noticeably rounded. Many of the very fine and a few of the smaller fine vertical tubular pores may be clay-filled, and the development of collars around the peripheries of the larger vertical tubular pore openings in the lower horizontal ped surfaces is weak but observable. Moderately thick clay skins may occur
in any of the abundance patterns but are most commonly found to occur as patchy abundance patterns superimposed over a more continuous pattern of one of the thinner classes of clay skins. Moderately thick clay skins are observable with good reliability across all texture classes and usually are observable without the aid of a hand lens.

Thick: (0.25 to 0.5 mm in thickness) Thick clay skins form a continuous, strongly light-reflecting surface film that accommodates all and modifies many of the irregularities on the micro-surface of the ped. Thick clay skins bridge over very fine, fine and medium sand and bridge up onto, but not over, coarse sand (0.5 to 1 mm) on the micro-surface of the ped. Most of the very fine and fine and a few of the smaller medium (0.5 to 1.0 mm in diameter) tubular pores do not open through the clay skin to the vertical surface of the ped, while tubular pores of the larger classes usually remain open through the clay skin to the vertical surface of the ped, and the edges of these pore openings are well rounded. Many of the very fine and fine and some of the smaller medium vertical tubular pores may be clay-filled, and the development of collars around the peripheries of the larger vertical tubular pore openings in the lower horizontal ped surfaces is easily observed. Thick clay skins may occur in
any of the abundance patterns but are most commonly found in the patchy abundance patterns superimposed over a more continuous pattern of thinner clay skins. Thick clay skins are observable with good reliability across all texture classes and are easily observed without the aid of a hand lens. Thick clay skins give the ped a varnished appearance and the clay skin itself often shows flow-line ridges and valleys.

**Very thick:** (Greater than 0.5 mm in thickness) Very thick clay skins form a continuous, strongly light-reflecting surface film that accommodates all and modifies most of the irregularities on the micro-surface of the ped. Very thick clay skins bridge over very fine, fine, medium and the smaller fractions of the coarse sand on the micro-surface of the ped. Very few tubular pores, except the larger sizes (1 to 4 mm in diameter), are open through the clay skin to the surface of the ped. Many of the vertical tubular pores of all but the larger sizes may be clay-filled and collar development is usually pronounced around the peripheries of the larger vertical tubular pore openings where not plugged with clay. Very thick clay skins may occur in any of the abundance patterns but are most commonly found in one of the patchy abundance patterns superimposed over a more continuous pattern of thinner clay skins. Very thick clay skins
are observable with good reliability across all texture classes and are very easily observed without the aid of a hand lens. Very thick clay skins give the ped a heavily-varnished appearance and the clay skin itself usually shows pronounced flow-line ridges and valleys.

(b) Standards for the surface area abundance and pattern of clay skins:

Extremely patchy: Less than 10 percent of ped face clay skin coated. Clay skins occur as isolated patches which do not merge to form a connected matrix.

Very patchy: Clay skins cover 10 to 25 percent of the ped face. Clay skins occur primarily as isolated patches which do not merge to form a connected matrix.

Moderately patchy: Clay skins cover 25 to 50 percent of the ped face. Clay skins occur primarily as isolated patches which do not merge to form a completely connected matrix, although some patches may coalesce to form matrix connections.

Slightly patchy: Clay skins cover 50 to 75 percent of the ped face. Clay skins occur primarily as coalescent patches which form a nearly completely connected matrix, although some isolated disconnected patches still occur.

Nearly continuous: Clay skins cover 75 to 90 percent of the ped face. Clay skins occur primarily as coalescent patches which form a completely connected matrix, with only a few uncoated voids present.
Continuous: Greater than 90 percent of the ped face clay skin coated. Occur primarily as a continuous, completely connected matrix, with only a few, if any, uncoated voids present.

(c) Standards for the placement or orientation of clay skins:

Clay skins oriented on vertical faces of the peds
Clay skins oriented on the horizontal faces of the peds
Clay skins oriented on both the vertical and horizontal faces of the peds
Clay skins as linings in tubular pores
Clay skins as linings in root channels
Clay skins as linings in stone pockets
Clay skins as bridges between sand grains
Clay skins oriented around the individual grains in the microfabric of the ped.

Standards for obtaining quantitative numerical values for clay skins. The standards for obtaining quantitative numerical values for clay skins involve the thickness and abundance of clay skins in combination with the orientation or placement of the clay skins on the peds.

The quantitative numerical values assigned to the abundance classes are based on the percent of the area covered used as class limits in the observational standards for the abundance of clay skins. The numerical values assigned to the thickness classes are based on the class limits used in the observational standards for the thickness of clay skins. The values in Table 4 were obtained by multiplying the
thickness values by the abundance values.

(a) Quantitative values for thickness times abundance of clay skins and their orientation on peds:

<table>
<thead>
<tr>
<th>Values of abundance classes</th>
<th>Values of thickness classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very thin</td>
</tr>
<tr>
<td>Extremely patchy</td>
<td>0.05</td>
</tr>
<tr>
<td>Very patchy</td>
<td>0.17</td>
</tr>
<tr>
<td>Moderately patchy</td>
<td>0.37</td>
</tr>
<tr>
<td>Slightly patchy</td>
<td>0.52</td>
</tr>
<tr>
<td>Nearly continuous</td>
<td>0.82</td>
</tr>
<tr>
<td>Continuous</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Much of the time, one of the more patchy patterns of thicker clay skins is superimposed over a more continuous pattern of thinner clay skins. When this condition exists it is handled by using the values in Table 4 in the following manner. On an example ped the vertical faces of the ped show clay skins that are thin, continuous and moderately thick, extremely patchy. The value for the thin, continuous element of the clay skin is 0.067 as given in Table 4. Next the table value for the moderately thick, extremely patchy element of the clay skin is 0.009 as given in Table 4. However, to avoid figuring in the clay skin value of the underlying thinner skin twice in areas on the ped where the thicker skin overlies the thinner skin whose value has already been taken into consideration once in the calculation, the value from Table 4 for the thin pattern equivalent of the moderately
thick skins, or 0.004, is subtracted from the table value for the moderately thick, extremely patchy element. Thus the value for the moderately thick, extremely patchy element would become 0.009 minus 0.004, or 0.005, which when added to the 0.067 value obtained for the thin, continuous element, would give a clay skin value of 0.072 for the vertical faces of the example ped.

The orientation or placement of clay skins on the peds is brought into the calculated clay skin values in the following manner and is best illustrated by example.

Example: A compound prismatic-blocky horizon having:

1. Primary prisms with clay skins on the:
   Vertical faces that are:
   Moderately thick, continuous and thick, very patchy
   $0.162 + (0.063 - 0.029) = 0.196$
   Horizontal faces that are:
   Moderately thick, continuous
   $0.162$
   Clay skin value for primary peds is: $0.162$
   $0.358$

2. Secondary blocks with clay skins on the:
   Vertical faces that are:
   Thin, continuous and moderately thick, slightly patchy
   $0.067 + (0.105 - 0.043) = 0.129$
   Horizontal faces that are:
   Thin, continuous
   $0.067$
   Clay skin value for secondary peds is: $0.067$
   $0.196$
   Clay skin value for the horizon is: $(0.358 + 0.196) = 0.554$

Standards for the characterization of soil reaction. The reaction standards as used in this study are involved primarily with the inherent presence and the secondary accumulation of the free carbonates of calcium and magnesium, gypsum and the more soluble salts commonly
found in soils.

**Standards for free calcium and magnesium carbonates.** Calcium and magnesium carbonates are often present in the soil as unleached constituents inherent to the parent material or as secondary accumulations resulting from soil formation processes. The physical forms in which they can occur are the disseminated, segregated and concretionary forms.

The disseminated carbonates are defined by these standards as the unlocalized concretions of finely divided carbonates that exist as a constituent of the fine earth materials. The disseminated carbonates differ relative to the type and degree or strength of effervescence that they display when they are treated with a standard amount of a standard normality hydrochloric acid, and it is on the basis of these differences, that the disseminated carbonates are characterized in this study.

The following are the quantitative standards for the observation and characterization of carbonates as developed and used in this study.

(a) Standards for the types of effervescence action:

- Delayed, very long-duration, high-bubble effervescence
- Delayed, very long-duration, low-fizz effervescence
- Delayed, long-duration, high-bubble effervescence
- Delayed, long-duration, low-fizz effervescence
- Delayed, short-duration, high-bubble effervescence
- Delayed, short-duration, low-fizz effervescence
- Instantaneous, very long-duration, high-bubble effervescence
Instantaneous, very long-duration, low-fizz effervescence

Instantaneous, long-duration, high-bubble effervescence

Instantaneous, short-duration, high-bubble effervescence

Instantaneous, short-duration, low-fizz effervescence

The terminology used in the above types of effervescence are defined in this study by the following standards:

Delayed effervescence: Effervescence begins as soon as 3 drops of 1 N hydrochloric acid are simultaneously applied to the soil material; however, the maximum action of the effervescence does not occur within the first second after the acid is applied.

Instantaneous effervescence: The maximum action of the effervescence occurs immediately or within the first second after 3 drops of 1 N hydrochloric acid are simultaneously applied to the soil material.

Short-duration effervescence: Effervescent action is completed in less than 3 seconds after 3 drops of 1 N hydrochloric acid have been simultaneously added to the soil material.

Long-duration effervescence: Effervescence continues for a period of from 3 to 5 seconds after 3 drops of 1 N hydrochloric acid have been simultaneously applied to the soil material.

Very long-duration effervescence: Effervescence continues for a period greater than 5 seconds after 3 drops of 1 N
hydrochloric acid have been simultaneously applied to
the soil material.

High-bubble effervescence: The action of effervescence is char-
acterized by the blossoming up of relatively large (1/16
to 1/4 inch, 1.5 - 6 mm, in diameter), well-formed bubbles
that are persistent, in that they do not rupture readily,
but to the contrary, grow in size and display a strong
tendency to be unicyclic in their development. The qual-
ity of high-bubble effervescence is best likened to that
of soap suds.

Low-fizz effervescence: The action of effervescence is char-
acterized by relatively small (less than 1/16 inch, 1.5 mm.
in diameter) bubbles that do not blossom up and grow
larger because of their thin consistence and the conse-
quent ease with which they break and rapidly reform, thus
tending to be multicyclic in development. The quality
of low-fizz effervescence is best likened to that of a
spilled carbonated beverage.

(b) Standards for the degree or strength of effervescence:

Very weak effervescence: The effervescent action is slight and
not easily observed. It often only can be differentiated
with difficulty from the emission of air bubbles under
conditions of dry or only slightly moist soil materials.

Weak effervescence: The effervescent action is easily observed
but is not pronounced. Gas is not emitted during the
effervescence in quantities sufficient to render it visible to the observer. The sounds accompanying the emission of gas are not audible to the observer at a distance of 12 inches from the ear.

Moderate effervescence: The effervescent action is prominent. Gas is given off in sufficient quantities during the maximum action of the effervescence so that a thin wisp of emitted gas is briefly visible to the observer. The sounds accompanying the emission of gas during the maximum action of the effervescence is barely audible to the observer at a distance of 12 inches from the ear.

Strong effervescence: The effervescent action is very prominent but not violent. Gas is emitted in sufficient quantities and over a sufficient period of time during the maximum action of effervescence to readily allow its observance. The sound accompanying the emission of gas is plainly audible to the observer at a distance of 12 inches from the ear, but is only barely audible at a distance of 24 inches from the ear.

Very strong effervescence: The effervescent action is violent. Gas is emitted in quantities that cause the emitted gas to be visible to the extent that the smoke from lighting a match is visible, and the gas is visible to the observer over a measurable period of time. The sound accompanying gas emission is plainly audible to the
observer at a distance between reaction and ear of greater than 24 inches.

The segregated carbonates are defined by these standards as the localized concentrations of carbonates having a consistence of slightly hard or less when dry. The concretionary carbonates are defined by these standards as the localized concentrations of carbonates having a consistence of hard or harder when dry. The segregated and concretionary forms of carbonate differ relative to the size, abundance, shape and boundary characteristics of the segregations and concretions per se, and it is on the basis of these differences, that the segregated and concretionary carbonates are characterized in this study.

The following are the standards for segregated and concretionary carbonates as developed and used in this study.

(a) Standards for size of segregations and concretions:

Very small: Segregations or concretions are less than 1/32 inch (.075 mm) in diameter along the greatest dimension.

Small: Segregations and concretions range between 1/32 to 1/8 inch (0.75 - 3 mm) in diameter along the greatest dimension.

Medium: Segregations and concretions range between 1/8 to 1/2 inch (3 - 12 mm) in diameter along the greatest dimension.

Large: Segregations and concretions range between 1/2 to 3/4 inch (12 - 18 mm) in diameter along the greatest dimension.

Very large: Segregations and concretions are greater than 3/4
inch (18 mm) in diameter along the greatest dimension.

(b) Standards for the abundance of segregations and concretions:

Very few: Less than 3 segregations or concretions in 16 square inches (100 sq. cm) of exposed surface.

Few: From 3 to 9 segregations or concretions in 16 square inches (100 sq. cm) of exposed surface.

Common: From 8 to 16 segregations or concretions in 16 square inches (100 sq. cm) of exposed surface.

Many: From 16 through 20 segregations or concretions in 16 square inches (100 sq. cm) of exposed surface.

Very many: Greater than 20 segregations or concretions in 16 square inches (100 sq. cm) of exposed surface.

(c) Standards for the shape of segregations or concretions:

Round: The variations in the cross-sectional dimensions of the individual segregation or concretion are less than one-fourth the shortest dimension.

Irregular: The variations in the cross-sectional dimensions of the individual segregation or concretion are greater than one-fourth the shortest dimension.

(d) Standards for the boundary characteristic of segregations and concretions:

The boundary characteristic of segregations is based on the distance over which the transition takes place between the segregation and the adjacent matrix material in which the segregation occurs. The boundary characteristic of concretions is based on
the thickness of the coating or rind of soft segregated carbonate encasing the hard concretion.

Abrupt boundary: The transition interval is less than one-eighth the diameter as taken along the shortest visible dimension of the segregation or concretion.

Sharp boundary: The transition interval ranges between one-eighth and one-fourth the diameter as taken along the shortest visible dimension of the segregation or concretion.

Clear boundary: The transition interval ranges between one-fourth and one-half the diameter as taken along the shortest visible dimension of the segregation or concretion.

Diffuse boundary: The transition interval is greater than one-half the diameter as taken along the shortest visible dimension of the segregation or concretion.

(e) Standards for the orientation of effervescence, segregations and concretions with respect to peds:

In the interiors of primary peds
On the faces of primary peds

In the interiors of secondary peds
On the faces of secondary peds

Standards for obtaining quantitative numerical values for free calcium and magnesium carbonates. The standards, as developed and used in this study, for obtaining quantitative values for free calcium and
magnesium carbonates, or percent calcium carbonate equivalent, involve
the degree or strength of effervescence, the abundance and size of
segregations and concretions, and the orientation of these features
with respect to peds, if peds are present.

(a) The quantitative values for disseminated carbonates, as based on
the degree or strength of effervescence and the duration of effer-
vescence, are given in Table 5.

Table 5. Quantitative Values for Disseminated Carbonates
as Based on Strength of Effervescence Times
Duration of Effervescence

<table>
<thead>
<tr>
<th>Degree or strength of</th>
<th>Values for duration of effervescence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short 1.0</td>
</tr>
<tr>
<td>Very weak</td>
<td>0.5</td>
</tr>
<tr>
<td>Weak</td>
<td>1.0</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.0</td>
</tr>
<tr>
<td>Strong</td>
<td>3.0</td>
</tr>
<tr>
<td>Very strong</td>
<td>3.5</td>
</tr>
</tbody>
</table>

(b) The quantitative values for segregated and concretionary carbonates
as based on the abundance and size of segregations and concretions,
are given in Table 6.

Table 6. Quantitative Values for Segregated and
Concretionary Carbonates as Based on
Abundance and Size of Segregations
and Concretions

<table>
<thead>
<tr>
<th>Abundance of segregations and concretions</th>
<th>Size of segregations and concretions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>Small 1.50  2.50  3.50  4.00  4.50</td>
</tr>
<tr>
<td>Very few</td>
<td>1.50  2.00  3.00  4.00  5.00  5.50</td>
</tr>
<tr>
<td>Common</td>
<td>2.50  3.00  4.00  5.00  6.00  6.50</td>
</tr>
<tr>
<td>Many</td>
<td>3.50  4.00  5.00  6.00  6.50  7.00</td>
</tr>
<tr>
<td>Very many</td>
<td>4.00  4.50  5.50  6.50  7.00  8.00</td>
</tr>
</tbody>
</table>
(c) \textbf{Quantitative standards for weighting differences in effervescence, segregation and concretions with respect to their orientation on pedds.}

When dealing with differences in disseminated carbonates between the ped face and the ped interiors, the appropriate value from Table 5 is multiplied by two for the interior condition and is used directly for the ped face condition. The volume differences of the different carbonate conditions existing between the ped faces and the ped interiors are closely approximated, in the case of disseminated carbonates, by following this procedure. In massive or single grain materials, the appropriate value from Table 5 is multiplied by three.

When dealing with differences in segregated and concretionary carbonates between the ped face and the ped interiors, the appropriate value is taken directly from Table 6 for the interior condition and for the ped face condition. The volume differences of the different carbonate conditions existing between the ped faces and the ped interiors are closely approximated, in the case of segregated and concretionary carbonates, by following this procedure. In massive or single grain materials, the appropriate value from Table 6 is multiplied by two.

(d) \textbf{Methods of calculating the quantitative numerical value for the total free calcium and magnesium carbonates, or calcium carbonate equivalent for a horizon:}
The example horizon has a weak, short-duration effervescence and a few, small segregations on the faces of the primary peds. The interiors of the primary peds have a moderate, long-duration effervescence and common, small segregations.

Using Tables 5 and 6 in conjunction with the orientation standards the calculations are made as follows:

Value of weak, short-duration effervescence on ped faces: 1.00
Value of few, small segregations on ped faces: 2.00
Value of carbonates on ped faces: 3.00

Value of moderate, long-duration effervescence in the interiors of the ped: \(3.00 \times 2 = 6.00\)
Value of common, small segregations in the interiors of the ped: 3.00
Value of carbonates in ped interiors: 9.00

Value of free calcium and magnesium carbonates, or percent calcium carbonate equivalent, for the horizon: \(3.00 + 9.00 = 12\)

Standards for gypsum and other soluble salts. Gypsum and other more soluble salts are often present in the soil as unleached constituents of the parent material or as secondary accumulations resulting from soil formation processes. These salts may occur in the soil in several relatively different physical forms. The basic physical form in which these salts are usually observed in the soil is as segregations; however, in the case of salts, the segregated form has been subdivided into salt segregations and salt crystal nests.

Salt segregations are defined by this study as localized concentrations of salts that do not effervesce with 1 N hydrochloric acid, and that consist of individual salt crystals that are too fine to distinguish as such with the unaided eye. Salt crystal nests are defined
by this study as localized concentrations of salts that do not effervesce with 1 N hydrochloric acid, and that consist of individual salt crystals that are of sufficient size to be distinguished as such with the unaided eye.

The salt segregations and salt crystal nests differ relative to size, abundance, shape and boundary characteristic of segregations and crystal nests per se, and it is on the basis of these differences that gypsum and other soluble salts are characterized in this study.

The following are the standards for salt segregations and nests of salt crystals as developed and used in this study.

(a) The standards for the size, abundance and shape of salt segregations and salt crystal nests are identical with those developed and stated earlier for segregated and concretionary carbonates.

(b) The standards for the boundary characteristic of salt segregations are the same as those developed and stated earlier for segregated carbonates.

The standards for the boundary characteristic of salt crystal nests are the same as those developed and stated earlier for segregated carbonates except for the following difference. The transition interval of salt crystal nests is defined by these standards as the distance between the edge of the closely nested salt crystals and the point where the matrix material is free of salt crystals.

Standards for the characterization of the biologic entities of soil morphology. The standards for the biologic entities of soil morphology,
as used in this study, are restricted to those resulting from the activities of certain groups of the soil fauna. The following standards are limited to the features of soil morphology that are the product of worm activity and the activities of burrowing animals.

**Standards for worm casts, channels and cavities.** The products of worm activity that are considered a part of soil morphology by this study are worm casts and filled and unfilled worm channels and cavities.

The standards, as developed and used in this study for the quantitative observation and characterization of these morphologic features resulting from worm activity, are as follows:

(a) **Standards for the size of worm casts and channels:**

Very fine: Less than 1/16 inch (1.5 mm) in cross-sectional diameter

Fine: From 1/16 to 1/8 inch (1.5 - 3 mm) in cross-sectional diameter

Medium: From 1/8 to 1/4 inch (3 - 6 mm) in cross-sectional diameter

Large: From 1/4 to 1/2 inch (6 - 12 mm) in cross-sectional diameter

Very large: Greater than 1/2 inch (12 mm) in cross-sectional diameter

(b) **Standards for the size of worm cavities:**

Very small: Less than 1/4 inch (6 mm) in cross-sectional diameter
Small: From 1/4 to 1/2 inch (6 - 12 mm) in cross-sectional diameter

Medium: From 1/2 to 3/4 inch (12 - 18 mm) in cross-sectional diameter

Large: From 3/4 to 1 inch (18 - 25 mm) in cross-sectional diameter

Very large: Greater than 1 inch (25 mm) in cross-sectional diameter

(c) Standards for the abundance of worm casts, channels, and cavities:

Very few: Less than 5 in 4 square inches (25 sq. cm) of exposed surface

Few: From 5 to 15 in 4 square inches (25 sq. cm) of exposed surface

Common: From 15 to 25 in 4 square inches (25 sq. cm) of exposed surface

Many: From 25 to 35 in 4 square inches (25 sq. cm) of exposed surface

Very many: More than 35 in 4 square inches (25 sq. cm) of exposed surface

Standards for krotovinas. The products of the activities of burrowing animals that are considered a part of soil morphology by this study are the krotovinas.

The standards as developed and used in this study for the quantitative observation and characterization of the morphologic features resulting from the activities of burrowing animals are as follows.
(a) Standards for the size of krotovinas:

- **Very small:** Less than 2 inches (5 cm) in cross-sectional diameter
- **Small:** From 2 to 4 inches (5 - 10 cm) in cross-sectional diameter
- **Medium:** From 4 to 6 inches (10 to 15 cm) in cross-sectional diameter
- **Large:** From 6 to 8 inches (15 - 20 cm) in cross-sectional diameter
- **Very large:** Greater than 8 inches (20 cm) in cross-sectional diameter

(b) Standards for the abundance of krotovinas:

Because krotovinas normally occur in relatively small numbers in the soil profile, the actual number of them present is used to characterize their abundance in a particular horizon or profile.

**Standards for the characterization of quartz.** These standards are concerned only with that fraction of the total quartz population that is visible in situ with a 10x hand lens.

The following standards were developed and used in this study to provide a basis for the quantitative observation and characterization of the quartz feature.

**Standards for the size, condition and condition abundance of quartz grains.** Quartz in the soil may vary in abundance, shape, and
in the general conditions of transparency and staining from the ped face to the ped interior, from one horizon to the next and from one profile to another.

(a) Standards for the shape of quartz grains:

Round: The corners and edges of the grain are well rounded.

Planes or other suggestions of angularity are not present.

Subangular: The corners and edges of the grain are slightly rounded. Planes are evident between the rounded edges.

Angular: The corners and edges of the grain are sharp and planes are prominent.

(b) Standards for the size of quartz grains:

Size characterization of the quartz grains within the quartz condition groups is of interest only under certain, rather rare circumstances. The following size standards may be used if the size characterization of the grains within a quartz condition group appears to be necessary for clarity or completeness of description.

Very fine: From 0.05 to 0.10 mm in diameter
Fine: From 0.10 to 0.25 mm in diameter
Medium: From 0.25 to 0.5 mm in diameter
Coarse: From 0.5 to 1 mm in diameter
Very coarse: From 1 to 2 mm in diameter

(c) Standards for the abundance of percussion scars on quartz grains:

Few: Percussion scars are present, but comprise less than 20 percent of the surface area of the grain.
Common: Percussion scars comprise from 20 to 60 percent of the surface area of the grain.

Many: Percussion scars comprise greater than 60 percent of the surface area of the grain.

(d) Standards for the general light transmissibility of quartz grains:

Transparent grains: Grains allow the passage of light and of clear views of objects beyond.

Translucent grains: Grains allow the passage of some light but not of clear views of objects beyond.

(e) Standards for the stainings of quartz grains:

Lightly stained: The color of the staining is of high value (Munsell value of greater than 5) within the hues and chromas characteristic of the staining agent.

Darkly stained: The color of the staining is of low value (Munsell value of 5 or less) within the hues and chromas characteristic of the staining agent.

(f) Standards for the condition abundance of quartz grains:

The following condition abundance standards are used where only scattered quartz grains are present, even though differences may exist between the ped faces and the ped interiors relative to the condition and abundance of the quartz grains present in these positions.

Very few: Less than 5 percent of that portion of the quartz population that is visible in situ with a 10x hand lens
Few: From 5 to 30 percent of that portion of the quartz population that is visible in situ with a 10x hand lens

Common: From 30 to 60 percent of that portion of the quartz population that is visible in situ with a 10x hand lens

Many: From 60 to 85 percent of that portion of the quartz population that is visible in situ with a 10x hand lens

Very many: Greater than 85 percent of that portion of the quartz population that is visible in situ with a 10x hand lens

The following condition abundance standards are used where quartz grains are present as coatings oriented on the faces of pads.

Where coatings are involved, the condition abundance standards are expressed in terms of the abundance, pattern, and thickness of the coatings per se. The standards used for these coatings are the same as those used for color coats earlier in these standards.

Standards for the characterization of dark minerals. These standards are concerned only with that fraction of the total dark-mineral population that is visible in situ with a 10x hand lens.

The dark minerals, as a group, are among the more easily weatherable minerals in the soil. Because of their dark color they are quite easily observed in most matrix colors encountered in soils, with the possible exception of extremely dark colored surface soils. As the result of this combination of weatherability and observability, the
dark minerals appear to be a good visual index of the amount of weathering accompanying soil development.

The following standards were developed and used in this study to provide a basis for the quantitative observation and characterization of the dark-mineral population in the soil profile.

Standards for the condition, size and abundance of dark minerals.

The dark minerals in the soil may vary in abundance, shape and orientation with respect to the ped from horizon to horizon and from profile to profile. The following are the standards for these features.

(a) Standards for the shape of dark minerals:

The shape standards for the dark minerals are the same as those given earlier under the shape standards for quartz grains.

(b) Standards for the size of dark minerals:

Size is used only occasionally in the characterization of the dark-mineral fraction of the soil. When size characterization is necessary for clear description, the same size standards are used as those used for quartz earlier in the standards.

(c) Standards for the abundance of dark minerals:

Very few: Less than two mineral grains visible in situ with a 10x hand lens per 1 square inch (6.5 sq. cm) of exposed surface.

Few: From 2 to 6 mineral grains visible in situ with a 10x hand lens per 1 square inch (6.5 sq. cm) of exposed surface.
Common: From 6 to 11 mineral grains visible in situ with a
10x hand lens per 1 square inch (6.5 sq. cm) of exposed
surface.

Many: From 11 through 15 mineral grains visible in situ with
a 10x hand lens per 1 square inch (6.5 sq. cm) of exposed
surface.

Very many: Greater than 15 mineral grains visible in situ with
a 10x hand lens per 1 square inch (6.5 sq. cm) of exposed
surface.

(d) Standards for the orientation of dark minerals:

Dark minerals on the faces of the peds

Dark minerals in the interiors of the peds

Standards for the characterization of tubular pores. These standards
concern only those pores in the soil that are tubular in shape regardless
of their mode of origin.

The following standards were developed and used in this study to
provide a basis for the quantitative observation and characterization
of the tubular pores in the soil profile.

Standards for the size, shape, directional orientation, condition
and abundance of tubular pores. The tubular pores vary in size, shape,
directional orientation, condition and abundance in the soil. The fol-
lowing standards were used for the characterization of these features
of tubular pores.
(a) Standards for the size of tubular pores:

1. Size in cross-section:
   
   Very fine: Less than 0.2 mm in diameter
   Fine: From 0.2 to 0.5 mm in diameter
   Medium: From 0.5 to 1 mm in diameter
   Large: From 1 to 4 mm in diameter
   Very large: Greater than 4 mm in diameter

2. Size in transverse-section:
   
   Very short: Less than 1 cm in length
   Short: From 1 to 5 cm in length
   Moderately long: From 5 to 12 cm in length
   Long: From 12 to 20 cm in length
   Very long: Greater than 20 cm in length

(b) Standards for the shape of tubular pores:

1. Shape in cross-section:
   
   Round: The variation in the diameter of the cross-section is less than one-fourth the shortest diameter.
   Oblong: The variations in the diameters of the cross-section is greater than one-fourth the shortest dimension.

2. Shape in transverse-section:
   
   Linear: The perpendicular displacement of the pore from a straight line drawn from one extremity of the pore to the other is less than one-tenth the overall length of the pore.
Curved: The single-cycle perpendicular displacement of the pore from a straight line drawn from one extremity of the pore to the other is greater than one-tenth the overall length of the pore.

Complex: The multi-cyclic perpendicular displacement of the pore from a straight line drawn from one extremity of the pore to the other is greater than one-tenth the overall length of the pore.

(c) Standards for the aspect of tubular pores:

Single or unbranched: Pores do not have a dendritic pattern

Compound or branched: Pores have a dendritic pattern

(d) Standards for the directional orientation of tubular pores:

Vertical: The directional line of the pore (a line drawn from one extremity of the pore to the other, without regard to the transverse shape) forms an angle of less than 15 degrees with a line perpendicular to the soil surface.

Horizontal: The directional line of the pore forms an angle of less than 15 degrees with a line parallel to the soil surface.

Angular: The directional line of the pore forms an angle of greater than 15 degrees with lines perpendicular to, or parallel to, the soil surface.

(e) Standards for the internal conditions of tubular pores:

Unobstructed: Pore passage is clear

Obstructed: Pore passage is obstructed, at least in part, by
roots, clay or other substances.

(f) Standards for the abundance of tubular pores:

Very few: Less than two pores visible in cross-section per square centimeter of exposed surface

Few: From 2 to 10 pores visible in cross-section per square centimeter of exposed surface

Common: From 10 to 20 pores visible in cross-section per square centimeter of exposed surface

Many: From 20 to 30 pores visible in cross-section per square centimeter of exposed surface

Very many: Greater than 30 pores visible in cross-section per square centimeter of exposed surface

(g) Standards for the orientation of tubular pores with respect to the peds:

Tubular pores occurring in the interiors of peds

Tubular pores occurring on the faces of peds

Standards for the characterization of soil consistence. Soil consistence is defined in the Soil Survey Manual (58), as: "The attributes of soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation by rupture." The following standards were used in this study for the characterization of soil consistence.

Standards for dry and moist consistence. The standards used in this study for soil consistence are after, but are slightly modified
from, those given in the Soil Survey Manual (53). The standards as used in this study involve only dry and moist consistency notations. In horizons having compound structure, the consistency determination is made on the smallest individual discrete ped, not one that can be separated into smaller discrete peds. The standards for soil consistency as used in this study are as follows.

(a) Standards for the determination of moist soil consistency:

**Moist soil consistency is determined at a moisture level approximately midway between air dry and field capacity.**

**Loose: Noncoherent**

Very friable: A discrete ped crushes very easily under very gentle pressure between thumb and forefinger.

Friable: A discrete ped crushes easily under gentle to moderate pressure between thumb and forefinger.

Firm: A discrete ped crushes under moderate pressure between thumb and forefinger but resistance is distinctly noticeable.

Very firm: A discrete ped crushes under strong pressure, but is barely crushable between thumb and forefinger.

Extremely firm: A discrete ped cannot be crushed between thumb and forefinger.

(b) Standards for the determination of dry soil consistency:

Dry soil consistency is determined at a moisture content approximating air-dryness.

**Loose: Noncoherent**
Soft: Discrete ped breaks to powder or individual grains under very slight pressure between thumb and forefinger.
Slightly hard: Discrete ped is easily broken under pressure between thumb and forefinger.
Hard: Discrete ped is barely breakable under pressure between thumb and forefinger.
Very hard: Discrete ped cannot be broken under pressure between thumb and forefinger, but can be broken in the hands with difficulty.
Extremely hard: Discrete ped cannot be broken in the hands.

Standards for the characterization of horizon boundaries. Horizon boundaries, as defined in these standards, are the characteristics of the transition between one recognized horizon and another within the soil profile. Although each individual feature of the morphology is often in transition and has its own individual transitional characteristics, and hence its own boundary, the boundary for the horizon as a whole is based on the combined effect of these individual changes as they affect the general degree of contrast between horizons.

The following standards were used in this study for the characterization of horizon boundaries.

Standards for the distinctness and pattern of horizon boundaries. Horizon boundaries vary as to their distinctness and pattern. The distinctness of the boundary between horizons depends on the width of the transition zone and on the degree of difference, or contrast, of the
horizons between which the boundary occurs. The pattern or topography of the boundary is the shape characteristic of the boundary between horizons.

The following standards for the distinctness and pattern of horizon boundaries were used in this study and are after those given in the Soil Survey Manual (58).

(a) Standards for the distinctness of horizon boundaries:

Abrupt: The horizon to horizon transition is less than 1 inch (2.5 cm) wide.

Clear: The horizon to horizon transition is from 1 to 2 1/2 inches (2.5 - 6.5 cm) inches wide.

Gradual: The horizon to horizon transition is from 2 1/2 to 5 inches (6.5 - 12.5 cm) wide.

Diffuse: The horizon to horizon transition is greater than 5 inches (12.5 cm) wide.

(b) Standards for the pattern of horizon boundaries:

Smooth: The boundary is nearly a plane.

Wavy: The boundary is undulating and the irregularities are wider than their depth.

Irregular: The boundary is undulating and the irregularities are deeper than their width.

Broken: Parts of the horizon are isolated or disconnected from other parts.
Methods of Recording

A soil morphology description card and a symbolization system for recording the features of morphology were developed by this study to accompany and facilitate the use of the quantitative standards presented in the preceding section. The card and symbolization system developed were used in recording the observations of morphology presented for the soil profiles studies in the final phases of the field investigations.

Description card. The soil morphology description card developed and used in this study appears as Appendix A.

Symbolization system. The symbolization system developed and used in this study for recording the features of soil morphology appears as Appendix B.

The symbols used in the system were made as connotative of the entity being symbolized as it was possible to make them. This was done to facilitate their rapid recall to the user.

Application of the Quantitative Standards, Numerical Values and Recording Methods Developed and Tested to Six Soil Profiles in Eastern South Dakota

The quantitative standards, numerical values and recording methods developed and tested in the preceding phases of the field investigations were applied to the field study of six soil profiles in eastern South Dakota.

The following are the results of this phase of the field investigations.
Descriptive Morphology

The descriptive morphology for each of the six soil profiles studied is presented in both the symbolized and narrative forms. The narrative description is a direct transcription of the symbolized morphology recorded on the field description card.

The legal description, factors of soil formation and the field and narrative descriptions of the profiles studied are presented below.

Profile T-1, Moody silty clay loam

Legal description. 350 feet east and 190 feet south of the west quarter-corner of Section 25, Township 95 north, Range 49 west, Union County, South Dakota

Factors of soil formation. The parent material in which this soil is developing is calcareous, medium-textured loess of Wisconsin age (16). The site at which the profile was described and sampled is located within the Southern Plateaus division of the Central Lowland as classified by Fenneman (15) and Rothrock (55) and revised by Flint (16). The topographic aspect of the profile site is that of a slightly convex, 2-percent sloping crest of a relatively broad-topped interfluve ridge that is oriented northwest-southeast in a rolling landscape, having a moderately thick loess mantle, a local relief differential of 50 to 75 feet and a well integrated dendritic drainage pattern. Because of the position occupied by this soil in the toposequence, the microclimatic conditions under which it is developing closely approximate those of the macroclimate of the area. The macroclimate of
the area is characterized by: (a) A period of 38 weeks during which
the ground is not frozen, (b) An average temperature for this period
of 59 to 60° F., (c) An average precipitation for this period of 23 to
24 inches, and (d) An average precipitation effectiveness of 3.18
(49, 62). The soil was cropped to oats at the time of sampling.

Field profile description. The symbolized field profile de-
scription of profile T-1, Moody silty clay loam, is shown in Figure
VIII.

Narrative profile description. The following narrative profile
description is a direct transcription of the symbolized field profile
description of profile T-1, Moody silty clay loam, shown in Figure VIII.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0 to 6 inches</td>
<td>Very dark grayish brown (10YR 3/2 moist, 4/2 dry) crushing to very dark gray blending to very dark grayish brown (10YR 3/1.5 moist, 1.25Y 4/2 dry); silty clay loam; large, puddled clods separating into primary peds that are high-very weak, coarse, rough-surface, unoriented subangular-angular blocks separating into subprimary peds that are low-moderate, very fine, irregular-surface, angular blocks; consistence is friable moist and slightly hard dry; noncalcareous; tubular pores are few, very fine, round, short, linear, multidirectional, unbranched and unobstructed; common, medium worm casts and filled worm channels of matrix color; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; a very few,</td>
</tr>
</tbody>
</table>
## PROFILE T-1: MOODY SILTY CLAY LOAM, UNION COUNTY, SOUTH DAKOTA

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth</th>
<th>Matric Potential</th>
<th>Colors</th>
<th>Other Notes</th>
<th>Texture</th>
<th>Clay Films</th>
<th>Consequence</th>
<th>Reaction</th>
<th>Minerals</th>
<th>Materials</th>
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<td>I</td>
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<tr>
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<tr>
<td>I</td>
<td>33-39</td>
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<tr>
<td>I</td>
<td>49-60</td>
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<td>Silt clay</td>
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</tbody>
</table>

**Legend:**
- **I:** Intensive
- **P:** Proficient
- **R:** Resultant
- **S:** Soil
- **D:** Depth
- **M:** Material
- **S:** Soil
- **P:** Potent

**Colors:**
- **10YR 3/1:** Yellowish Brown
- **10YR 4/1:** Yellowish Brown
- **10YR 4/2:** Yellowish Brown
- **10YR 4/3:** Yellowish Brown
- **10YR 4/5:** Yellowish Brown

**Clay Films:**
- **None:** None

**Consequence:**
- **Class:** Class 0

**Reaction:**
- **Calcium Carbonate:** Calcium Carbonate

**Minerals:**
- **Quartz:** Quartz

**Chemical Composition:**
- **Organic Matter:** Organic Matter
- **Carbon:** Carbon
- **Nitrogen:** Nitrogen

**Special Features:**
- **Mottling:** Mottling only in the interior of the primary plane
- **In Predominance:** In Predominance

**Sampling:**
- **Sample:** Sample 1

**Notes:**
- **Footnotes:** Footnotes
- **Other Notes:** Other Notes

**Diagram:**
- **Moody Silty Clay Loam**

**Figure VIII:** Symbolized field profile description of profile T-1.
subangular dark minerals. This changes with an anthropic (plow depth) but mixed boundary because of worm working, to,

B2A1 6 to 11 inches

Dark grayish-brown blending toward brown (10YR 4/2.5 moist, 1.25Y 5/3 dry)

interior matrix color with common, medium and fine worm casts and filled worm channels of matrix color and a few, fine and medium, very dark grayish-brown (10YR 3/2 moist, 4/2 dry) worm casts and filled worm channels and with thin, moderately-patchy, very dark-gray (10YR 3/1 moist, 4/1.5 dry) organically-stained coatings on the vertical and horizontal faces of the primary and secondary peds; silty clay loam; primary peds are low-weak, coarse and medium, rough-surface, subangular prisms separating into secondary peds that are low-weak, coarse, rough-surface, subangular blocks separating in turn into subsecondary peds that are ortho-moderate, very fine, irregular-surface, unoriented subangular-angular blocks; very thin, extremely-patchy clay skins on the vertical and horizontal faces of the primary, secondary, and sub-secondary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are few, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout and a very few lightly iron-stained angular transparent quartz grains in the B2 materials only; a very few, subangular dark minerals. This changes with a mixed boundary, because
of worm working, to,

B21  11 to 17 inches  Dark grayish-brown blending toward brown (10YR 4/2.5 moist, 5/3 dry) interior matrix color with common, fine and medium worm casts and filled worm channels of matrix color and common, fine and medium, very dark-gray blending toward very dark grayish-brown (10YR 3/1.5 moist, 4/1.5 dry) worm casts and filled worm channels and with thin, moderately-patchy, very dark-gray blending toward very dark grayish-brown (10YR 3/1.5 moist, 4/1.5 dry) organically-stained coatings on both the vertical and horizontal faces of the primary and secondary peds; silty clay loam; primary peds are high weak, medium and coarse, irregular-surface, oriented subangular-angular prisms separating into secondary peds that are ortho-moderate, very fine, irregular-surface, unoriented subangular-angular blocks; thin, extremely-patchy clay skins on the vertical and horizontal faces of primary peds and lining tubular pores and root channels and very thin, extremely-patchy clay skins on the vertical and horizontal faces of the secondary peds; consistence is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and a very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout and a few lightly iron-stained angular transparent quartz grains in the interiors of the primary peds; a very few, subangular dark minerals. This changes clearly with a smooth boundary to,
B22 17 to 22 inches   Dark grayish-brown blending toward brown (10YR 4/2.5 moist, 5/3 dry) interior matrix color with common, medium and small worm casts and filled worm channels of matrix color and common, medium and small, very dark-gray blending toward very dark grayish-brown (10YR 3/1.5 moist, 4/1.5 dry) worm casts and filled worm channels and with thin, moderately-patchy, dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5/2.5 dry) coatings on the vertical faces of the primary peds; silt loam; primary peds are ortho-moderate, medium, irregular-surface, oriented subangular-angular prisms separating into secondary peds that are ortho-moderate, very fine and fine, irregular-surface, unoriented subangular-angular blocks; very thin, extremely-patchy clay skins on both the vertical and horizontal faces of the primary and secondary peds and lining tubular pores and root-channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout with a few lightly iron-stained subangular translucent and a few lightly iron-stained angular transparent quartz grains in the interiors of the primary peds; a very few, subangular dark minerals. This grades with a smooth boundary into.

B23 22 to 27 inches   Dark-brown to brown (1.25Y 4/3 moist, 5.5/3.5 dry) interior matrix color with
a few, medium and fine, dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5.5/3 dry) worm casts and filled worm channels and with thin, moderately-patchy, dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5/2.5 dry) slightly-reduced coatings on the vertical and horizontal faces of the primary peds; silt loam; primary peds are low-moderate, medium, rough-surface oriented subangular-angular prisms separating into subprimary peds that are high-weak, fine and medium, rough-surface, angular blocks; very thin, extremely-patchy clay skins on both the vertical and horizontal faces of the primary and subprimary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed, and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent, common angular translucent and common angular transparent quartz grains throughout and a few lightly iron-stained angular transparent quartz grains in the interiors of the primary peds; a very few, subangular dark minerals. This grades with a smooth boundary into, B24  27 to 33 inches  Dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5.5/3 dry) interior matrix color with thin, moderately-patchy dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5/2.5 dry) slightly-reduced ped coatings on the vertical and horizontal faces of the primary peds; silt loam; primary peds are high-weak, medium and coarse, rough-surface,
oriented subangular-angular prisms separating into secondary peds that are ortho-weak, medium and coarse, rough-surface, angular blocks; very thin, extremely-patchy clay skins on both the vertical and horizontal faces of the primary and subprimary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; a few, small, unfilled and a few small filled worm cavities; as a percentage of the total visible quartz, there are common angular translucent, common angular transparent and a few subangular transparent quartz grains throughout and with a few lightly iron-stained angular transparent quartz grains in the interiors of the primary peds; a very few, subangular and angular dark minerals on the faces of the primary peds and a few, subangular and angular dark minerals in the interiors of the primary peds. This grades with a smooth boundary into,

B31 33 to 39 inches Dark grayish-brown blending toward olive-brown (2.5Y 4/3 moist, 5.5/3 dry) interior matrix color with common, medium, faint, sharp-boundary, gray blending toward light brownish-gray (2.5Y 5/1 moist, 7/1 dry) mottles narrowly encircled by a few, fine, faint, clear-boundary, yellowish-brown (10YR 5/4 moist, 6/4 dry) iron stains, and with a few, fine, faint, abrupt-boundary dark yellowish-brown (7.5 YR 3/4 moist, 4/4 dry) iron stains; thin, nearly-continuous, dark grayish-brown blending toward brown (1.25Y 4/2.5 moist, 5/2.5 dry) slightly-oxidized coatings
on the vertical faces of the primary peds restrict the mottling and
iron staining to the interiors of the primary peds; silt loam; primary
peds are high-weak, very coarse, rough-surface, subangular-angular
oriented prisms separating into subprimary peds that are low-weak,
coarse, rough-surface, subangular-angular prisms; very thin, extremely-
patchy clay skins on the vertical faces of both the primary and sub-
primary peds; consistence is friable moist and hard dry; noncalcareous;
tubular pores are many, very fine, round, short, linear, multidirec-
tional, unbranched and unobstructed and few, medium, round, long;
linear, vertical, unbranched and unobstructed; as a percentage of the
total visible quartz, there are common angular translucent, common,
angular transparent and a few subangular translucent quartz grains
throughout; a few, subangular dark minerals on the faces of the primary
peds and common, angular dark minerals in the interiors of the primary
peds. This grades with a smooth boundary into,

B32 39 to 43 inches  Dark grayish-brown blending toward
          olive-brown (2.5Y 4/3 moist, 5.5/3 dry)
interior matrix color with thin, very patchy, dark grayish-brown blend-
ing toward olive-brown (2.5Y 4/2.5 moist, 5/2 dry) slightly-reduced
coatings on the vertical faces of the primary peds; mottles on the
faces of the primary peds are common, fine and medium, faint, sharp-
boundary, gray blending toward light brownish gray (2.5Y 6/1 moist,
7/1 dry) narrowly encircled with a few, fine, faint, clear-boundary,
yellowish-brown (10YR 5/4 moist, 6/4 dry) iron stains and with a few,
scattered, fine, faint, abrupt-boundary, dark-brown (7.5YR 3/4 moist,
4/4 dry) iron stains; mottles in the interiors of the primary peds are common, medium, faint, abrupt-boundary gray blending toward light brownish gray (2.5Y 6/1 moist, 7/1 dry, narrowly encircled with common, medium, faint, clear-boundary, yellowish-brown (10YR 5/4 moist, 6/4 dry) iron stains, and with a few, scattered, fine, faint, abrupt-boundary dark-brown (7.5Y 3/4 moist, 4/4 dry) iron stains; silt loam; primary peds are ortho-weak, very coarse, rough-surface, oriented subangular-angular prisms; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is friable moist and slightly hard dry; noncalcareous; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed; as a percentage of the total visible quartz, there are common angular translucent, common, angular transparent, and a few subangular translucent quartz grains throughout; common angular dark minerals throughout. This grades with a smooth boundary into:

C1 43 to 46 inches Dark grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6/2.5 dry) matrix color with common, medium, faint, abrupt-boundary, gray blending toward light-brownish-gray (2.5Y 6/1 moist, 7/1 dry) mottles encircled with common, medium, faint, clear-boundary, yellowish-brown (10YR 5/4 moist, 6/4 dry) iron stains; a few, fine, faint, abrupt-boundary, dark-brown (7.5YR 3/4 moist, 4/4 dry) iron stains and a few, fine, prominent, abrupt-boundary, black (10YR 2/1 moist, 3/1 dry) manganese stains throughout; massive silt loam;
consistency is friable moist and slightly hard dry; noncalcareous; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed and few, medium, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common angular transparent, common angular translucent and a few subangular translucent quartz grains throughout; common, angular dark minerals throughout. This changes clearly with a wavy boundary to:

C1ca 46 to 60 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6/2.5 dry) matrix color with common, coarse, faint, abrupt-boundary, gray blending toward light brownish-gray (2.5Y 6/1 moist, 7/1 dry) mottles encircled with common, coarse, faint, abrupt-boundary, yellowish-brown (10YR 5/4 moist, 6/4 dry) iron stains; a few, fine, faint, abrupt-boundary, dark-brown (7.5YR 3/4 moist, 4/4 dry) iron stains and a few, fine, prominent, abrupt-boundary, black (10YR 2/1 moist, 3/1 dry) manganese stains throughout; massive silt loam; consistency is friable moist and slightly hard dry; weakly calcareous throughout with instantaneous, short-duration, high bubble-up effervescence; a few, small, round, abrupt-boundary carbonate segregations having a very few, very small, hard carbonate concretions as cores; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed and few, medium, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total quartz, there are common angular translucent,
common angular transparent and a few subangular translucent quartz grains throughout; common, angular dark minerals throughout; 35 to 50 percent of the mineral grains are thinly frosted.

<table>
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<tr>
<th>Depth Range</th>
<th>Description</th>
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<tr>
<td>60 to 69 inches</td>
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<td>69 to 78 inches</td>
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<td>78 to 87 inches</td>
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<td>87 to 96 inches</td>
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<td>96 to 105 inches</td>
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<tr>
<td>105 to 114 inches</td>
<td>Sampled but not described</td>
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**Profile T-2, Moody silty clay loam**

Legal description. 660 feet west and 250 feet south of the north quarter corner of Section 10, Township 109 north, Range 48 west, Brookings County, South Dakota.

**Factors of soil formation.** The parent material in which this soil is developing is calcareous, medium-textured loess of Wisconsin age overlying calcareous, medium-textured glacial till of Iowan age (16). The site at which the profile was described and sampled is located within the Coteau des Prairies division of the Central Lowland as classified by Fenneman (15) and Rothrock (55) and revised by Flint (16). The topographic aspect of the profile site is that of a slightly convex, west-facing, 2-percent slope near the crest of a broad-topped interfluve ridge in a gently undulating to undulating, thinly loess-mantled landscape having a local relief differential of 30 to 35 feet. As a result of the position occupied by this soil in the toposequence,
the microclimatic conditions under which it is developing closely approximate those of the macroclimate of the area. The macroclimate of the area is characterized by: (a) A period of 34 weeks during which the ground is not frozen, (b) An average temperature for this period of 57 to 59° F., (c) An average precipitation for this period of 18 to 19 inches, and (d) An average period precipitation effectiveness of 2.80 (49, 62). The soil was cropped to alfalfa and brome at the time of sampling.

Field profile description. The symbolized field profile description of profile T-2, Moody silty clay loam, is shown in Figure IX.

Narrative profile description. The following narrative profile description is a direct transcription of the symbolized field profile description of profile T-2, Moody silty clay loam, shown in Figure IX.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
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</thead>
</table>
| A11p    | 0 to 5 inches | Black (10YR 2/1 moist) with no change in moist color on crushing, and dark grayish brown (10YR 4/1.5 dry) with no change in dry color on crushing and with a very few, medium worm casts and filled worm channels of matrix color; silty clay loam; primary peds are low-weak, coarse, rough-surface subangular blocks separating into secondary peds that are high-weak, irregular-surface, very fine and fine granules; consistence is friable moist and slightly hard dry; noncalcareous; tubular pores are very few, very fine, round, very short, angular, unbranched and unobstructed; as a percentage of the total quartz, there are many
**Figure 11. Symbolized field profile description of profile T-2.**

**Profile T-2: Moody Silty Clay Loam, Brookings County, South Dakota**

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>Color</th>
<th>Texture</th>
<th>Clay Films</th>
<th>Reaction</th>
<th>Mineralogy</th>
<th>Core Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>CRUshed</td>
<td>10%Y R 10%Y</td>
<td>21%Y 10%Y</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
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<tr>
<td>5-8</td>
<td>CRUshed</td>
<td>10%Y R 10%Y</td>
<td>21%Y 10%Y</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
</tr>
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<td>8-16</td>
<td>1.25Y</td>
<td>1.25Y</td>
<td>4/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
</tr>
<tr>
<td>16-20</td>
<td>2.5Y 42</td>
<td>2.5Y</td>
<td>4/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
</tr>
<tr>
<td>20-26</td>
<td>2.5Y 43</td>
<td>2.5Y</td>
<td>5/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
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<td>26-30</td>
<td>2.5Y 48</td>
<td>2.5Y</td>
<td>5/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
</tr>
<tr>
<td>30-42</td>
<td>2.5Y 49</td>
<td>2.5Y</td>
<td>5/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
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<tr>
<td>42-49</td>
<td>2.5Y</td>
<td>2.5Y</td>
<td>5/3</td>
<td>N O E</td>
<td>C O</td>
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<td>49-60</td>
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<td>2.5Y</td>
<td>5/3</td>
<td>N O E</td>
<td>C O</td>
<td>N O E</td>
</tr>
</tbody>
</table>

**Special Features:**
- The entire profile is covered with a thin layer of loamy sand.
- The interior of the profile has a sandy layer.
- The composite texture appears to be a sandy loam.
- Some parts are dry and thin.
- 75-85% of the mineral grains in the 5th horizon are thinly fractured, 20-30% parts are thicker fractured on ped faces.
- 75-85% of the mineral grains are thinly fractured throughout the horizon.
- 75-85% of the mineral grains are thinly fractured throughout the macroscopic.
subangular transparent and common subangular transparent quartz grains; a very few, subangular dark minerals. This changes with an anthropic (plow depth) boundary to,

A12p 5 to 8 inches Black (10YR 2/1 moist) with no change in moist color on crushing, and dark gray (10YR 4/1 dry) crushing to dark gray blending toward dark grayish brown (10YR 4/1.5 dry) and with a very few, medium worm casts and filled worm channels of matrix color; silty clay loam; primary peds are ortho-weak, coarse, rough-surface subangular blocks separating into secondary peds that are low-moderate, very fine and fine, irregular-surface, oriented subangular-angular blocks; consistence is friable moist and hard dry; noncalcareous; tubular pores are very few, very fine, round, very short, curved, angular, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent and common subangular transparent quartz grains throughout; a very few, subangular dark minerals throughout. This changes with an anthropic (plow depth) boundary to,

B21 8 to 16 inches Black to very dark-gray blending toward very dark-brown to very dark grayish-brown (10YR 2.5/1.5 moist, 4.5/1.5 dry) interior matrix color with a very few, medium, black (10YR 2/1 moist, 3.5/1 dry) and a very few, medium, dark grayish-brown (1.25Y 4/2 moist, 5/2 dry) worm casts and filled worm channels and with thin, moderately-patchy, black (10YR 2/1 moist, 4/1 dry) organically-stained coatings on the vertical faces of
the primary and subprimary peds; silty clay loam; primary peds are high-weak, coarse, irregular-surface, oriented subangular-angular prisms separating into subprimary peds that are low-moderate, coarse, irregular-surface, short, oriented subangular-angular prisms separating in turn into secondary peds that are ortho-moderate, fine and medium, irregular-surface, oriented subangular-angular blocks; very thin, extremely-patchy clay skins on the vertical and horizontal faces of the primary, subprimary, and secondary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, vertical and angular, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent and a few subangular transparent quartz grains throughout and a few lightly iron-stained subangular translucent quartz grains in the interiors of the primary peds; a very few, subangular dark minerals throughout. This grades with a smooth boundary into.

B22 16 to 20 inches Dark grayish-brown (1.25Y 4/2 moist, 5/2.5 dry) interior matrix color with a very few, medium worm casts and filled worm channels of matrix color and a few, medium, black (10YR 2/1 moist, 3.5/1 dry) worm casts and filled worm-channels and with thin, nearly-continuous, very dark-gray (10YR 3/1 moist, 4/1.5 dry) organically-stained coatings on the vertical faces of the primary and subprimary peds and thin, slightly-patchy, organically-stained coatings of the same color on the vertical faces of the secondary peds; silty clay loam; primary peds are ortho-moderate,
coarse, and medium irregular-surface, oriented subangular-angular prisms separating into subprimary peds that are low-moderate, coarse, irregular-surface, short, oriented subangular-angular prisms separating in turn into secondary peds that are ortho-moderate, medium and coarse, irregular-surface, oriented subangular-angular blocks; very thin, extremely-patchy clay skins on the vertical and horizontal faces of the primary, subprimary, and secondary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; noncalcareous; tubular pores are very many, very fine, round, short, linear, vertical and angular, unbranched and unobstructed and few, medium, round, long, linear, vertical, unbranched and unobstructed, as a percentage of the total visible quartz, there are very many subangular translucent and a few subangular transparent quartz grains throughout and a very few lightly iron-stained subangular translucent quartz grains in the interiors of the primary peds; a few, subangular dark minerals throughout. This grades with a smooth boundary into,

B23

20 to 26 inches  Dark-brown to brown blending toward dark grayish-brown to olive-brown

(1.25Y 4/3 moist, 5/3 dry) interior matrix color with a very few, medium worm casts and filled worm channels of matrix color and with thin, moderately-patchy, dark-brown blending toward dark grayish-brown to olive-brown (1.25Y 3.5/3 moist, 5/2 dry) slightly-reduced, organically-stained coatings on the vertical faces of the primary peds and thin, very-patchy, slightly-reduced, organically-stained coatings of the same colors on the vertical faces of secondary peds; silt loam
close to a silty clay loam; primary peds are ortho-moderate, coarse, irregular-surface, oriented subangular-angular prisms separating into secondary peds that are ortho-weak, medium and coarse, rough-surface angular blocks; very thin, very-patchy and thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels and very thin, extremely-patchy clay skins on the horizontal faces of the primary peds and on the vertical and horizontal faces of the secondary peds; consistence is friable moist and hard dry; noncalcareous; tubular pores are very many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and few, medium, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent, a few subangular transparent and a very few lightly iron-stained subangular translucent quartz grains throughout; a few, subangular dark minerals on the faces of the primary peds and common, angular dark minerals in the interiors of the primary peds. This changes abruptly with a smooth boundary to:

B2ca  26 to 30 inches  Grayish-brown to dark grayish-brown blending toward light olive-brown to olive-brown (2.5Y 4.5/3.5 moist, 5.5/3 dry) interior matrix color with a very few, medium worm casts and filled worm channels of matrix color and with no readable ped coatings; silt loam; primary peds are high-weak, coarse, rough-surface, oriented subangular-angular prisms separating into secondary peds that are low-weak, medium and coarse, rough-surface, angular blocks; very thin, extremely-patchy clay skins
on the vertical faces of the primary and secondary peds and lining tubular pores and root channels; consistence is friable moist and slightly hard dry; weakly calcareous on the faces of the primary peds and moderately calcareous in the interiors of the primary peds with instantaneous, short-duration, high bubble-up effervescence; a few, small, irregular, diffuse-boundary line segregations in the interiors of the primary peds; tubular pores are very many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and few, fine, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz; there are very many subangular translucent and a few subangular transparent quartz grains throughout and with a very few lightly iron-stained subangular translucent quartz grains on the faces of the primary peds; common, subangular dark minerals on the faces of the primary peds and many angular dark minerals in the interiors of the primary peds; 50 to 65 percent of the mineral grains are thinly frosted on the faces of the primary peds and 75 to 95 percent of the mineral grains are frosted in the interiors of the primary peds. This changes clearly with a smooth boundary to, B3ca 30 to 42 inches. Grayish-brown to dark grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6/2 dry) interior matrix color with a very few, medium, filled worm channels and worn cavities of matrix color; silt loam; primary peds are low-weak, very coarse, rough-surface, angular prisms; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root
channels; consistence is friable moist and slightly hard dry; moderately calcareous throughout with instantaneous, short-duration, high bubble-up effervescence; very many, small, irregular, abrupt-boundary and common, medium, irregular abrupt-boundary carbonate segregations on the faces of the primary peds and a few, medium, irregular, sharp-boundary carbonate segregations in the interiors of the primary peds; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and common, fine, round, long, linear, vertical and angular, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent and a few angular transparent quartz grains throughout and a very few lightly iron-stained subangular translucent quartz grains on the faces of the primary peds; many angular dark minerals throughout; 75 to 95 percent of the mineral grains are thinly frosted. This changes clearly with a smooth boundary and a pebble-line contact to.

Dica 42 to 49 inches Light olive-brown to light yellowish-brown blending toward olive-yellow (2.5Y 5.5/5 moist, 7.5/3 dry) interior matrix color with thick, continuous grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 5.5/3 dry) sand coatings on the vertical faces of the primary peds; a composite texture of sandy loam, with the exteriors of the peds being sand and the ped interiors being loam; primary peds are ortho-moderate, very coarse (1 to 2 feet in diameter), smooth-surface, oriented sub-angular-angular prisms; common clay bridges between sand grains on the faces of the peds; consistence is firm moist and very hard dry; weakly
calcareaous on the ped faces and moderately calcareaous in the interiors of the peds with instantaneous, short-duration, high bubble-up effervescence throughout; a few small, irregular, clear-boundary carbonate segregations on the faces of the peds and a few, medium and a few, small, irregular, abrupt-boundary carbonate segregations in the interiors of the peds; tubular pores are common, very fine, round, moderately-long, linear, vertical, unbranched and unobstructed; common, fine, round, moderately-long, linear, vertical, unbranched and unobstructed; and a few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent and a very few angular transparent quartz grains on the faces of the peds and very many subangular translucent and a few angular transparent quartz grains in the interiors of the peds; very many, subangular dark minerals on the faces of the peds and common, subangular dark minerals in the interiors of the peds; 40 to 55 percent of the mineral grains are thinly frosted on the faces of the peds and 75 to 90 percent of the mineral grains are thinly frosted in the interiors of the peds. This changes abruptly with a smooth boundary to,

D2ca  49 to 60 inches + Light-olive brown (2.5Y 5/5 moist, 7/3 dry) matrix color with a few, medium, very faint, clear-boundary, yellowish-brown (10YR 5/6 moist, 7/6 dry) iron stains in the interiors of the primary peds; loam; primary peds are ortho-moderate, very coarse (1 to 2 feet in diameter), smooth-surface, oriented subangular-angular prisms which separate in
their interiors to secondary peds that are high-very weak, fine and medium, horizontal blocks of the structured till; very thin, very patchy clay skins on the vertical and horizontal faces of the primary peds and lining tubular pores, root channels, and stone pockets; consistency is firm moist and hard dry; moderately calcareous throughout with instantaneous, short-duration, low-fizz effervescence; common, small, irregular, clear-boundary threads and seams of segregated carbonates oriented between the horizontal faces of the horizontal blocks; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed; few, fine, round, moderately-long, linear, vertical, unbranched and unobstructed; and a very few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent, common subangular transparent and a few angular transparent quartz grains throughout; common subangular dark minerals throughout; 75 to 90 percent of the mineral grains are thinly frosted.

Profile 7-3, Agar silt loam

Legal description. 1760 feet west and 440 feet south of the west quarter corner of Section 36, Township 120 north, Range 75 west, Potter County, South Dakota.

Factors of soil formation. The parent material in which this soil is developing is calcareous, medium-textured loess of Wisconsin age overlying calcareous, moderately fine-textured glacial till of Iowan age (16). The site at which the profile was described and
sampled is located within the Coteau du Missouri division of the Missouri Plateau as classified by Fenneman (15) and Rothrock (55) and revised by Flint (16). The topographic aspect of the profile site is that of a 2-percent, east-facing slope on the gently sloping, slightly convex crest of a relatively broad-topped interfluve in a thinly loess mantled landscape having a local relief differential of 30 to 40 feet. As a result of the position in which this soil occurs in the toposequence, the microclimatic environment under which it is developing closely resembles that of the macroclimate of the area. The macroclimate of the area is characterized by: (a) A period of 34 weeks during which the ground is not frozen, (b) An average temperature for this period of 57 to 58°F, (c) An average precipitation for this period of 15 to 16 inches, and (d) An average precipitation effectiveness for this period of 2.25 (49, 62). The site was in range at the time of sampling with the dominant grass species being Bouteloua gracilis and Buchloe dactyloides.

Field profile description. The symbolized field profile description of profile T-3, Agar silt loam, is shown in Figure X.

Narrative profile description. The following narrative profile description is a direct transcription of the symbolized field profile description of profile T-3, Agar silt loam, shown in Figure X.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 3 inches</td>
<td>Black to very dark gray (10YR 2.5/1 moist, 4/1 dry) crushing to black to</td>
</tr>
</tbody>
</table>
### PROFILE T-3: AGAR SILT LOAM, POTTER COUNTY, SOUTH DAKOTA

**Pedology Map Description**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>Texture</th>
<th>Structure</th>
<th>Clay Films</th>
<th>Confinement</th>
<th>Tillage Pores</th>
<th>Erosion</th>
<th>Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>I A1</td>
<td>Crushed</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<td>None</td>
</tr>
<tr>
<td>I B21</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
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<tr>
<td>I B23</td>
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<td>None</td>
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<tr>
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<td>None</td>
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<td>II D23</td>
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<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

**Special Features**

- 75-95 percent of the mineral grains in the ped interior are evenly sized; no ped district ed red fringes on pedon edges.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
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- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.
- No size, shape, or color changes throughout the horizon.

**Table Notes**

- MPS: Mineral Percentage
- VC: Vein Count
- CPR: Color Purity Rating
- L: Length
- W: Width
- H: Height
Very dark gray blending toward very dark grayish brown to dark grayish brown (10YR 2.5/1.5 moist, 4/1.5 dry); silt loam; in the upper 1 1/4 inches the primary peds are high-very weak, fine and medium, rough-surface, subangular blocks separating into secondary peds that are high-very weak, smooth-surface, very fine platelets having relatively short horizontal axes; in the lower 1 3/4 inches the primary peds are ortho-weak, medium and coarse, irregular-surface, oriented subangular-angular blocks separating into secondary peds that are low-weak, medium and coarse, irregular-surface plates; constisence is friable moist and soft dry; noncalcareous; tubular pores are very few, very fine, round, short, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent and common angular transparent quartz grains in the interiors of the primary peds and many subangular translucent and many angular transparent quartz grains frosting the faces of the primary peds; a very few, subangular dark minerals. This changes clearly with a smooth boundary to,

B21 3 to 8 inches Dark-brown (10YR 3.5/3 moist, 4.5/2.5 dry) interior matrix color with thin, nearly-continuous, very dark-gray blending toward very dark grayish-brown (10YR 3/1.5 moist, 4/1.5 dry) organically-stained coatings on the vertical and horizontal faces of the primary peds and thin, moderately-patchy, organically-stained coatings of the same colors on the vertical and horizontal faces of the secondary peds; silty clay loam; primary peds are low-moderate, fine and very fine, irregular-surface,
oriented subangular-angular prisms separating into secondary peds that are ortho-moderate, fine, medium, and very fine, irregular-surface subangular blocks; thin, nearly-continuous and moderate, very-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels and thin, very-patchy and moderately-thick, extremely-patchy clay skins on the horizontal faces of the primary peds and on the vertical and horizontal faces of the secondary peds; consistency is friable moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and occur primarily in the interiors of the primary peds; as a percentage of the total visible quartz, there are common subangular translucent and common angular transparent quartz grains throughout and a very few lightly iron-stained subangular translucent and a very few lightly iron-stained angular transparent quartz grains in the interiors of the primary peds; a very few, subangular dark minerals.

This changes clearly with a smooth boundary to,

B22 8 to 17 inches Dark-brown to brown (1.25Y 4/3 moist, 4.5/2.5 dry) interior matrix color with thin, slightly-patchy, dark-gray blending toward dark grayish-brown (10YR 4/1.5 moist, 4.5/2.5 dry) organically-stained coatings on the vertical faces of the primary and secondary peds; silty clay loam; primary peds are ortho-moderate, coarse, irregular-surface, oriented subangular-angular prisms separating into subprimary peds that are high-moderate, medium and fine, smooth-surface, oriented subangular-angular prisms separating in turn into secondary peds that are
low-moderate, medium and coarse, irregular-surface, oriented subangular-angular blocks; thin, slightly-patchy and moderately-thick, very-patchy clay skins on the vertical faces of the primary and subprimary peds and lining tubular pores and root channels and thin, very-patchy clay skins on the horizontal faces of the primary and subprimary peds and thin, very-patchy and moderately-thick, extremely-patchy clay skins on the vertical and horizontal faces of the secondary peds; consistency is friable moist and hard dry; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and occur primarily in the interiors of the primary peds; as a percentage of the total visible quartz, there are many subangular translucent and a few angular transparent quartz grains throughout and a few lightly iron-stained angular transparent quartz grains throughout; a few, subangular and angular dark minerals. This changes abruptly with a wavy boundary to.

B2cm  17 to 21 inches  Dark grayish-brown blending toward olive-brown (2.5Y 4/3 moist, 5.5/2.5 dry) interior matrix color with thin, slightly-patchy, dark grayish-brown to grayish-brown blending toward olive-brown (2.5Y 4.5/2.5 moist, 6/1.5 dry) slightly-reduced coatings on the vertical faces of the primary peds; silt loam; primary peds are ortho-moderate, coarse, rough-surface, oriented subangular-angular prisms separating into secondary peds that are low-weak, coarse, rough-surface, oriented subangular-angular blocks; thin, extremely-patchy clay skins on the vertical and horizontal faces of the primary peds and lining tubular pores and root
channels; consistence is friable moist and very hard dry; moderately calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the vertical faces of the primary peds and with instantaneous, short-duration, high bubble-up effervescence in the interiors of the primary peds; segregated carbonates absent on the vertical faces of the primary peds but many, medium, irregular, clear-boundary carbonate segregations and a few, small, irregular, clear-boundary carbonate segregations occur in the interiors of the primary peds; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed throughout and many, very fine, round, short, curved, horizontal, unbranched and unobstructed in the interiors of the primary peds; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout and a very few lightly iron-stained subangular translucent and a very few lightly iron-stained angular transparent quartz grains on the faces of the primary peds; common, angular dark minerals in the interiors of the primary peds and a few angular and subangular dark minerals on the faces of the primary peds; 50 to 75 percent of the mineral grains on the faces of the primary peds are thinly frosted and 75 to 90 percent of the mineral grains in the interiors of the primary peds are thinly frosted. This changes clearly with a wavy boundary to,

B31ca 21 to 30 inches Dark grayish brown to grayish brown blending toward light olive brown
(2.5Y 4.5/2.5 moist, 6/2 dry); silt loam; primary peds are low-moderate,
coarse, irregular-surface, oriented subangular-angular prisms separating into low-weak, coarse, rough-surface, oriented subangular-angular blocks; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is friable moist and very hard dry; moderately calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the faces of the primary peds and with instantaneous, short-duration, high bubble-up effervescence in the interiors of the primary peds; a few, medium, irregular, clear-boundary carbonate segregations and a few, small, irregular, clear-boundary carbonate segregations on the faces of the primary peds and many, medium, irregular, clear boundary carbonate segregations in the interiors of the primary peds; tubular pores are common, very fine, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular-translucent and a few angular transparent quartz grains on the faces of the primary peds; common, angular dark minerals on the faces of the primary peds and many, angular dark minerals in the interiors of the primary peds; 75 to 95 percent of the mineral grains are thinly frosted. This changes clearly with a smooth boundary to,

B32ca

30 to 39 inches

dark grayish brown to grayish brown blending toward olive brown to light olive brown (2.5Y 4.5/2.5 moist, 5.5/2.5 dry) with no readable ped coatings; silt loam; primary peds are high-weak, very coarse, irregular-surface, oriented subangular-angular prisms; very thin, extremely-
patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is friable moist and hard dry; moderately calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the faces of the primary peds and instantaneous, short-duration, high bubble-up effervescence in the interiors of the primary peds; a few, medium, irregular, clear-boundary carbonate segregations in the interiors of the primary peds; tubular pores are few, very fine, round, long, linear, vertical, unbranched and unobstructed; few, fine, round, long, linear, vertical, unbranched and unobstructed; few, fine, round, long, linear, vertical, unbranched and unobstructed; few very fine, round, short, curved, horizontal, unbranched and unobstructed; and a few, fine, round, short, linear, horizontal, unbranched and unobstructed; as a percentage of the total visible quartz, there are many, angular dark minerals in the interiors of the primary peds and common, angular dark minerals on the faces of the primary peds; 75 to 95 percent of the mineral grains thinly frosted throughout. This grades with a smooth boundary into,

C1ca 39 to 48 inches Dark grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/2.5 moist, 5.5/2.5 dry) matrix color with a few, fine, faint, clear-boundary yellowish-brown iron stains (10YR 5/4 moist, 6.5/4 dry) and a few, fine, faint, clear-boundary gray mottles (7.5/0 moist, 6.5/0 dry); silt loam; primary peds are low-weak, very coarse, rough-surface, oriented subangular-angular prisms; consistence is friable moist and hard dry; moderately calcareous on the faces of the primary peds with
instantaneous, short-duration, high bubble-up effervescence and weakly calcareous in the interiors of the primary peds with instantaneous, short-duration high bubble-up effervescence; a few, medium, irregular, sharp-boundary carbonate segregations on the faces of the primary peds and common, medium, irregular, clear-boundary carbonate segregations in the interiors of the primary peds; tubular pores are very few, fine, round, long, linear, vertical, unbranched and unobstructed; few, very fine, round, long, linear, vertical, unbranched and unobstructed; and a few, very fine, round, short, curved, horizontal, unbranched and unobstructed; as a percentage of the total visible quartz, there are many, subangular translucent and a few, angular transparent quartz grains; many, angular dark minerals throughout; 75 to 95 percent of the mineral grains on the faces of the primary peds are thinly frosted and 50 to 75 percent of the mineral grains in the interiors of the primary peds are thinly frosted. This changes abruptly with a wavy pebble-line contact to,

**Dica** 43 to 60 inches  Very dark grayish brown to dark grayish brown (2.5Y 3.5/2 moist, 5/2 dry); clay loam glacial till; massive; consistence is firm moist and hard dry; weakly calcareous throughout with instantaneous, short-duration, high bubble-up effervescence; a few, medium, irregular, sharp-boundary carbonate segregations throughout; tubular pores are very few, fine, round, long, linear, vertical, unbranched and unobstructed and a few, very fine, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common
subangular translucent and common angular transparent quartz grains; many, angular and subangular dark minerals throughout; 10 to 15 percent of the mineral grains are thinly frosted.

---
60 to 78 inches  Sampled but not described
---
78 to 87 inches  Sampled but not described
---
87 to 105 inches  Sampled but not described

Profile T-4, Vienna Loan

Legal description. 4 of a mile north and 155 feet west of the southwest corner of Section 14, Township 118 north, Range 52 west, Cuming County, South Dakota

Factors of soil formation. The parent material in which this soil is developing is calcareous, medium-textured till of Tazwell age (16). The site at which the profile was described and sampled is located within the Coteau des Prairies division of the Central Lowlands as classified by Fenneman (15) and Bothrock (55) and revised by Flint (16). The topographic aspect of the profile site is that of a west-facing, 2-percent, convex, gently sloping crest of a relatively broad-topped interflue ridge in an undulating landscape, having an integrated drainage pattern and a local relief differential of 50 to 60 feet. As a result of the position occupied by this soil in the toposequence, the microclimatic conditions under which it is developing closely approximate those of the macroclimate of the area. The macroclimate of the area is characterized by: (a) A period of 33 weeks during which the ground is not frozen, (b) An average temperature for
this period of 56 to 57° F., (c) An average precipitation for this period of 17 to 18 inches, and (d) An average precipitation effectiveness for this period of 2.64 (49, 62). The soil was cropped to alfalfa at the time of sampling.

**Field profile description.** The symbolized field profile description of profile T-4, Vienna loam, is shown in Figure XI.

**Narrative profile description.** The following narrative profile description is a direct transcription of the symbolized field profile description of profile T-4, Vienna loam, shown in Figure XI.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1p</td>
<td>0 to 5 inches</td>
<td>Black (10YR 2/1 moist) with no change in moist color on crushing, and very dark gray (10YR 3/1 dry) crushing to very dark gray to dark gray (10YR 3.5/1 dry); loam; primary peds are low-moderate, coarse and very coarse, irregular-surface subangular blocks separating to secondary peds that are low-weak, medium, rough-surface granules and high-weak, very fine, irregular-surface crumbs; consistence is very friable moist and soft dry; noncalcareous; as a percentage of the total visible quartz, there are many subangular translucent, common angular transparent, and a few organically-stained subangular translucent quartz grain; a very few, subangular dark minerals. This changes clearly with a smooth boundary to</td>
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### Profile T-4: Vienna Loam, Corbinton County, South Dakota

#### Field Description of Profile T-4

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<th>Clay Fraction (%)</th>
<th>Organic Matter (%)</th>
<th>Base Saturation (%)</th>
<th>Exchangeable Ca (ppm)</th>
<th>Exchangeable Mg (ppm)</th>
<th>Exchangeable K (ppm)</th>
<th>Exchangeable H (ppm)</th>
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<td>0</td>
<td>0</td>
<td>Sand, granite</td>
</tr>
</tbody>
</table>

#### Special Features
- B: MOTTLED IN THE INTERIOR OF THE PED applauding
- C: MOTTLED IN THE INTERIOR OF THE PED applauding
- D: MOTTLED IN THE INTERIOR OF THE PED applauding
- E: MOTTLED IN THE INTERIOR OF THE PED applauding
- F: MOTTLED IN THE INTERIOR OF THE PED applauding
- G: MOTTLED IN THE INTERIOR OF THE PED applauding
- H: MOTTLED IN THE INTERIOR OF THE PED applauding
- I: MOTTLED IN THE INTERIOR OF THE PED applauding
- J: MOTTLED IN THE INTERIOR OF THE PED applauding
- K: MOTTLED IN THE INTERIOR OF THE PED applauding
- L: MOTTLED IN THE INTERIOR OF THE PED applauding
- M: MOTTLED IN THE INTERIOR OF THE PED applauding
- N: MOTTLED IN THE INTERIOR OF THE PED applauding
- O: MOTTLED IN THE INTERIOR OF THE PED applauding
- P: MOTTLED IN THE INTERIOR OF THE PED applauding
- Q: MOTTLED IN THE INTERIOR OF THE PED applauding

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**Figure VI.** Symbolised field profile description of profile T-4.
A1B2  5 to 12 inches  Black to very dark-gray blending toward
Very dark-brown to very dark grayish-brown (10YR 2.5/1.5 moist, 4/1 dry) interior matrix color with thin, nearly-continuous, black (10YR 2/1 moist, 3.5/1 dry) organically-stained coatings on both the vertical and horizontal faces of the primary and secondary peds; clay loam; primary peds are low-moderate, coarse and medium, irregular-surface, oriented subangular-angular prisms separating into secondary peds that are high-weak, coarse, irregular-surface, oriented subangular-angular blocks; very thin, extremely-patchy clay skins on the horizontal faces of the primary and secondary peds; consistence is friable moist and slightly hard dry; noncalcareous; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent, common angular transparent, and a few organically-stained subangular translucent quartz grains; a very few, subangular dark minerals. This grades with a smooth boundary into,

B21  12 to 18 inches  Very dark grayish-brown (1.25Y 3/2 moist, 4/2 dry) interior matrix color with thin, nearly-continuous, very dark-brown (10YR 2/2.5 moist, 4/1 dry) organically-stained coatings on both the vertical and horizontal faces of the primary peds and on the vertical faces of the secondary peds; clay loam; primary peds are ortho-moderate, coarse, smooth-surface, oriented subangular-angular prisms separating into secondary peds that are low-moderate, coarse, rough-surface subangular blocks; thin, moderately-
patchy clay skins on the vertical faces of the primary peds and very thin, extremely-patchy clay skins on the horizontal faces of the primary peds and on the vertical and horizontal faces of the secondary peds; consistence is firm moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed, and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz; there are many subangular translucent and common angular transparent quartz grains throughout, and with a few lightly iron-stained subangular transparent quartz grains in the interiors of the primary peds; a few, subangular dark minerals throughout. This changes clearly with a smooth boundary to,

B22 18 to 23 inches Olive-brown (2.5Y 4/4 moist, 4.5/3 dry) interior matrix color with thin, slightly-patchy, very dark grayish-brown to dark grayish-brown (10YR 3.5/2.5 moist, 4.5/1.5 dry) organically-stained coatings on the vertical faces of the primary and secondary peds; clay loam; primary peds are orthomoderate, coarse, irregular-surface, oriented subangular-angular prisms separating to secondary peds that are low-weak, coarse, rough-surface subangular blocks; thin, very patchy clay skins on the vertical faces of the primary peds, very thin, extremely-patchy clay skins on the horizontal faces of the primary peds and on both the vertical and horizontal faces of the secondary peds, and thin, continuous and moderately-thick, moderately-patchy clay skins lining tubular pores, root channels, and stone pockets; consistence is firm moist and hard dry; noncalcareous;
tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent and common angular transparent quartz grains throughout and a few lightly iron-stained subangular translucent and a few lightly iron-stained angular transparent quartz grains in the interiors of the primary pods; a few, subangular and angular dark minerals throughout. This changes clearly with a smooth boundary to.

B2ca 23 to 27 inches Grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 6/3.5 dry)

interior matrix color with a few, fine, distinct, abrupt-boundary, dark-brown to brown (7.5/4 4/4 moist, 5/6 dry) iron stains in the interiors of the primary pods and with thin, moderately-patchy, dark grayish-brown blending toward olive-brown (2.5Y 4/3 moist, 5/2.5 dry), slightly-reduced, organically-stained coatings on the vertical faces of the primary pods; loam; primary pods are low-moderate, coarse, irregular-surface, oriented subangular-angular prisms; thin, very patchy clay skins on the vertical faces of the primary pods and lining tubular pores; root channels, and stone pockets; consistence is firm moist and hard dry; moderately calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the ped faces and with instantaneous, short-duration, high bubble-up effervescence in the ped interiors; a very few, small, irregular, diffuse-boundary carbonate segregations in the interiors of the pods; thin carbonate
coats on the undersides of gravels; tubular pores are many, very fine, round, small, linear, multidirectional, unbranched and unobstructed, and a very few, medium, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent and common angular transparent quartz grains throughout; a few, angular dark minerals on the ped faces and common, angular dark minerals in the interiors of the peds; 90 to 100 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into,

B3loca 27 to 37 inches Grayish-brown to light brownish-gray blending toward light olive-brown to light yellowish-brown (2.5Y 5.5/3 moist, 7/3 dry) interior matrix color with a few, fine, distinct, abrupt-boundary, dark-brown to brown (7.5YR 4/4 moist, 5/6 dry) iron stains in the interiors of the primary peds and with thin, moderately-patchy grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 6/2 dry) slightly-reduced, organically-stained coatings on the vertical faces of the primary peds; loam; primary peds are ortho-weak, very coarse, irregular-surface, oriented subangular-angular prisms separating into low-weak, very coarse, irregular-surface horizontal blocks that are of geologic origin and are inherent to the structured glacial till; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores, root channels, and stone pockets; consistence is firm moist and very hard dry; moderately calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the faces of the primary
peds and with instantaneous, long-duration high bubble-up intermixed with low-fizz effervescence; common, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and many, small and medium, irregular, sharp-boundary carbonate segregations in the interiors of the primary peds; thin carbonate coats on the undersides of gravels; tubular pores are very many, very fine, round, short, linear, vertical, unbranched and unobstructed and very few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; a few, angular dark minerals on the faces of the primary peds and common, angular dark minerals in the interiors of the primary peds; 90 to 100 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into.

B32ca 37 to 45 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6.5/2.5 dry) interior matrix color with a few, fine, distinct, abrupt-boundary, dark-brown to brown (7.5Y 4/4 moist, 5/6 dry) iron stains and common, medium, distinct, abrupt-boundary black (10YR 2/1 moist, 3/1 dry) manganese stains primarily in the interiors of the primary peds and with thin, nearly-continuous, dark grayish-brown to grayish-brown (2.5Y 4.5/2.5 moist, 7/2.5 dry) slightly-reduced coatings on the vertical faces of the primary peds; loam; primary peds are low-weak, very coarse, irregular-surface, oriented subangular-angular prisms separating into ortho-weak, very
coarse and coarse, irregular-surface horizontal blocks that are of geologic origin and are inherent to the structured till; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores, root channels, and stone pockets; consistency is firm moist and very hard dry; moderately calcareous throughout with instantaneous, long-duration, low-fizz effervescence; common, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and a very few, small, irregular abrupt-boundary carbonate segregations on the faces of the primary peds and a very few, small, irregular, abrupt-boundary carbonate segregations in the interiors of the primary peds; thin carbonate coats on the undersides of gravels; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed and very few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent quartz grains throughout; common, angular dark minerals throughout; 70 to 90 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into,

C1oa 45 to 53 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6/2.5 dry) interior matrix color with common, medium, distinct, diffuse-boundary, dark yellowish-brown (10YR 4/6 moist, 6/6 dry) iron stains; a few, fine, distinct, abrupt-boundary, dark-brown to brown (7.5YR 4/4 moist, 5/6 dry) iron stains; and a few, fine and medium, distinct, abrupt-boundary, black (10YR 2/1 moist,
3/1 dry) manganese stains; loam; primary structure is ortho-weak, coarse and very coarse, irregular-surface horizontal blocks that are of geologic origin and inherent to the structured till; consistence is firm moist and very hard dry; weakly calcareous throughout with instantaneous, long-duration, high bubble-up effervescence on the faces of the horizontal blocks and with instantaneous, long-duration, low-fizz effervescence in the interiors of the horizontal blocks; common, small, irregular, diffuse-boundary carbonate segregations on the structure faces and a very few, small, irregular, diffuse-boundary carbonate segregations in the interiors of the structure units; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent quartz grains throughout; many, angular dark minerals throughout; 50 to 75 percent of the mineral grains are thinly frosted. This changes clearly with a smooth boundary to,

C2ea 53 to 60 inches + Dark grayish-brown to grayish-brown (2.5Y 4.5/2 moist, 6/2.5 dry) interior matrix color with common, medium, distinct, diffuse-boundary, dark yellowish-brown (10YR 4/6 moist, 6/6 dry) iron stains; a few, fine, distinct, abrupt-boundary dark-brown to brown (5YR 4/4 moist, 5/6 dry) iron stains; and a few, fine and medium, distinct, abrupt-boundary, black (10YR 2/1 moist, 3/1 dry) manganese stains; loam; primary structure is high-weak, coarse, irregular-surface, horizontal blocks that are of geologic origin and are inherent to the structured till; consistence is very firm moist and very hard dry; weakly calcareous
throughout with instantaneous, long-duration, low-fizz effervescence throughout; a few, small, irregular, diffuse-boundary, carbonate segregations on the structure faces and a very few, small, irregular, diffuse-boundary carbonate segregations in the interiors of the structure units; tubular pores are few, very fine, round, short, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are very many subangular translucent quartz grains throughout; many, angular dark minerals throughout; 50 to 75 percent of the mineral grains are thinly frosted.

Profile T-5, Houdek loam

**Legal description.** 400 feet west and 200 feet north of the southwest corner of Section 10, Township 119 north, Range 65 west, Spink County, South Dakota

**Factors of soil formation.** The parent material in which this soil is developing is calcareous, medium to moderately fine-textured glacial till of Mankato age (16). The site at which the profile was described and sampled is located within the James River Lowland division of the Central Lowland as classified by Fenneman (15) and Rothrock (55) and revised by Flint (16). The topographic aspect is that of an east-facing, gently sloping, convex crest of a low undulation in a gently undulating till plain with a local relief differential of 10 feet and a poorly integrated drainage pattern. Because of the position occupied by this soil in the toposquence, the microclimatic environment under which it is developing closely approximates that of
the macroclimate of the area. The macroclimate of the area is characterized by: (a) A period of 34 weeks during which the ground is not frozen, (b) An average temperature for this period of 53 to 59°F, (c) An average precipitation for this period of 16 to 17 inches, and (d) An average precipitation effectiveness of 2.46 (49, 62). The site was in range at the time of sampling with the dominant grass species being Stipa comata and Agropyron smithii.

Field profile description. The symbolized field profile description of profile T-5, Houdek loam, is shown in Figure XII.

Narrative profile description. The following narrative profile description is a direct transcription of the symbolized field profile description of profile T-5, Houdek loam, shown in Figure XII.

| Horizon | Depth | Color (10YR 2/1 moist, 3.5/1 dry) crushing to black blending toward very dark brown (10YR 2/1.5 moist, 4/1 dry); loam; in the upper 1 1/2 inches the primary peds are ortho-very weak, coarse, rough-surface granules separating into subprimary peds that are high-weak, fine and very fine, irregular-surface granules; in the lower 1 1/2 inches the primary peds are high-weak, coarse, irregular-surface granules separating into subprimary peds that are high-very weak, medium and fine, rough-surface granules; consistence is friable moist and soft dry; noncalcareous; tubular pores are few, very fine, round, short, linear, multidirectional, unbranched and unobstructed; as a percentage of the total |
## PROFILE T-5: HOUEK LOAM; SPINK COUNTY, SOUTH DAKOTA

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<th>Layer</th>
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<th>Color</th>
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<th>Solution</th>
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### Special Features
- 75-95 percent of the mineral grains are yellow in red interiors; 31-46 percent mixed powdery grains on red faces.
- 88-100 percent of the mineral grains are evenly scattered in red interiors; 31-46 percent mixed powdery grains on red faces.
- 75-95 percent of the mineral grains are evenly scattered in red interiors; 31-46 percent mixed powdery grains on red faces.
visible quartz, there are many subangular translucent and common angular transparent quartz grains; a very few, subangular dark minerals. This changes clearly with a smooth boundary to,

32A1 3 to 6 inches Very dark-brown to very dark grayish-brown (10YR 2.5/2 moist, 3.5/2 dry) interior matrix color with moderately-thick, continuous, black (10YR 2/1 moist, 4/1 dry) organically-stained coatings on the vertical and horizontal faces of the primary peds and thin, extremely-patchy, black (10YR 2/1 moist, 3/1 dry) organically-stained coatings on the vertical and horizontal faces of the secondary peds; heavy loam; primary peds are high-weak, coarse and very coarse, irregular-surface, subangular prisms separating into secondary peds that are high-very weak, medium, rough-surface, subangular blocks; very thin, extremely-patchy clay skins on a few of the inside vertical and horizontal faces of the secondary peds; consistence is friable moist and slightly hard dry; non-calcareous; tubular pores are few, very fine, round, short, linear, vertical, unbranched and unobstructed, and few, fine, round, short, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; a very few, subangular dark minerals. This grades with a smooth boundary into,

32 6 to 18 inches Dark-brown (1.25Y 3.5/3 moist, 4.5/3 dry) interior matrix color with thin, slightly-patchy, black to very dark-gray (10YR 2/1.5 moist, 4/1.5 dry)
organically-stained coatings on the vertical faces of the primary peds and thin, moderately-patchy, black blending toward very dark-brown (10YR 2/1.5 moist, 4/1.5 dry) organically-stained coatings on the horizontal faces of the primary peds; clay loam; primary peds are ortho-weak, coarse, rough-surface, oriented subangular-angular prisms separating into subprimary peds that are ortho-moderate, medium and fine, irregular-surface, oriented subangular-angular prisms which in turn separate into secondary peds that are low-moderate, medium and coarse, irregular-surface, oriented subangular-angular blocks; thin, extremely-patchy clay skins on the vertical faces of the primary peds and thin, very-patchy and moderately-thick, extremely-patchy clay skins on the vertical and horizontal faces of the subprimary and secondary peds, and lining tubular pores and root channels; consistence is firm moist and hard dry; noncalcareous; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, fine, round, short, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent, common angular transparent, and common lightly iron-stained subangular translucent quartz grains; a very few, subangular and angular dark minerals on the faces of the primary and subprimary peds and a few, angular dark minerals in the interiors of the primary and subprimary peds. This changes abruptly with a wavy boundary to,

S2ca 18 to 21 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 5.5/2.5 dry) interior matrix color with
a few, fine, faint, abrupt-boundary, strong-brown (7.5YR 3/3 moist, 4/4 dry) iron stains primarily in the interiors of the primary pedds, and with thin, nearly-continuous, dark grayish-brown blending toward olive-brown (2.5Y 4/3 moist, 5/3 dry) organically-stained coatings on the vertical faces of the primary pedds; clay loam; primary pedds are ortho-moderate, coarse and medium, smooth-surface, oriented subangular-angular prisms separating into secondary pedds that are low-week, coarse, irregular-surface, oriented subangular-angular blocks; thin, very-patchy clay skins on the vertical faces of the primary pedds and lining tubular pores and root channels, and thin, extremely-patchy clay skins on the vertical faces of the secondary pedds; consistence is firm moist and hard dry; moderately calcareous on the faces of the primary pedds and strongly calcareous throughout the interiors of the primary pedds; instantaneous, long-duration, high bubble-up effervescence; a few, medium, irregular, abrupt-boundary and a few, small, round, abrupt-boundary carbonate segregations in the interiors of the primary pedds; thin, carbonate coats on the undersides of gravels; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, fine, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are common subangular translucent, common angular transparent, and a few lightly iron-stained subangular translucent quartz grains; a few, angular and subangular dark minerals on the faces of the primary pedds and common, angular dark minerals in the interiors of the primary pedds; 35 to 55 percent of the mineral grains on the
facies of the primary peds are thinly frosted and 75 to 95 percent of the mineral grains in the interiors of the primary peds are thinly frosted. This grades with a smooth boundary into.

B31ca  21 to 25 inches  Grayish-brown blending toward light olive-brown (2.5Y 5/2.5 moist, 6.5/2 dry) interior matrix color with a few, fine, faint, abrupt-boundary, strong-brown (7.5YR 3/3 moist, 4/4 dry) iron stains, and with thin, nearly-continuous dark grayish-brown blending toward olive-brown (2.5Y 4/3 moist, 5/3 dry) organically stained coatings on the vertical faces of the primary peds; heavy loam; primary peds are high-weak, very coarse and coarse, irregular-surface, oriented subangular-angular prisms separating into secondary peds that are ortho-very weak, coarse, rough-surface, angular blocks; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is firm moist and very hard dry; moderately calcareous on the faces of the primary peds and strongly calcareous in the interiors of the primary peds; instantaneous, long-duration, high bubble-up effervescence; a few, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and many, medium, irregular, clear-boundary carbonate segregations in the interiors of the primary peds; thin carbonate coats on the undersides of gravels; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and a few, fine, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and
common angular transparent quartz grains; a few, angular and subangular dark minerals on the faces of the primary peds and common, angular dark minerals in the interiors of the primary peds; 35 to 55 percent of the mineral grains on the faces of the primary peds are thinly frosted and 75 to 95 percent of the mineral grains in the interiors of the primary peds are thinly frosted. This grades with a smooth boundary into,

**B32ca** 25 to 33 inches  Grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 6/3 dry)

Interior matrix color with a few, fine, distinct, diffuse-boundary, yellowish-brown (10YR 5/6 moist, 6/6 dry) iron stains, a few, medium, distinct, abrupt-boundary, gray to light-gray (N 6/0 moist, 7/0 dry) mottles, and a few, fine, distinct, abrupt-boundary, strong-brown (7.5YR 3/3 moist, 4/4 dry) soft, iron segregations, and with thin, nearly-continuous grayish-brown blending toward light olive-brown (2.5Y 5/2.5 moist, 6.5/2 dry) slightly-reduced coatings on the vertical faces of the primary peds; loam; primary peds are low-weak, very coarse, rough-surface, oriented subangular-angular prisms separating into secondary structure units that are ortho-very weak, fine, rough-surface, horizontal blocks that are of geologic origin and are inherent to the structured glacial till; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is firm moist and very hard dry; moderately calcareous on the faces of the primary peds and strongly calcareous in the interiors of the primary peds; instantaneous, long-duration, high
bubble-up intermixed with low-fizz effervescence; a few, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and very many, medium, irregular, clear-boundary, carbonate segregations in the interiors of the primary peds; thin carbonate coats on the undersides of gravels; a few, small, salt segregations; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed and a few, fine, round, moderately-long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz; there are many subangular translucent and common angular transparent quartz grains; common, angular dark minerals on the faces of the primary peds and many, angular dark minerals in the interiors of the primary peds; 70 to 75 percent of the mineral grains on the faces of the primary peds are thinly frosted and 95 to 100 percent of the mineral grains in the interiors of the primary peds are thinly frosted. This changes clearly with a smooth boundary to,

C11cacs 33 to 42 inches Grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 5Y 6.5/3 dry) interior matrix color with a few, fine, distinct, diffuse-boundary, yellowish-brown (10YR 5/6 moist, 6/6 dry) iron stains, a few, medium, distinct, abrupt-boundary, gray to light-gray (N 6/0 moist, 7/0 dry) mottles, common, fine, distinct, abrupt-boundary, strong-brown (7.5YR 3/3 moist, 4/4 dry) soft, iron segregations, and a few, fine, distinct, abrupt-boundary, black (10YR 2/1 moist, 3/1 dry) manganese stains; loam glacial till; structure units are ortho-weak, fine and medium, irregular-surface, horizontal blocks that are of geologic origin and are
inherent to the structured glacial till; consistence is very firm
moist and very hard dry; moderately calcareous throughout; instantaneous,
long-duration, high bubble-up intermixed with low-fixe effervescence; common, medium, irregular, diffuse-boundary, carbonate segregations in the form of seams between the horizontal faces of the horizontal blocks; thin carbonate coats on the undersides of gravels; a few, small, individual gypsum crystals; common, small, salt segregations; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed and few, very fine, round, short, linear, horizontal, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; many, angular dark minerals; 95 to 100 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into,

C12oacs 42 to 60 inches + Grayish-brown blending toward light olive-brown (2.5Y 5/3 moist, 5Y 6/3 dry) matrix color with a few, fine, distinct, diffuse-boundary, yellowish-brown (10YR 5/6 moist, 6/6 dry) iron stains, common, medium, distinct, abrupt-boundary, gray to light-gray (8 6/0 moist, 7/0 dry) mottles, common, fine, distinct, abrupt-boundary, strong-brown (7.5YR 3/3 moist, 4/4 dry) soft iron segregations, and common, fine, distinct, abrupt-boundary, black (10YR 2/1 moist, 3/1 dry) manganese stains; loam glacial till; structure units are ortho-moderate, coarse and very coarse, smooth-surface, horizontal blocks that are of geologic origin and are inherent to the structured glacial till; consistence is very
firm moist and very hard dry; weakly calcareous throughout; instantaneous, long-duration, high bubble-up intermixed with low-fizz effervescence; a few, small, threads and seams of segregated carbonates; a few, small, individual gypsum crystals; common, small, salt segregations; tubular pores are very few, very fine, round, short, linear, vertical unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; very many, angular dark minerals; 20 to 30 percent of the mineral grains are thinly frosted.

Profile T-6, Williams loam

Legal description. 120 yards north and 100 feet east of the west quarter corner of Section 5, Township 114 north, Range 70 west, Hand County, South Dakota

Factors of soil formation. The parent material in which this soil is developing is calcareous, medium to moderately fine-textured glacial till of Mankato age (16). The site at which the profile was described and sampled is located within the Coteau du Missouri division of the Missouri Plateau as classified by Fenneman (15) and Rothrock (55) and revised by Flint (16). The topographic aspect of the profile site is that of a southeast-facing, very gently sloping, convex crest of a low undulation in a gently undulating till plain having a poorly integrated drainage pattern and a local relief differential of 10 to 12 feet. As a result of the position occupied by this soil in the toposquence, the microclimatic conditions under which it is developing
are nearly the same as those of the macroclimate. The macroclimate of the area is characterized by: (a) A period of 34 weeks during which the ground is not frozen, (b) An average temperature for this period of 57 to 59°F, (c) An average precipitation for this period of 15 to 16 inches, and (d) An average precipitation effectiveness for this period of 2.27 (49, 62). The site was in range at the time of sampling with the dominant grass species being Bouteloua gracilis, Stipa comata and Agropyron smithii.

Field profile description. The symbolized field profile description of profile T-6, Williams loam, is shown in Figure XIII.

Narrative profile description. The following narrative profile description is a direct transcription of the symbolized field profile description of profile T-6, Williams loam, shown in Figure XIII.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0 to 4 inches</td>
<td>Black blending toward very dark brown (10YR 2/1.5 moist) with no change in moist color, on crushing and dark gray (1.25Y 4/1 dry) crushing to very dark grayish brown blending toward dark grayish brown (1.25Y 3.5/2 dry); loam; in the upper 1 1/2 inches the primary peds are ortho-very weak, coarse and very coarse, rough-surface granules separating into sub-primary peds that are high-weak, fine and very fine smooth-surface granules; in the lower 2 1/2 inches the primary peds are ortho-weak, very coarse, rough-surface granules; consistence is friable moist and soft dry; noncalcareous; tubular pores are very few, very fine, round,</td>
</tr>
<tr>
<td>Depth</td>
<td>Material</td>
<td>Horizon</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure XI.** Symbolized field profile description of profile T-6.
very short, curved, multidirectional, unbranched and unobstructed and primarily in the interiors of the primary peds; as a percentage of the total visible quartz, there are common angular transparent and common subangular translucent quartz grains in the interiors of the peds and many subangular translucent and many angular transparent quartz grains frosting the faces of the primary peds; a very few, subangular dark minerals. This changes clearly with a smooth boundary to,

B21 4 to 8 1/2 inches Very dark grayish-brown blending toward dark-brown (10YR 3/2.5 moist, 4/2.5 dry) interior matrix color with thin, nearly-continuous, very dark-brown to very dark grayish-brown (10YR 2.5/2 moist, 4/1.5 dry) organically-stained coatings on both the vertical and horizontal faces of the primary, subprimary and secondary peds; clay loam; primary peds are ortho-weak, medium and coarse, rough-surface, oriented subangular-angular prisms separating into subprimary peds that are ortho-moderate, fine, irregular-surface, oriented subangular-angular prisms which in turn separate into secondary peds that are high-moderate, medium and fine, irregular-surface, oriented subangular-angular blocks; thin, slightly-patchy and moderately-thick, very-patchy clay skins on the vertical and horizontal faces of the primary, subprimary and secondary peds and lining tubular pores and root channels; consistence is firm moist and hard dry; noncalcareous; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed and primarily in the interiors of the primary peds; as a percentage of the total visible quartz, there are common subangular translucent
and common angular transparent quartz grains throughout and a few lightly iron-stained subangular translucent quartz grains in the interiors of the primary, subprimary and secondary peds; a very few, subangular and angular dark minerals. This grades with a smooth boundary into,

B22 3 1/2 to 13 inches Very dark grayish-brown to dark grayish-brown (10YR 3.5/2 moist, 1.25Y 4.5/2 dry) interior matrix color with thin, moderately-patchy, very dark grayish-brown (10YR 3/2 moist, 4/2.5 dry) organically-stained coatings on the vertical faces of the primary and subprimary peds and thin, extremely-patchy, organically-stained coatings of the same color on the horizontal faces of the primary and subprimary peds and on the vertical and horizontal faces of the secondary peds; clay loam; primary peds are ortho-moderate, coarse and medium, irregular-surface, oriented subangular-angular prisms separating into subprimary peds that are high-moderate, fine, smooth-surface, oriented subangular-angular prisms which in turn separate into secondary peds that are ortho-moderate, medium and coarse, irregular-surface, oriented subangular-angular blocks; thin, slightly-patchy and moderately-thick, very-patchy clay skins on the vertical and horizontal faces of primary and subprimary peds and lining tubular pores and root channels, and thin, very-patchy and moderately-thick, extremely-patchy clay skins on the vertical and horizontal faces of the secondary peds; consistence is firm moist and hard dry; noncalcareous; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and
unobstructed; a few, fine, round, short, linear, vertical, unbranched and unobstructed; and very few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout and a few lightly iron-stained subangular translucent quartz grains in the interiors of the primary, subprimary and secondary peds; a few, subangular and angular dark minerals. This changes clearly with a wavy boundary to,

**B2ca**

13 to 21 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/2.5 moist, 6/2 dry) interior matrix color with thin, moderately-patchy, dark grayish-brown (2.5Y 4/2 moist, 5/2 dry) organically-stained coatings on the vertical faces of the primary peds; clay loam; primary peds are low-moderate, coarse and medium, irregular-surface, oriented subangular-angular prisms separating into high-weak, coarse and medium, irregular-surface, oriented subangular-angular blocks; thin, very-patchy clay skins on the vertical and horizontal faces of the primary and secondary peds and lining tubular pores and root channels; consistency is firm moist and hard dry; moderately calcareous on the faces of the primary peds and strongly calcareous in the interiors of the primary peds; instantaneous, long-duration, low-fizz intermixed with high bubble-up effervescence throughout; a few small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and common, medium, irregular, sharp-boundary carbonate segregations and many, small, round, abrupt-boundary, carbonate
segregations in the interiors of the primary peds; thin carbonate coatings on the undersides of gravels; tubular pores are common, very fine, round, short, linear, multidirectional, unbranched and unobstructed; and few, fine, round, short, linear, vertical, unbranched and unobstructed; and very few, large, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains throughout, and a very few lightly iron-stained subangular translucent quartz grains on the faces of the primary peds; a few, subangular dark minerals on the faces of the primary peds and common, subangular and angular dark minerals in the interiors of the primary peds; 100 percent of the mineral grains are thinly frosted in the interiors of the primary peds and 80-95 percent of the mineral grains are thinly frosted on the faces of the primary peds. This grades with a wavy boundary into.

B31cacs 21 to 27 inches Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6/3 dry) interior matrix color with a few, fine, distinct, abrupt-boundary, dark yellowish-brown (10YR 4/6 moist, 6/6 dry) iron stains in the interiors of the primary peds and with thin, nearly-continuous, grayish-brown blending toward light olive-brown (2.5Y 5/2.5 moist, 6/2 dry) slightly-reduced coatings on the vertical faces of the primary peds; loam; primary peds are high-weak, very coarse, rough-surface, oriented subangular-angular prisms separating into secondary peds that are ortho-weak, coarse and medium,
irregular-surface, oriented subangular-angular blocks; thin, very-patchy clay skins on the vertical faces of the primary peds and thin, extremely-patchy clay skins on the horizontal faces of the primary peds, on the vertical and horizontal faces of the secondary peds and lining tubular pores and root channels; consistence is firm moist and hard dry; moderately calcareous throughout; instantaneous, long-duration, low-fizz intermixed with high bubble-up effervescence on the faces of the primary peds and instantaneous, short-duration, low-fizz effervescence in the interiors of the primary peds; a few, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds, and common, medium, irregular, sharp-boundary and common, small, round, abrupt-boundary carbonate segregations in the interiors of the primary peds; thin carbonate coatings on the undersides of gravels; a few, small, individual gypsum crystals and a very few, small, salt segregations in the interiors of the primary peds; tubular pores are many, very fine, round, short, linear, multidirectional, unbranched and unobstructed and very few, large, round, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and a few angular transparent quartz grains throughout, and a very few lightly iron-stained subangular translucent quartz grains on the faces of the primary peds; common, angular dark minerals on the faces of the primary peds and many, angular dark minerals in the interiors of the primary peds; 75 to 90 percent of the mineral grains are thinly frosted throughout. This grades with a smooth boundary into,
B32caca  27 to 36 inches  Dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/3 moist, 6.5/3 dry) interior matrix color with common, medium, distinct, diffuse-boundary, yellowish-brown iron stains (10YR 5/6 moist, 7/6 dry), a few, medium, distinct, abrupt-boundary, gray to light-gray mottles (10 6/0 moist, 7/0 dry), and a very few, fine, distinct, abrupt-boundary, strong-brown (7.5YR 4/6 moist, 5/6 dry) soft iron segregations primarily in the interiors of the primary peds and with thin, nearly-continuous, dark grayish-brown to grayish-brown blending toward olive-brown to light olive-brown (2.5Y 4.5/2.5 moist, 6.5/2 dry) slightly-reduced coatings on the vertical faces of the primary peds; loam; primary peds are low-weak, very coarse, rough-surface, oriented subangular-angular prisms separating into ortho-very weak, coarse, rough-surface horizontal blocks that are of geologic origin and inherent to the structured till; very thin, extremely-patchy clay skins on the vertical faces of the primary peds and lining tubular pores and root channels; consistence is firm moist and hard dry; moderately calcareous on the faces of the primary peds and weakly calcareous in the interiors of the primary peds with instantaneous, long-duration, low-fizz intermixed with high bubble-up effervescence throughout; a very few, small, irregular, diffuse-boundary carbonate segregations on the faces of the primary peds and a few, small, irregular, sharp-boundary carbonate segregations in the interiors of the primary peds; thin carbonate coatings on the undersides of gravels; a few, small, individual gypsum crystals and a few, small, salt segregations;
tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed and few, fine, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and a few angular transparent quartz grains; many, angular dark minerals throughout; 75 to 90 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into.

Cicacos 36 to 46 inches No matrix color; many, fine, distinct, diffuse-boundary, yellowish-brown iron stains (10YR 5/6 moist, 7/6 dry), many, fine, distinct, abrupt-boundary gray to light-gray mottles (10YR 6/0 moist, 7/0 dry), a few, fine, distinct, abrupt-boundary, strong-brown soft iron segregations (7.5YR 4/6 moist, 5/6 dry), and a very few, fine, prominent, abrupt-boundary, black manganese stains (10YR 2/1 moist, 3/1 dry); loam; primary peds are low-weak, coarse, rough-surface horizontal blocks that are of geologic origin and are inherent to the structured till; consistence is firm moist and hard dry; weakly calcareous throughout with instantaneous, short-duration, low-fizz effervescence throughout; a few, small, threads and seams of segregated carbonates and thin carbonate coatings on the undersides of gravels; a few, small, individual gypsum crystals and common, small, salt segregations; tubular pores are common, very fine, round, short, linear, vertical, unbranched and unobstructed and few, fine, round, large, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; many, angular
dark minerals throughout; 50 to 75 percent of the mineral grains are thinly frosted. This grades with a smooth boundary into, C2ccs 46 to 60 inches No matrix color; many, fine, distinct, diffuse-boundary yellowish-brown iron stains (10YR 5/6 moist, 7/6 dry), many, fine, distinct, abrupt-boundary, gray to light-gray mottles (11 6/0 moist, 7/0 dry), a few, fine, distinct, abrupt-boundary, strong-brown soft iron segregations (7.5YR 4/6 moist, 5/6 dry), and a few, fine, prominent, abrupt-boundary, black manganese stains (10YR 2/1 moist, 3/1 dry); loam; primary peds are low-weak, coarse, rough-surface horizontal blocks that are of geologic origin and are inherent to the structured till; consistence is firm moist and hard dry; weakly calcareous throughout with instantaneous, short-duration, low-fizz effervescence throughout; a few, small, individual gypsum crystals and many, small, salt segregations; tubular pores are few, very fine, round, short, linear, vertical, unbranched and unobstructed and few, fine, round, long, linear, vertical, unbranched and unobstructed; as a percentage of the total visible quartz, there are many subangular translucent and common angular transparent quartz grains; many, angular dark minerals throughout; 25 to 40 percent of the mineral grains are thinly frosted.

Graphic Morphology

The application of the quantitative numerical values accompanying the quantitative standards to the descriptive morphology of the six profiles studied made possible the graphic presentation of the
morphologic features of these profiles. The procedures used in calculating the graphed values are given in the preceding section of the thesis and will not be discussed again here.

The graphic presentations of the quantitative morphology for certain of the major features of morphology for the soil profiles investigated are shown in Figures XIV through XXXII which are included within the following section of the thesis.

Discussion of the Field Morphology Studies

The following discussions concern the results of the field morphology studies of the six profiles investigated employing the quantitative methods of study developed by the earlier phases of this problem.

The discussions of the capabilities and usefulness of the quantitative standards, the quantitative numerical values and the recording methods per se, as tools in the investigation of soil genesis and classification problems and their use as a basis for the quantitative recognition and characterization of classificational units will be reserved for the final discussions and conclusions of the thesis.

Sequence and Thickness of Horizons

The general breakdown of the sequence and thickness of horizons for the six profiles studied is shown in Table 7. The characterization of the macroclimatic environment of the six profiles is given in Table 8. The breakdown of the sequence and thickness of horizons by climatic groupings of the six profiles studied is shown in Table 9. The climatic
Table 7. Breakdown of the Horizon Sequence and Thickness for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Sequence and thickness of horizons</th>
<th>So. Moody (loess)</th>
<th>No. Moody (loess)</th>
<th>Vienna (till)</th>
<th>Houdek (till)</th>
<th>Williams (till)</th>
<th>Agar (loess)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-1</td>
<td>T-2</td>
<td>T-4</td>
<td>T-5</td>
<td>T-6</td>
<td>T-7</td>
</tr>
<tr>
<td>A1 horizon in inches *</td>
<td>8.5</td>
<td>8.0</td>
<td>8.5</td>
<td>4.5</td>
<td>4.0</td>
<td>3.0</td>
</tr>
<tr>
<td>A1B2 horizon in inches</td>
<td>0.0</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>B2A1 horizon in inches</td>
<td>5.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Leached B2 horizon in inches *</td>
<td>24.5</td>
<td>18.0</td>
<td>14.5</td>
<td>13.5</td>
<td>9.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Unleached B2 horizon in inches</td>
<td>0.0</td>
<td>4.0</td>
<td>4.0</td>
<td>3.0</td>
<td>8.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Total B2 horizon in inches *</td>
<td>24.5</td>
<td>22.0</td>
<td>18.5</td>
<td>16.5</td>
<td>17.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Leached B3 horizon in inches</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Leached B2 and B3 horizons in inches *</td>
<td>34.5</td>
<td>18.0</td>
<td>14.5</td>
<td>14.5</td>
<td>9.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Unleached B3 horizon in inches</td>
<td>0.0</td>
<td>12.0</td>
<td>18.0</td>
<td>12.0</td>
<td>15.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Total B2 and B3 horizons in inches *</td>
<td>34.5</td>
<td>34.0</td>
<td>36.5</td>
<td>28.5</td>
<td>32.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Leached C or D horizon in inches</td>
<td>3.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total leached horizons in inches</td>
<td>46.0</td>
<td>26.0</td>
<td>23.0</td>
<td>18.5</td>
<td>13.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Leached B2/A1 ratio</td>
<td>2.9</td>
<td>2.3</td>
<td>1.7</td>
<td>3.0</td>
<td>2.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Total B/A1 ratio</td>
<td>4.1</td>
<td>4.3</td>
<td>4.4</td>
<td>5.7</td>
<td>8.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Total B/leached B ratio</td>
<td>1.0</td>
<td>1.9</td>
<td>2.5</td>
<td>2.1</td>
<td>3.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Leached B/unleached B ratio</td>
<td>34.5</td>
<td>1.1</td>
<td>0.7</td>
<td>0.9</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Leached horizons/unleached horizons ratio</td>
<td>3.3</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
</tr>
</tbody>
</table>

* Figures include one-half the thickness of the A1B2 or B2A1 transition horizons when present.
Table 8. Characterization of the Elements of the Macroclimate for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Elements of the macroclimate</th>
<th>So. Moody</th>
<th>No. Moody</th>
<th>Increasing aridity</th>
<th>Vienna</th>
<th>Houde</th>
<th>Williams</th>
<th>Agar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual precipitation</td>
<td>25-26&quot; (+)</td>
<td>22-23&quot; (-)</td>
<td>20-21&quot; (+)</td>
<td>18-19&quot; (+)</td>
<td>17-18&quot; (+)</td>
<td>17-18&quot; (-)</td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>49-50°F</td>
<td>44-45°F</td>
<td>42-43°F (+)</td>
<td>44-45°F</td>
<td>44-45°F</td>
<td>44-45°F</td>
<td></td>
</tr>
<tr>
<td>Mean number of weeks ground not frozen</td>
<td>38-39</td>
<td>34-35 (+)</td>
<td>33-34</td>
<td>34-35 (-)</td>
<td>34-35 (+)</td>
<td>33-34</td>
<td></td>
</tr>
<tr>
<td>Mean precipitation for period of unfrozen ground</td>
<td>23-24&quot;</td>
<td>18-19&quot; (+)</td>
<td>17-18&quot; (+)</td>
<td>16-17&quot; (+)</td>
<td>15-16&quot; (+)</td>
<td>15-16&quot; (-)</td>
<td></td>
</tr>
<tr>
<td>Mean temperature for period of unfrozen ground</td>
<td>59-60°F</td>
<td>57-58°F</td>
<td>56-57°F</td>
<td>58-59°F (-)</td>
<td>57-58°F</td>
<td>57-58°F (+)</td>
<td></td>
</tr>
<tr>
<td>Mean P-E index for period of unfrozen ground</td>
<td>3.1-3.3 (+)</td>
<td>2.7-2.9 (-)</td>
<td>2.5-2.7 (-)</td>
<td>2.3-2.5</td>
<td>2.1-2.3 (+)</td>
<td>2.1-2.3 (-)</td>
<td></td>
</tr>
</tbody>
</table>

(+): Because of the geographic location of the profile site, the climatic environment is more nearly characterized by the upper limit of the given range in the climatic element.

(-): Because of the geographic location of the profile site, the climatic environment is more nearly characterized by the lower limit of the given range in the climatic element.
Table 9. Breakdown of the Horizon Sequence and Thickness by Climatic Groupings of the Six Profiles Studied

<table>
<thead>
<tr>
<th>Sequence and thickness of horizons</th>
<th>Increasing aridity</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>So. Moody T-1</td>
<td>No. Moody T-2, T-4</td>
<td>Houdek T-5</td>
<td>Agar Williams T-3, T-6</td>
</tr>
<tr>
<td>A1 horizon in inches *</td>
<td>8.5</td>
<td>8.25</td>
<td>4.5</td>
<td>3.5</td>
</tr>
<tr>
<td>A1B2 horizon in inches</td>
<td>0.0</td>
<td>3.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>B2A1 horizon in inches</td>
<td>5.0</td>
<td>0.0</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Leached B2 horizon in inches *</td>
<td>24.5</td>
<td>16.25</td>
<td>13.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Unleached B2 horizon in inches</td>
<td>0.0</td>
<td>4.0</td>
<td>3.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Total B2 horizon in inches *</td>
<td>24.5</td>
<td>20.25</td>
<td>16.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Leached B3 horizon in inches</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Leached B2 and B3 horizons in inches *</td>
<td>34.5</td>
<td>16.25</td>
<td>13.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Unleached B3 horizon in inches</td>
<td>0.0</td>
<td>15.0</td>
<td>12.0</td>
<td>16.5</td>
</tr>
<tr>
<td>Total B2 and B3 horizons in inches *</td>
<td>34.5</td>
<td>35.25</td>
<td>28.5</td>
<td>33.5</td>
</tr>
<tr>
<td>Leached C or D horizon in inches</td>
<td>3.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total leached horizons in inches</td>
<td>46.0</td>
<td>24.5</td>
<td>18.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Leached B2/A1 ratio</td>
<td>2.9</td>
<td>2.0</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Total B/A1 ratio</td>
<td>4.1</td>
<td>4.3</td>
<td>5.7</td>
<td>9.9</td>
</tr>
<tr>
<td>Total B/leached B ratio</td>
<td>1.0</td>
<td>2.2</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Leached B/unleached B ratio</td>
<td>34.5</td>
<td>0.9</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Leached horizons/unleached horizons ratio</td>
<td>3.3</td>
<td>0.7</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Figures include one-half the thickness of the A1B2 or B2A1 transition horizons when present.
groupings of profiles made in Table 9 were based on the degree of similarity or difference between the elements of the macroclimates characterizing the individual profiles as shown in Table 8.

All of the profiles studied have A1 or Ap horizons as the surface horizon. The A1 or Ap horizons decrease in thickness in the direction of the more arid climatic environments across the loess soil-climosequence, the glacial till soil-climosequence and the general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. The increasing aridity across the general soil-climosequence gives rise to a biosequence in which short, shallow-rooting grasses replace the taller, deeper-rooting grasses, thus limiting the deposition of organic matter, the staining agent of the A1 horizon, to somewhat shallower depths in the profile. Where a glacial till derived profile and a loess derived profile occur within the same or very similar general macroclimatic areas, as in the case of profiles T-6 and T-3, or T-4 and T-2, the soils developed in glacial till have slightly thicker A horizons than do those developed in loess. As shown in Table 7, the range in thickness of the A1 horizon across the soil-climosequence is slightly wider in the loess derived soils than it is in the soils developed in glacial till.

The kind and sequence of the horizons immediately underlying the uppermost A1 or Ap horizon shows an interesting evolutionary pattern across the general soil-climosequence. In profiles T-3 and T-6, the most arid members of the general soil-climosequence, the A1 horizons are among the thinnest in the soil-climosequence and are immediately
underlain by a B2 horizon. In profile T-5, the slightly less arid member of the general soil-climosequence, the A1 horizon is the same thickness as are those of profiles T-3 and T-6, but it is immediately underlain by a B2A1 horizon. The micromorphologic characteristics of this horizon indicate a slight encroachment of the A1 horizon on the upper portion of the B2 horizon has taken place, thus tending to thicken the total A1 horizon. In profile T-4, the somewhat more humid member of the general soil-climosequence, the A1 is considerably thicker than is that of profile T-5, and is immediately underlain by an A1B2 horizon. The micromorphological characteristics of this horizon would seem to indicate that the encroachment of the A1 horizon on the upper portion of the B2 horizon is in a more advanced stage than is that represented in the B2A1 horizon of profile T-5, thus tending to thicken the total A1 horizon over that of profile T-5. In profile T-2, the next most humid member of the general soil-climosequence, the encroachment of the A1 horizon on the upper B2 horizon appears to be complete, in that the A1p horizon is immediately underlain by another A1 horizon. The macroclimatic conditions representative of profile T-2 appear to be the most favorable to the construction and developmental stability of the A1 horizon thickness. In profile T-1, the most humid and warmest member of the general soil-climosequence, the constructional processes of A1 horizon formation appear to have given way to processes that are destroying the A1 characteristics. Although the A1 horizon of profile T-1 is immediately underlain by a B2A1 horizon, the micromorphologic characteristics of this horizon and the underlying
B21 would appear to be indicative not only of destructional A1 horizon processes but also of destructional B2 horizon processes, thus tending to reduce the thickness of the A1 horizon. This is somewhat of a reversal of the evolutionary trend shown in profiles T-5, T-4 and T-2, in which the micromorphologic characteristics indicated destruction of the upper B2 horizon as the result of constructional A1 horizon processes.

Leached (noncalcareous) B2 horizons were present in all the profiles studied. The leached B2 horizons, like the A1 horizons, decrease in thickness in the direction of the more arid climatic environments across the loess soil-climosequence, the glacial till soil-climosequence and the general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. The decreasing thickness of the leached B2 horizon with increasing aridity is probably a reflection of the decreasing moisture available to accomplish leaching and B2 horizon development. Under generally equivalent macroclimatic conditions, the leached B2 horizons are thicker in the soils developed in loess than they are in the soils developed in glacial till. The greater thickness of the leached B2 horizons in the loess derived soils is probably a function of the generally lower bulk density and greater permeability of loess when compared with that of glacial till. The range in thickness of the leached B2 horizons across the general soil-climosequence is wider in the loess derived soils than it is in the soils developed in glacial till. This relationship would appear to indicate that the thickness
of the leached B2 horizon is a function of the interaction of macroclimate with the permeability characteristic of the parent material.

All of the profiles studied, with the exception of profile T-1, have an unleached (calcareous) B2 horizon immediately below the leached B2 horizons. The thickness of the unleached B2 horizons shows only weak climatic stratification. The unleached B2 horizons, tend to increase in thickness in the direction of the more arid climatic environments across the loess soil-climosequence, the glacial till soil-climosequence and the general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. However, the absence of an unleached B2 horizon in profile T-1, representing the most humid member of the soil-climosequence, and the presence of the thickest unleached B2 horizon in profile T-6, representing one of the two most arid members of the soil-climosequence, would appear to be significant from the standpoint of the degree of weathering and profile development involved.

The combined thickness of the leached and unleached B2 horizons, or total thickness of the B2 horizons, like that of the A1 and leached B2 horizons, decreases in the direction of the more arid climatic environments across the loess soil-climosequence, the glacial till soil-climosequence and the general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. Again this difference appears to be attributable to the decrease in the amount of moisture available to accomplish leaching, promote weathering and translocate clay to greater depths in the
soil profile. The combined thickness of the leached and unleached B2 horizons is greater in the loess derived soils than it is in the glacial till derived soils and this relationship appears to be a function of the greater permeability of the loessial material. The total range in the combined thickness of the leached and unleached B2 horizons is wider across the loess soil-climosequence than it is across the glacial till soil-climosequence. This would seem to indicate that the thickness of the total B2 horizon also is a function of the interaction of macroclimate with the permeability characteristic of the parent material.

Leached B3 horizons only were present in profile T-1. The presence per se of a leached B3 horizon in the warmest and most humid member of the general soil-climosequence would appear to indicate the existence of a rather strong weathering differential between profile T-1 and the other profiles in the soil-climosequence.

The combined thickness of the leached B2 and B3 horizons also decreases in the direction of the more arid climatic environments in the loess soil-climosequence, the glacial till soil-climosequence and the general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 8. This relationship again probably can be explained by the decreasing amount of moisture available to carry on leaching and weathering, and the translocation of clay to greater depths in the profile. When profiles developed in loess and profiles developed in glacial till occur in the same or in similar macroclimatic environments, as in the
case of profiles T-3 and T-6, or T-2 and T-4, the soils developed in
loess have thicker leached B horizons than do the glacial till derived
soils. This relationship would appear to be a function of the greater
permeability of the loessial materials. The range in the total thick-
ness of the leached B horizons is slightly wider across the loess
soil-climosequence. This would seem to indicate that the total thick-
ness of the leached B horizon is a function of the interaction be-
tween the macroclimate and the permeability characteristic of the
parent material.

The thickness of the unleached B3 horizons, as shown in Tables
7 and 9, exhibits no stratification with respect to the macroclimate
or to the permeability of the parent materials. However, the absence
of unleached B3 horizons in profile T-1 again would appear to be an
indication of a significant weathering differential between profile T-1
and the other profiles in the general soil-climosequence.

The combined thickness of the leached and unleached B2 and B3
horizons, as shown in Tables 7 and 9, displays little direct stratifi-
cation with the macroclimate in the loess soil-climosequence, the gla-
cial till soil-climosequence, the general soil-climosequence or with
the soil-climosequence of the climatically grouped profiles; however,
the mean thickness of the leached and unleached B2 and B3 horizons for
profiles T-3, T-5 and T-6, representing the more arid range of the
general soil-climosequence, is slightly less than is that for profiles
T-1, T-2 and T-4, representing the more humid range of the general
soil-climosequence. The combined thickness of the leached and
unleached B2 and B3 horizons averages slightly thicker in the profiles of the loess soil-climosequence than it does in the profiles of the glacial till soil-climosequence.

As shown in Tables 7 and 9, only profile T-1 has leached material below the B horizon. The presence of a leached C horizon below the B horizon would seem to indicate deeper weathering in the T-1 profile, the warmest and most humid member in the general soil-climosequence, than in the other profiles in the general soil-climosequence.

The total thickness of the leached horizons decreases in the direction of the more arid macroclimatic environments across the loess, glacial till and general soil-climosequences as shown in Table 7, and across the soil-climosequence of the climatically grouped profiles as shown in Table 9. The differential in the depth of leaching across all the soil-climosequences strongly reflects the decreasing amount of moisture available to accomplish leaching as the climatic environment becomes more arid. Where profiles developed in loess and profiles developed in glacial till occur in the same or in similar macroclimatic regimes, as in the case of profiles T-3 and T-6, or T-2 and T-4, the soils developed in loess have thicker leached zones than do those developed in glacial till. This relationship also would appear to be a function of the higher permeability of the loessial parent materials.

The ratios of the thickness of the leached B2 horizon to the thickness of the A1 horizon show little direct stratification with climate across the loess, glacial till, or general soil-climosequence, as shown in Table 7, however, the mean leached B2/A1 ratio for profiles
T-1, T-2, and T-4, representing the more humid range in the general soil-climosequence, is 2.3:1, in contrast to a mean leached B2/A1 ratio of 3.3:1 for profiles T-5, T-3, and T-6, representing the more arid range in the general soil-climosequence. The leached B2/A1 ratios show more direct stratification with the macroclimate across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. The lowest leached B2/A1 ratios occur in profiles T-4 and T-2, where the mean annual precipitation ranges from 20 to 22 inches and the mean annual temperature ranges between 42 and 45°F. As both the mean annual precipitation and temperature increase over that representative for profiles T-4 and T-2, as in the case of profile T-1, the leached B2 thickens with little or no accompanying thickening of the A1, resulting in a higher leached B2/A1 ratio. On the other hand, where the mean annual precipitation decreases and the mean annual temperature remains about the same as that representative for profiles T-4 and T-2, as in the cases of profiles T-5, T-3, and T-6, the A1 horizons decrease in thickness more rapidly than do the leached B2 horizons and again result in higher leached B2/A1 ratios.

The ratios of the thickness of the total B horizon to the thickness of the A1 horizon show direct stratification with the macroclimate. The total B/A1 ratios become successively higher in the direction of the more arid climatic environments across the loess, glacial till and general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9.
The ratios of the total thickness of the B horizon to the thickness of the leached B horizon show direct stratification with the macroclimate across the loess, glacial till and general soil-climosequence, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. The total B/leached B ratios increase with increasing aridity across the soil-climosequence.

The ratios of the total thickness of the leached B horizon to the total thickness of the unleached B horizon show direct stratification with the macroclimate across the loess, glacial till and general soil-climosequences, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9.

The leached B horizon/unleached B horizon ratios decrease with increasing aridity across the soil-climosequence.

The ratios of the total thickness of the leached horizons to the total thickness of the unleached horizons show direct stratification with the macroclimate across the loess, glacial till and general soil-climosequences, as shown in Table 7; and across the soil-climosequence of the climatically grouped profiles, as shown in Table 9. The leached horizons/unleached horizons ratios decrease with increasing aridity across the soil-climosequence.

Soil Color

The graphic presentation of the color phases of the soil morphology studies are shown in Figures XIV through XX.
Munsell value-component of soil color. The Munsell value-component of the ped interior colors and of the ped face colors by horizons for the six profiles studied is shown in Figures XIV and XV respectively. The plotted values are the means of the dry and moist Munsell value notations. The Munsell value-component of the horizon colors by horizons for the six profiles studied is shown in Figure XVI. The plotted values in Figure XVI are the means of the dry-moist Munsell value notations of the ped interior colors as shown in Figure XIV, and of the ped face colors as shown in Figure XV. The distribution curves for the value-component of the ped interior, ped face and mean horizon colors shown in Figures XIV, XV and XVI, are characterized in Tables 10, 11 and 12. From the distribution curves themselves and from their characterization, relationships between the value-component of the ped interior, ped face and mean horizon colors can be shown. Relationships of the value-component with the macroclimate and with the parent material also can be shown.

The distribution curves of the value-component of the ped interior, ped face and mean horizon colors for profile T-1 have a distinctly different shape characteristic than do those representative of the equivalent curves for the other five profiles. The shape characteristic of the value-component distribution curves for profile T-1 would appear to reflect the effects of deeper and more intense weathering than do the curves for the other profiles. The development of relatively light value-components in the B2A1 and B21 horizons in profile T-1 would seem to be the result of more intensive weathering in
Figure XIV. Mean dry-moist Munsell value-component of the ped interior color by horizons for the six profiles studied.
Figure XV. Mean dry-moist Munsell value-component of the ped face color by horizons for the six profiles studied.
Figure XVI. Mean dry-moist Munsell value-component of the mean horizon color by horizons for the six profiles studied.
this area of the profile and because of its location in the horizon sequence is suggestive of incipient A2 horizon formation. The distribution curves for the value-component of the ped interior, ped face and mean horizon colors for profiles T-2, T-4, T-5, T-6 and T-3, have generally similar shape characteristics; however, they do show definite progression in directional changes in the curve placement characteristic. The fact that the value-component curve for the ped face colors of profile T-6 is nearly the same as that for the ped interior colors of profile T-5, and the value-component curve for the ped face colors of profile T-5 is nearly the same as that for the ped interior colors of profile T-4, would appear to indicate that an evolutionary relationship exists between adjacent profiles across the soil-climosequence with respect to value-component genesis.

As shown in the upper portion of Table 10, the mean dry-moist Munsell value-component of the crushed, of the uncrushed and of the mean horizon color of the A1 horizon is 3 or darker in the loess derived soils (T-1, T-2 and T-3) and is 3 or lighter in the profiles developed in glacial till (T-4, T-5 and T-6). The mean dry-moist value-components of the crushed color, the uncrushed color and the mean horizon color of the A1 horizons are strongly stratified with the macroclimate across the soil-climosequence. The darkest mean dry-moist value-component of the crushed color, the uncrushed color and the mean horizon color of the A1 horizon occurs in profile T-4, which is developing under moderate precipitation and the coolest temperature environment in the soil-climosequence. This climatic environment
Table 10. Mean Dry-Moist Value-Component of the A1 and Leached B2 Horizons for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Mean dry-moist value-component values</th>
<th>A1 horizon</th>
<th>Leached B2 horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crushed</td>
<td>Uncrushed</td>
<td>Horizon mean</td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>T-2 No. Moody</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>2.75</td>
<td>2.75</td>
<td>2.82</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>3.00</td>
<td>2.75</td>
<td>2.88</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>2.75</td>
<td>3.00</td>
<td>2.88</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>3.25</td>
<td>3.25</td>
<td>3.25</td>
</tr>
</tbody>
</table>

Profiles grouped on the basis of distribution curve characteristics:

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Mean dry-moist value-component values</th>
<th>A1 horizon</th>
<th>Leached B2 horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crushed</td>
<td>Uncrushed</td>
<td>Horizon mean</td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>T-2 No. Moody</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>2.88</td>
<td>2.75</td>
<td>2.82</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>3.00</td>
<td>2.75</td>
<td>2.88</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>3.12</td>
<td>3.12</td>
<td>3.06</td>
</tr>
</tbody>
</table>
appears to more strongly favor the accumulation of organic matter than do the climatic environments of the other profiles. As the temperature and precipitation increase, or as the temperature increases and the precipitation decreases from that representative for profile T-4, the mean dry-moist value-component of the crushed colors, the uncrushed colors and the mean horizon colors of the A1 horizon progressively become lighter.

As shown in Table 10, when the mean dry-moist value-components of all the subhorizons within the leached B2 horizon are averaged, the mean dry-moist value-components of the total leached B2 horizons for the six profiles studied appear to be strongly stratified with the macroclimate across the soil-climosequence, having a similar pattern of climatic stratification to that of the A1 horizon. The darkest mean dry-moist value-components of the ped interior, the ped face and the mean horizon colors of the leached B2 horizons occur in profile T-5. As the temperature and precipitation increase, or as the temperature increases and the precipitation decreases from that representative for profile T-5, the mean dry-moist value-component of the leached B2 horizons progressively becomes lighter.

When the profiles are grouped on the basis of the similarities of their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 10, the same relationships are apparent between the value-component and the macroclimate as were shown by the individual profile sequence in the upper bracket of Table 10.
Table 11. Mean Dry-Moist Value-Component of the Horizon of Maximum, or Lightest, Value-Component Development for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Mean dry-moist value-component values</th>
<th>Ped interior</th>
<th>Ped face</th>
<th>Mean maximum in the column</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>maximum</td>
<td>maximum</td>
<td></td>
</tr>
<tr>
<td>Individual profiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td>T-1 So. Moody (loess)</td>
<td>5.75</td>
<td>4.50</td>
<td>4.63</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>5.25</td>
<td>5.25</td>
<td>5.25</td>
<td></td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>6.25</td>
<td>5.75</td>
<td>5.87</td>
<td></td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>5.75</td>
<td>5.75</td>
<td>5.62</td>
<td></td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>5.50</td>
<td>5.50</td>
<td>5.50</td>
<td></td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>5.25</td>
<td>5.25</td>
<td>5.25</td>
<td></td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td>T-1 So. Moody (loess)</td>
<td>4.74</td>
<td>4.50</td>
<td>4.63</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td></td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>5.75</td>
<td>5.50</td>
<td>5.56</td>
<td></td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>5.75</td>
<td>5.25</td>
<td>5.62</td>
<td></td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td></td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>5.38</td>
<td>5.38</td>
<td>5.38</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 11, the maximum, or lightest, mean dry-moist value-component development in the color profiles of the loess derived soils is darker than 5.5 and is 5.5 or lighter in the profiles developed in glacial till. The maximum, or lightest, mean dry-moist value-component developed in the ped interior, ped face and mean horizon colors is darker than 5.25 in the loess profiles. The maximum, or lightest, mean dry-moist value-component developed in the ped interior, ped face and mean-horizon colors in the glacial till derived soils shows climatic stratification, ranging between 6.25 and 5.50, with the values progressively becoming darker with increasing aridity across the soil-climosequence. The mean dry-moist value-components of the ped interior color, the ped face color and the mean horizon color in the horizon in
which the maximum, or lightest, value-component in the solum is developed also are strongly stratified with the macroclimate across the soil-climosequence. The maximum mean dry-moist value-components of the ped interior colors, the ped face colors and the mean horizon colors in the horizon in which the maximum, or lightest, value-components in the solum occur, are in profile T-4 and progressively become darker as the temperature and precipitation increase or as the temperature increases and the precipitation decreases from that representative for profile T-4.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 11, the same relationships are evident between the value-component and the macroclimate as were shown by the individual profile sequence in the upper bracket of Table 11.

Depth in the profile of the maximum value-component development. As shown in Table 12, the depth in the profile at which the midpoint of the maximum, or lightest, mean dry-moist value-component is developed in the ped interior colors shows stratification with the macroclimate across the general soil-climosequence, becoming successively shallower with increasing aridity. The stratification of this factor with climate is even more apparent when the soil parent material is held constant, as within the loess soil-climosequence or within the glacial till soil-climosequence. Where profiles developed in glacial till and profiles developed in loess are developing under the same or similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-3
Table 12. Characterization of the Distribution Curves of the Value-Component of Color for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Individual profiles</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ped interior</td>
<td>Ped</td>
<td>Mean</td>
</tr>
<tr>
<td>Increasing aridity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody</td>
<td>51.5</td>
<td>51.5</td>
<td>51.5</td>
</tr>
<tr>
<td>T-2 No. Moody</td>
<td>36.0</td>
<td>36.0</td>
<td>36.0</td>
</tr>
<tr>
<td>T-4 Vienna</td>
<td>32.0</td>
<td>41.0</td>
<td>36.5</td>
</tr>
<tr>
<td>T-5 Houdek</td>
<td>23.0</td>
<td>33.2</td>
<td>28.1</td>
</tr>
<tr>
<td>T-6 Williams</td>
<td>16.5</td>
<td>27.8</td>
<td>22.1</td>
</tr>
<tr>
<td>T-3 Agar</td>
<td>25.5</td>
<td>22.5</td>
<td>24.0</td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody</td>
<td>51.5</td>
<td>51.5</td>
<td>51.5</td>
</tr>
<tr>
<td>T-2 No. Moody</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna</td>
<td>34.0</td>
<td>38.5</td>
<td>36.3</td>
</tr>
<tr>
<td>T-5 Houdek</td>
<td>23.0</td>
<td>33.2</td>
<td>28.1</td>
</tr>
<tr>
<td>T-6 Williams</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Agar</td>
<td>21.0</td>
<td>25.1</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Note: In the upper bracket of this table, the underlined data are for profiles developed in loess and data not underlined are for profiles developed in glacial till.
and T-6, the maximum, or lightest, mean dry-moist value-component development in the ped interiors occurs at a greater depth in the profile in the loess derived soils than it does in the glacial till derived soils. When the depths of the lightest mean dry-moist ped interior value-component development for the loess derived soils and for the glacial till derived soils are averaged, as in the lower portion of Table 12, the effect of the parent material is minimized and the depth of the midpoint of the maximum mean dry-moist value-component development in the ped interiors shows strong climatic stratification, becoming progressively shallower in the profile with increasing aridity across the soil-climosequence.

It would appear therefore, that the depth in the profile at which the maximum mean dry-moist value-component development in the ped interiors occurs is stratified with climate and with the soil parent material across the soil-climosequence and is strongly stratified with climate when the parent material is held constant across the soil-climosequence.

Also of interest, especially in the soils of the glacial till soil-climosequence, is the progressive development in prominence of the mean dry-moist value-component maximum in the ped interiors accompanying the increasing depth of the maximum with decreasing aridity across the soil-climosequence.

The depths in the profile at which the midpoint of the maximum mean dry-moist value-component is developed on the ped faces show weak climatic stratification across the general soil-climosequence. However,
when the soil parent material is held constant, as in the case of the profiles within the loess soil-climosequence or within the glacial till soil-climosequence, the depths in the profile at which the midpoint of the maximum mean dry-moist value-component development on the ped faces occurs show strong climatic stratification, becoming progressively shallower with increasing aridity across the climosequence. Where profiles developed in loess and profiles developed in glacial till occur in the same or in very similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-3 and T-6, the maximum mean dry-moist value-component development on the ped faces occurs at a greater depth in the profile in the profiles derived from glacial till than it does in the profiles developed in loess.

It is of interest to note that the above relationship represents a reversal of the pattern of value-component distribution shown by the ped interiors, in which the maximum mean dry-moist value-component development occurred at greater depths in the profile in the loess derived profiles than it did in the profiles developed in glacial till. It also is of interest to note that in the profiles derived from loess, the maximum mean dry-moist value-component development in the ped interiors and on the ped faces occurs either at the same, or at very nearly the same depth in the profile. This is in rather sharp contrast to the profiles derived from glacial till, in which the maximum mean dry-moist value-component development occurs at a much greater depth in the profile on the faces of the peds than it does in the interiors of the peds. Also of interest in this connection is that in
this study, where a loess derived profile and a glacial till derived profile occur within the same or in very nearly the same macroclimatic environments, the maximum mean dry-moist value-component development on the ped faces occurs at a greater depth in the profile in profiles developed in glacial till than it does in those developed in loess, but the maximum mean dry-moist value-component development in the ped interiors occurs at a shallower depth in the profile in profiles developed in glacial till than it does in those developed in loess.

The above relationships would appear to indicate that the relatively high air-water permeability generally associated with loessial materials allows water and air and the resultant accompanying weathering processes responsible for the genesis of the value-component to proceed downward through the profile along the ped faces and through the mass of the ped interiors at comparatively the same rate. On the other hand, the relatively low air-water permeability generally associated with glacial till materials appears to retard the movement of water and air into and downward through the mass of the ped interiors, thus forcing an increased volume of water and air and the resultant accompanying weathering processes responsible for value-component genesis to follow the path of least resistance, the relatively open passageways or channels formed by the planes of the adjacent natural ped faces, in their downward movement through the profile. Value-component genesis would appear, on the basis of these relationships, to be more strongly ped-oriented in profiles developing in low-permeability materials and less strongly ped-oriented in profiles developing
in more rapidly permeable materials.

In the light of the above mentioned relationships it also is of interest to note what seems to be an evolutionary intergradational characteristic between the profiles within the glacial till soil-climosequence, as shown by the value-component curves of the ped faces and those of the ped interiors. The value-component curve of the ped face colors in profile T-6, developing in the most arid climatic environment in the glacial till soil-climosequence, is very similar to the value-component curve of the ped interior colors in profile T-5, which is developed in a slightly more humid climatic environment in the glacial till soil-climosequence. In a like manner, the value-component curve of the ped faces in profile T-5 is very much like the value-component curve of the ped interiors in profile T-4, developing in the most humid climatic environment in the glacial till soil-climosequence.

However, in spite of the above mentioned relationships, when the depths of the midpoints of the developed mean dry-moist value-component maximums on the ped faces of the loess derived profiles and of the glacial till derived profiles, occurring within the same or in very similar macroclimatic environments are averaged, as in the lower bracket of Table 12, the effect of the parent material differences are minimized and the depths of the midpoints of the developed mean dry-moist value-component maximums on the ped faces, like those in the ped interiors, show strong climatic stratification, becoming progressively shallower in depth in the profile with increasing aridity across the soil-climosequence.
When the depths in the profile at which the midpoint of the maximum mean dry-moist value-component developed in the ped interiors and that on the ped faces are averaged, the mean depth in the profile at which the midpoint of the maximum mean dry-moist value-component development occurs shows climatic stratification across the general soil-climosequence, becoming progressively shallower with increasing aridity of the climate. The stratification of this factor with climate is even more evident when the soil parent material is held constant, as within the loess soil-climosequence or within the glacial till soil-climosequence. Where profiles developed in glacial till and profiles developed in loess are developing under the same or very similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-3 and T-6, the maximum mean dry-moist value-component development occurs at a greater depth in the profile in the loess derived soils than it does in the soils derived from glacial till. When the depths of the maximum mean dry-moist value-component development in the loess derived soils and those of the soils developed in glacial till are averaged, as in the lower bracket of Table 12, the effect of the parent material difference is cancelled out and the depth at which the midpoints of the maximum mean dry-moist value-component development occurs in the profile is strongly stratified with climate across the soil-climosequence.

Range in the value-component development with depth in the profile. The range in the mean dry-moist value-component developed in the ped interior colors between the profile surface minimum and the developed profile maximum shows stratification with the macroclimate across
the general soil-climosequence.

As shown in Table 12, the greatest range is developed in profile T-4, which is developing under a macroclimate that is characterized by a mean annual precipitation of 20 to 21 inches and a mean annual temperature of 42 to 43°F, the coolest temperature environment in the general soil-climosequence. The interaction of the cool temperatures with the moderate precipitation in this environment favors the accumulation of organic matter in the A horizon, resulting in the darkest value-component A horizon colors and consequently the lowest value-component minimum for the profile surface in the soil-climosequence. The dark value-component of the A horizon colors would appear to indicate that the constructional processes responsible for the dark colors associated with A1 horizon development reach a maximum under the climatic environment of profile T-4. The climatic environment associated with profile T-4 also appears to favor the development of the highest value-component maximums in the profile occurring in the soil-climosequence. The low value-component minimums at the profile surface in combination with the high value-component profile maximums result in the relatively wide range in value-component development expressed in profile T-4.

As both the mean annual precipitation and temperature progressively increase over that representative for profile T-4, as in the cases of profiles T-2 and T-1, the range in the mean dry-moist value-component developed in the ped interior colors between the profile surface minimum and the developed profile maximum progressively decreases. The interaction of the increasing temperature and increasing
precipitation in this environment does not appear to as strongly favor the accumulation of organic matter in the A1 horizon as does the environment associated with profile T-4. The less favorable conditions for organic matter accumulation would appear to be the result of the stronger weathering and increased microorganism activity brought about by the progressively increasing precipitation and temperature of the macroclimatic environment. These weathering and biologic processes tend to result in the destruction of organic matter which brings about lighter value-component A1 horizon colors and as a consequence the profile surface value-component minimums progressively become higher in profiles T-2 and T-1 than that of profile T-4. The climatic environment associated with profiles T-2 and T-1 also appear to be less favorable for the development of the high value-component maximums in the profile that were representative of profile T-4. The progressively higher value-component minimums at the profile surface in combination with the progressively lower value-component profile maximums in profiles T-2 and T-1, result in value-component development ranges that are progressively narrower than that expressed in profile T-4.

On the other hand, as the mean annual precipitation progressively decreases and the mean annual temperature increases from that representative of profile T-4, as is the case from profile T-5 to profiles T-6 and T-3, the range in the mean dry-moist value-component developed in the ped interior colors between the profile surface minimum and the developed profile maximum progressively decreases. The interaction of the decreasing precipitation and increased temperature
in these environments does not appear to as strongly favor the accumulation of organic matter in the A1 horizon as does the environment associated with profile T-4. The less favorable conditions for organic matter accumulation would appear to be the result of the reduced weathering potential and the restricted growth of the vegetative cover brought about by the increased aridity of the macroclimatic environment. Although these environmental conditions tend to favor the constructional accumulation of organic matter in the A1 horizon, the constructional processes proceed at a somewhat reduced rate compared to that in profile T-4. The limited rate of organic matter accumulation representative of profiles T-5, T-6 and T-3 results in lighter value-component A1 horizon colors and as a consequence the profile surface value-component minimums for these profiles become progressively higher with increasing aridity across the climosequence. The climatic environments associated with profiles T-5, T-6 and T-3 also appear to be less favorable for the development of the high value-component maximums in the profile that were representative of T-4. The progressively higher value-component minimums at the profile surface in combination with the progressively lower value-component profile maximums in profiles T-5, T-6 and T-3, result in value-component development ranges that are progressively narrower than that expressed in profile T-4.

The range in the mean dry-moist value-component developed in the ped face and mean horizon colors between the profile surface minimum and the developed profile maximum shows the same pattern and degree of stratification with the macroclimate as that exhibited by the ped
interior colors.

Although the range in the mean dry-moist value-component developed in the ped interior, ped face and mean horizon colors between the profile surface minimum and the developed profile maximum is stratified with the macroclimate across the general soil-climosequence, the ranges tend to be somewhat wider in the profiles derived from glacial till than in those developed in loessial materials.

It is of interest to note that the range in the mean dry-moist value-component developed between the profile surface minimum and the developed profile maximum is the same in the ped interior colors as it is in the ped face colors in profiles T-1, T-2 and T-3, developed in loessial materials and in profile T-6, developed in glacial till. The range in the mean dry-moist value-component developed between the profile surface minimum and the developed profile maximum or profile T-4 is wider in the ped interior colors than in the ped face colors. The range in profile T-5, which is developing in a somewhat more arid climatic environment than is profile T-4, is wider in the ped face colors than in the ped interior colors, representing a reversal of the range pattern shown by profile T-4.

It is of interest to note the magnitudes of the ranges per se along with what appears to be an evolutionary relationship between the range magnitude and its orientation with respect to the peds from one profile to the next across the soil-climosequence. As shown in Table 12, profile T-3, the most arid member of the soil-climosequence, has the lowest (2.00 Munsell units of value) range and shows no range
magnitude differential between the ped faces and the ped interiors. Profile T-6, developing in a climatic environment that is slightly less arid than that of profile T-3, has a slightly higher (2.50) range than that of profile T-3, but like T-3, shows no range magnitude differential between the ped faces and the ped interiors. Profile T-5, developing in a slightly more humid climatic environment than that of profile T-6, has a somewhat higher range in both the ped interior and ped face colors than that of profile T-6; however, the range magnitude in the ped interior colors of profile T-5 is not as high (2.75) as the range magnitude of the ped faces (3.00) which is approaching the range of profile T-4, the next most humid profile in the soil-climosequence. The range magnitude in profile T-4 is considerably higher in both the ped interior and ped face colors than that representative of profile T-5; however, in the case of profile T-4 the range magnitude of the interior colors is slightly higher (3.50) than that of the ped face colors (3.25) which appears to be evolving in the direction of the next most humid profile in the soil-climosequence, profile T-2, in which the range magnitude of both the ped interior and ped face colors are again lower (2.25) than those of profile T-4.

Mean increase in the value-component per unit of depth to the profile maximum. As shown in Table 12, the mean increase in the mean dry-moist value-component in the ped interior, ped face and mean horizon colors per inch of depth from the profile surface minimum to the developed profile maximum appears to be only weakly stratified if stratified at all with the macroclimate across the general soil-climosequence.
However, when the parent material is held constant, as in the loess soil-climosequence or in the till soil-climosequence, this feature appears to be strongly stratified with the macroclimate, increasing with increasing aridity across the soil-climosequence.

The mean increase in the mean dry-moist value-component in the ped interior, ped face and mean horizon colors per inch of depth from the profile surface minimum to the developed profile maximum, as shown in Table 12, is considerably greater in the profiles developed in glacial till than in those derived from loessial materials. This difference is probably the result of the inherent permeability differential between the loess and glacial till parent materials. However, when the mean increase in the mean dry-moist value-component in the ped interior, ped face and mean horizon colors per inch of depth from the profile surface minimum to the developed profile maximum in loess derived soils and in glacial till derived soils occurring in the same or in very similar macroclimatic environments are averaged, as in the lower bracket of Table 12, the effect of the parent material on this feature is minimized and the feature again appears to be stratified with the macroclimate across the soil-climosequence. The greatest mean increase in the mean dry-moist value-component in the ped interior, ped face and mean horizon colors per inch of depth between the prescribed limits occurs in profile T-5 and progressively and rapidly decreases in profiles T-4, T-2 and T-1 in the direction of decreasing aridity across the soil-climosequence. The mean also decreases very slightly in profiles T-3 and T-6 with increasing aridity over that representative of
profile T-5, but this difference is small and may or may not be significant.

Of interest to this discussion is the fact that the mean increase in the mean dry-moist value-component per inch of depth from the profile surface minimum to the developed profile maximum remains the same or at most only changes very slightly between the ped interior colors and those of the ped faces in the loess derived profiles. However, in the soils developed in glacial till, the mean increase in the mean dry-moist value-component per inch of depth from the profile surface minimum to the developed profile maximum is much greater in the ped interior colors than it is in the ped face colors. These relationships also probably are a function of the permeability characteristic of the parent materials and tend to support the concept advanced earlier that value-component genesis is more strongly ped-oriented in soils developing in relatively low permeability materials than in those developing in materials having relatively high permeability rates.

**Depth of ped-oriented value-component differences.** As shown in Table 12, the depth in the profile at which the mean dry-moist value-component of the ped interior colors is the same as that of the ped face colors only appears to be weakly stratified with the macroclimate across the general soil-climosequence. However, when the parent material is held constant, as in the loess soil-climosequence or in the glacial till soil climosequence, the depth in the profile at which the mean dry-moist value-component of the ped interior colors is the same as that of the ped face colors appears to be strongly stratified with
climate, becoming progressively shallower in the profile with increasing aridity across the soil-climosequence.

Where profiles developed in glacial till and profiles developed in loess are developing under the same or very similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-3 and T-6, the depth in the profile at which the mean dry-moist value-component of the ped interior colors is the same as that of the ped face colors is greater in the glacial till profiles than it is in those developed in loessial materials. However, when the depths in the loess derived profiles and the depths in the glacial till derived soils are averaged, as in the lower bracket of Table 12, the effect of the parent material is minimized and the depths are strongly stratified with climate, becoming shallower in the profile with increasing aridity across the soil-climosequence.

(Hue x chroma)-component of soil color. The mean Munsell (hue x chroma)-component of the ped interior colors and of the ped face colors by horizons for the six profiles studied is shown in Figures XVII and XVIII respectively. The plotted values are the means of the dry and moist weighted Munsell hue notations times the Munsell chroma notations of the ped interior colors and of the ped face colors respectively by horizons. The mean Munsell (hue x chroma)-component of the horizon colors by horizons for the six profiles studied is shown in Figure XIX. The plotted values in Figure XIX are the means of the Munsell (hue x chroma)-component notations of the ped interior colors, as shown in Figure XVII and of the ped face colors, as shown in Figure XVIII, by horizons.
Figure XVII. Mean dry-moist Munsell (hue x chroma) - component of the ped interior color by horizons for the six profiles studied.
Figure XVIII. Mean dry-moist Munsell (hue x chroma)-component of the ped face color by horizons for the six profiles studied.
Figure XIX. Mean dry-moist Munsell (hue x chroma)–component of the mean horizon color by horizons for the six profiles studied
The distribution curves for the (hue x chroma)-component of the ped interior, ped face and mean horizon colors, shown in Figures XVII, XVIII and XIX, are characterized in Tables 13, 14 and 15. From the distribution curves themselves and from the analyses made of them, relationships between the (hue x chroma)-components of the ped interior, ped face and mean horizon colors can be shown. Relationships of the (hue x chroma)-component of soil color with the macroclimate and with the parent material also can be shown.

The distribution curves of the (hue x chroma)-component of the ped interior colors, as shown in Figure XVII, can be grouped on the basis of their general shape and position characteristics into four groups. (a) Profile T-1: The distribution curve for profile T-1 shows a distinctly thicker amplitude peak than do those of the other profiles. The depth in the profile of the lower limit of the amplitude peak appears to be extended, probably as the result of the deeper weathering induced by and associated with the highest temperature and precipitation macroclimatic environment of the general soil-climosequence. The shallowness in the profile of the upper limit of the amplitude peak probably is associated with the encroachment of the B2 horizon on the A1 horizon that is accompanying the destructive A1 horizon processes active in profile T-1. (b) Profiles T-2 and T-4: The distribution curves for profiles T-2 and T-4 have distinctly different shape characteristics when compared with those of the other profiles. The upper portion of the curves are concave in contrast to the convex aspect of the upper portion of the curves representing the other profiles. The
depressed aspect of the upper portion of these curves appears to be the result of the thicker A1 horizons resulting from the constructional processes of A1 horizon formation active in these profiles; the masking effect of the organic staining on the expression of the chroma-component in the upper B horizon of these profiles; and the periodic very weak reducing conditions brought about in this portion of the profile by the relatively high water holding capacity of the organic matter present in combination with the cooler temperatures of the macroclimatic environment. The amplitude peaks in profiles T-2 and T-4 are considerably thinner than that in profile T-1, as the result of the depressed upper portions of the curves for profiles T-2 and T-4; and they occur at a greater depth in the profile than do those of profiles T-5, T-6 and T-3, probably as the result of the deeper weathering activity associated with the more humid climatic environments in which these profiles are developing. The amplitude peaks in profiles T-2 and T-4 also have lower (hue x chroma) maximums than do those of the other profiles. (c) Profile T-5: The distribution curve for profile T-5 has similar shape characteristics to those representative of profile T-6 and T-3, but differs from them in having a somewhat thicker amplitude peak at a greater depth in the profile. These differences would appear to be attributable to the somewhat deeper weathering activity resulting from the slightly less arid climatic environment, and to the downward displacement of the B2 horizon as a result of the afore-cited A1 horizon encroachment on the B2 horizon evident in profile T-5. (d) Profiles T-6 and T-3: The distribution curves for profiles T-6 and T-3 have
relatively thin amplitude peaks that occur at very shallow depths in the profile and it is the extreme shallowness in the profile of the amplitude peak that comprises the difference between the distribution curves for profiles T-6 and T-3 and that of profile T-5. The shallowly positioned amplitude peaks in profiles T-3 and T-6 appear to be a reflection of the most arid climatic conditions in the general soil-climosequence and the lack of any encroachment of the A1 horizon on the B2 horizon. The amplitude peak in profile T-3, developing in loess, is slightly thicker than is that in profile T-6, developing in glacial till and would appear to be the result of the greater permeability of the loessial materials.

The distribution curves of the (hue x chroma)-component of the ped face colors, as shown in Figure XVIII, can be grouped on the basis of their general shape and position characteristics into three groups.

(a) Profiles T-1 and T-2: The distribution curves for profiles T-1 and T-2 have a distinctly different shape characteristic than do those of the other profiles. Both curves in this group are characterized by a comparatively thick inverted amplitude peak immediately below the surface horizon that is formed as the result of the relatively high (hue x chroma)-component in the ped face colors in the surface horizon, indicative of the destructive A1 horizon processes, and the somewhat lower (hue x chroma)-component in the ped face colors of the horizon or horizons immediately underlying the surface horizon. These inverted amplitude peaks appear to reflect the stronger weathering activity brought about by and associated with the highest temperature and
precipitation climatic environment in the general soil-climosequence, and appear to represent an initial stage in the development of incipient A2 horizons, which as such would seem to indicate the incipience of the podzolization process in the genesis of these profiles. The amplitude peaks occurring below the inverted amplitude peaks in profiles T-1 and T-2 are thicker and attain their peak maximum at a greater depth in the profile than do those present in the other profiles. The greater depth in the profile of the peak maximum in profile T-1 and T-2 also would appear to be the result of the stronger weathering potential of the macroclimatic environment. (b) Profiles T-4 and T-5: The distribution curves for profiles T-4 and T-5, as a result of the decreased weathering activity brought about by and associated with the increasing aridity across the soil-climosequence, lack the inverted amplitude peaks that are representative of profiles T-1 and T-2. The upper portion of the distribution curves for profiles T-4 and T-5 are concave, as they were in the distribution curves of the ped interior colors for profiles T-2 and T-4 in Figure XVII, and can be similarly explained. The amplitude peaks in profiles T-4 and T-5 are thinner than are those in profiles T-1 and T-2 and reach a peak maximum at a somewhat shallower depth in the profile. (c) Profiles T-6 and T-3: The distinctive feature of the distribution curves for profiles T-6 and T-3 is the extreme shallowness of the amplitude peak in the profile. The shallowly positioned amplitude peaks in profiles T-6 and T-3 appear to be a reflection of the weakening weathering potential resulting from and associated with the most arid climatic conditions
in the general soil-climosequence, and the lack of evident encroachment of the A1 horizon on the B2 horizon. The amplitude peak in profile T-3, developing in loess, is somewhat thicker and less pronounced than is that in profile T-6, developing in glacial till. This relationship would appear to be the result of the greater permeability of the loessial materials.

The distribution curves of the (hue x chroma)-component of the mean horizon colors, as shown in Figure XIX, are not easily grouped. The evolutionary nature of the progressive curve transitions from profile T-1 through profile T-6 across the general soil-climosequence seems to preclude any attempt at grouping at this level.

As shown in the upper bracket of Table 13, the mean dry-moist Munsell (hue x chroma)-components of the crushed, of the uncrushed and of the mean horizon color of the A1 horizon appear to be strongly stratified with the macroclimate across the soil-climosequence. The lowest, or weakest, mean dry-moist (hue x chroma)-components developed in the crushed color, the uncrushed color and the mean horizon color of the A1 horizon occur in profile T-4, which is developing under moderate precipitation and the coolest temperature regime in the general soil-climosequence. As the temperature and precipitation increase or as the temperature increases and the precipitation decreases from that representative of profile T-4, the mean dry-moist (hue x chroma)-components developed in the crushed, the uncrushed and the mean horizon colors of the A1 horizons progressively become higher, or stronger.
### Table 13. Mean Dry-Moist (Hue x Chroma)-Component of the A1 and B Horizons for the Six Profiles Studied

<table>
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<td>Horizon</td>
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<td>T-3 Agar (loess)</td>
<td>4.38</td>
<td>3.25</td>
<td>3.81</td>
<td>7.03</td>
<td>5.25</td>
</tr>
</tbody>
</table>
As shown in the upper bracket of Table 13, when the mean dry-moist (hue x chroma)-components of all the subhorizons within the leached B2 horizon of the profile are averaged, the mean dry-moist (hue x chroma)-components of the leached B2 horizons for the six profiles studied appear to be strongly stratified with the macroclimate across the general soil-climosequence, having a similar pattern of climatic stratification to that of the A1 horizon. The lowest, or weakest, mean (hue x chroma)-component development in the ped interiors of the leached B2 horizon is in profile T-4 and as the temperature and precipitation increase or as the temperature increases and the precipitation decreases from that representative of profile T-4, the mean dry-moist (hue x chroma)-component development in the ped interiors of the leached B2 horizon progressively increases, or becomes stronger. The lowest, or weakest, mean (hue x chroma)-component development on the ped faces of the leached B2 horizon is in profile T-5 and it progressively increases, or becomes stronger, as the temperature and precipitation increase or as the temperature increases and the precipitation decreases from that representative of profile T-5. The weakest mean (hue x chroma)-component development in the horizon colors of the leached B2 horizon is in profile T-4 and it progressively increases, or becomes stronger, as the temperature and precipitation increase, or as the temperature increases and the precipitation decreases from that representative of profile T-4.

When the profiles are grouped on the basis of the similarities of their distribution curves and the grouped profiles are averaged, as
in the lower bracket of Table 13, the same relationships between the (hue x chroma)-component and the macroclimate are evident as were shown by the individual profile sequence in the upper bracket of Table 13.

Table 14. Mean Dry-Moist (hue x Chroma)-Component of the Horizon of Maximum, or Strongest, (hue x Chroma)-Component Development for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Mean dry-moist (hue x chroma)-component values</th>
<th>Ped interior maximum</th>
<th>Ped face maximum</th>
<th>Mean maximum in the column</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual profiles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aridity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>climate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aridity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>climate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 14, the mean dry-moist (hue x chroma)-components of the ped interior color and the mean horizon color in the horizon in which the maximum, or strongest, (hue x chroma)-component in the solum is developed are strongly stratified with the macroclimate across the soil-climosequence. The lowest, or weakest, mean dry-moist (hue x chroma)-component development in the ped interior colors and in the mean horizon colors in the solum is in profiles T-4 and T-5 respectively and it progressively increases, or becomes stronger, as the temperature
and precipitation increase or as the temperature increases and the precipitation decreases from that representative for profiles T-4 and T-5.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 14, the same relationships are evident between the (hue x chroma)-component and the macroclimate as were shown by the individual profile sequence in the upper bracket of Table 14.

Depth in the profile of the maximum (hue x chroma)-component development. As shown in Table 15, the depth in the profile at which the midpoint of the maximum, or strongest, mean dry-moist (hue x chroma)-component is developed in the ped interior colors, the ped face colors and the mean horizon colors shows strong stratification with the macroclimate across the general soil-climosequence.

The midpoint of the maximum, or strongest, mean dry-moist (hue x chroma)-component development in the ped interior colors, the ped face colors and the mean horizon colors occurs at the greatest depth in the profile in profile T-2. As the precipitation progressively decreases from that representative for profile T-2, as from profile T-2 through profile T-3, the depths in the profile of the midpoint of the maximum, or strongest, mean dry-moist (hue x chroma)-component development in the ped interior colors, the ped face colors and the mean horizon colors become successively shallower in the direction of increasing aridity across the soil-climosequence. This would appear to be a reflection of the decreasing effective depth and influence of weathering on the constructive processes of grassland soil formation, brought
Table 15. Characterization of the Distribution Curves of the (Hue x Chroma)-Component of Soil Color for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Depth in the profile in inches of the midpoint of the (hue x chroma)-component maximum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B. Range in the (hue x chroma)-component in Munsell units between the profile minimum nearest the surface and the profile maximum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. Mean increase in the (hue x chroma)-component in Munsell units per inch of depth between the minimum nearest the surface and the profile maximum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>D. Depth in inches at which the (hue x chroma)-components of the ped interiors and the ped faces are the same or below which peds do not occur</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Ped interior face</th>
<th>Munsell</th>
<th>Ped interior face</th>
<th>Munsell</th>
<th>Ped interior face</th>
<th>Munsell</th>
<th>Ped interior face</th>
<th>Munsell</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual profiles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td>T-1 So Moody</td>
<td>10.5</td>
<td>27.8</td>
<td>23.6</td>
<td>3.50</td>
<td>2.50</td>
<td>3.00</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>T-2 No Moody</td>
<td>23.0</td>
<td>28.0</td>
<td>25.3</td>
<td>3.73</td>
<td>3.23</td>
<td>3.50</td>
<td>175</td>
</tr>
<tr>
<td>Aridity</td>
<td>T-4 Vienna</td>
<td>20.5</td>
<td>26.5</td>
<td>20.3</td>
<td>4.00</td>
<td>3.00</td>
<td>3.50</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>T-5 Houdek</td>
<td>12.0</td>
<td>21.3</td>
<td>16.6</td>
<td>3.75</td>
<td>3.00</td>
<td>3.37</td>
<td>313</td>
</tr>
<tr>
<td>Climate</td>
<td>T-6 Williams</td>
<td>6.2</td>
<td>10.8</td>
<td>8.5</td>
<td>3.25</td>
<td>3.25</td>
<td>3.25</td>
<td>520</td>
</tr>
<tr>
<td></td>
<td>T-3 Agar</td>
<td>5.5</td>
<td>9.0</td>
<td>7.2</td>
<td>3.75</td>
<td>2.00</td>
<td>2.87</td>
<td>682</td>
</tr>
<tr>
<td><strong>Profiles grouped on the basis of distribution curve characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td>T-1 So Moody</td>
<td>10.5</td>
<td>27.8</td>
<td>23.6</td>
<td>3.50</td>
<td>2.50</td>
<td>3.00</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>T-2 No Moody</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Aridity</td>
<td>T-4 Vienna</td>
<td>21.7</td>
<td>24.2</td>
<td>22.9</td>
<td>3.87</td>
<td>3.13</td>
<td>3.50</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>T-5 Houdek</td>
<td>12.0</td>
<td>21.3</td>
<td>16.6</td>
<td>3.75</td>
<td>3.00</td>
<td>3.37</td>
<td>313</td>
</tr>
<tr>
<td>Climate</td>
<td>T-6 Williams</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td></td>
<td>T-3 Agar</td>
<td>5.8</td>
<td>9.0</td>
<td>7.8</td>
<td>3.50</td>
<td>2.62</td>
<td>3.06</td>
<td>601</td>
</tr>
</tbody>
</table>

Note: In the upper bracket of this table, the underlined data are for profiles developed in loess and data not underlined are for profiles developed in glacial till.
about by and associated with the successively increasing aridity across the soil-climosequence. The midpoint of the maximum mean dry-moist (hue x chroma)-component development in the ped interior colors, the ped face colors and the mean horizon colors occurs at a slightly shallower depth in the profile in profile T-1 than it does in profile T-2. The slightly shallower and more strongly developed (hue x chroma)-component maximums in profile T-1 would appear to indicate the weak movement of reduced iron from the ped faces in the zone of the incipient A2 horizon formation resulting from the stronger weathering processes induced by the high temperature and precipitation elements of the macroclimatic and its accumulation in the oxidized form in the underlying horizon.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 15, similar relationships are evident between the depth in the profile of the maximum mean dry-moist (hue x chroma)-component of the ped interior colors and the macroclimatic as were shown in the individual profile sequence in the upper bracket of Table 15. However, the depths in the profile of the maximum mean dry-moist (hue x chroma)-component of the ped face colors and of the mean horizon colors, as shown in the lower bracket of Table 15, are greatest in profile T-1 and successively become shallower in the profile with increasing aridity across the soil-climosequence of the grouped profiles.
The minimum of the maximum, or strongest, mean dry-moist (hue x chroma)-component development in the ped face colors occurs at a greater depth in the profile than the midpoint of the maximum mean dry-moist (hue x chroma)-component development in the ped interiors in all the profiles across the soil-climosequence except profile T-4. This relationship appears to indicate that (hue x chroma)-component genesis is strongly ped-oriented across the range of parent materials involved in this study.

Range in the (hue x chroma)-component development with depth in the profile. The range in the mean dry-moist (hue x chroma)-component developed in the ped interior colors and in the mean horizon colors between the profile minimum nearest the surface and the developed profile maximum shows strong stratification with the macroclimate across the general soil-climosequence. The range in the mean dry-moist (hue x chroma)-component developed in the ped face colors between the profile minimum nearest the surface and the developed profile maximum does not appear to be stratified with the macroclimate across the general soil-climosequence.

As shown in Table 15, the greatest range in the mean dry-moist (hue x chroma)-component development in the ped interior colors and in the mean horizon colors between the profile minimum nearest the surface and the developed profile maximum occurs in profile T-4, which is developing under a macroclimate that is characterized by moderate precipitation and the coolest temperature environment in the general soil-climosequence. This environment appears to be the most favorable
for the accumulation of organic matter in the A1 horizon, resulting in
the darkest value-component A1 horizons in the soil-climosequence. The
dark value-component developed in the A1 horizon tends to repress and
mask the development of the (hue x chroma)-component of the A1 horizon
thus resulting in the lowest, or weakest, (hue x chroma)-component pro-
file surface minimum in the soil-climosequence. It is this very low
profile surface minimum, rather than an unusually strong profile max-
imum, that is responsible for the relatively high range in the (hue x
chroma)-component development in profile T-4.

As both the mean annual precipitation and temperature progressively increase over that representative of profile T-4, as in the
cases of profiles T-2 and T-1, the range in the mean dry-moist (hue x chroma)-component in the ped interior colors and in the mean horizon
colors between the profile minimum nearest the surface and the devel-
oped profile maximum progressively decreases. The successively lighter
value-component development in the A1 horizon colors of profiles T-2
and T-1, resulting from the less favorable conditions for organic mat-
ter accumulation brought on by the increased temperatures and precipi-
tation characteristics of the macroclimates representative for pro-
files T-2 and T-1, allows stronger development and expression of the
(hue x chroma)-component in the A1 horizons thus giving profiles T-2
and T-1 considerably higher profile surface minimums. Although the
developed profile maximums in profiles T-2 and T-1 increase over that of profile T-4, it is the proportionately greater increase in the pro-
file surface minimums in profiles T-2 and T-1 over that of profile
T-4 that is responsible for the relatively lower (hue x chroma)-component ranges in these profiles.

As the mean annual precipitation progressively decreases and the temperatures increase from that representative of profile T-4, as from profile T-4 through profile T-3, the range in the mean dry-moist (hue x chroma)-component developed in the ped interior colors and in the mean horizon colors between the profile minimum nearest the surface and the developed profile maximum progressively decrease from that developed in profile T-4. The successively lighter value-component development in the A1 horizon colors of profiles T-5, T-6 and T-3, resulting from the successively less favorable conditions for organic matter accumulation brought on by the increasing temperature and progressively decreasing precipitation characteristics of the macroclimates representative for profiles T-5, T-6 and T-3 allows stronger development and expression of the (hue x chroma)-component in the A1 horizon colors, thus giving profiles T-5, T-6 and T-3 slightly higher profile surface minimums. Although the profile surface minimums in profiles T-5, T-6 and T-3 are slightly higher than are those of profile T-4, it is the proportionately greater increase in the developed profile maximums in profiles T-5, T-6 and T-3 over that of profile T-4 that is responsible for the relatively lower (hue x chroma)-component ranges in these profiles.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 15, similar relationships are evident
between the range in the mean dry-moist (hue x chroma)-component development in the ped interior colors and the mean horizon colors between the profile minimum nearest the surface and the developed profile maximum and the macroclimate as were shown in the individual profile sequence in the upper bracket of Table 15. However, the range in the mean dry-moist (hue x chroma)-component development in the ped face colors between the profile minimum nearest the surface and the developed profile maximum appears to be stratified with the macroclimate across the soil-climosequence of the grouped profiles, although climatic stratification was not evident across the soil-climosequence of the individual profiles in the upper bracket of Table 15.

The ranges in the mean dry-moist (hue x chroma)-component development between the profile minimum nearest the surface and the developed profile maximum are larger in the ped interior colors than they are in the ped face colors across the soil-climosequence except in profile T-5. This relationship appears to indicate that (hue x chroma)-component genesis is strongly ped-oriented across the parent material range involved in this study.

Mean increase in the (hue x chroma)-component per unit of depth to the profile maximum. As shown in Table 15, the mean increases in the mean dry-moist (hue x chroma)-component in the ped interior colors, in the ped face colors, and in the mean horizon colors per inch of depth from the profile minimum nearest the surface to the developed profile maximum appear to be strongly stratified with the macroclimate across the general soil-climosequence.
The smallest increase in the mean dry-moist (hue × chroma)-component per inch of depth from the profile minimum nearest the surface to the developed profile maximum occurs in profile T-2 in the interior colors and in profile T-1 in the ped face colors and in the mean horizon colors. As the precipitation successively decreases across the soil-climosequence from profile T-1 or T-2 through profile T-3, the increases in the mean dry-moist (hue × chroma)-component per inch of depth from the profile minimum nearest the surface to the developed profile maximum in the ped interior colors, in the ped face colors and in the mean horizon colors become successively higher.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 15, similar relationships are evident between the mean increases in the mean dry-moist (hue × chroma)-component in the ped interior colors, the ped face colors and the mean horizon colors per inch of depth from the profile minimum nearest the surface to the developed profile maximum and the macroclimate as were shown in the individual profile sequence in the upper bracket of Table 15. The mean increases in the mean dry-moist (hue × chroma)-component per inch of depth from the profile minimum nearest the surface to the developed profile maximum are larger in the ped interior colors than they are in the ped face colors across the soil-climosequence. This relationship also appears to indicate that (hue × chroma)-component genesis is strongly ped-oriented across the parent material range involved in this study.
Depth of ped-oriented (hue x chroma)-component differences. As shown in Table 15, the depth in the profile at which the mean dry-moist (hue x chroma)-component development in the ped interior colors is the same as that in the ped face colors shows little, if any, stratification with the macroclimate across the general soil-climosequence. However, when the parent material is held constant, as in the loess soil-climosequence or in the glacial till soil-climosequence, the depth in the profile at which the mean dry-moist (hue x chroma)-component of the ped interior colors is the same as that of the ped face colors appears to be stratified with climate, becoming progressively shallower in the profile with increasing aridity across the soil-climosequence.

Where profiles developed in glacial till and profiles developed in loess are developing under the same or very similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-3 and T-6, the depth in the profile at which the mean dry-moist (hue x chroma)-component of the ped interior colors is the same as that of the ped face colors is greater in the glacial till profiles than it is in those developed in loessial materials. However, when the depths in the loess derived profiles and the depths in the glacial till derived profiles are averaged, as in the lower bracket of Table 15, the effect of the parent material on this factor is minimized and the depths are then strongly stratified with the macroclimate, becoming successively shallower with increasing aridity across the soil-climosequence of the grouped profiles.

Color Coats. The color coat values for the color coatings on the primary structure pede in the subhorizons of the B horizon for the six
profiles studied are shown in Figure XX. The plotted color coat values are based on the abundance and thickness of the color coatings and were computed using the procedures developed and reported in the earlier phases of the field studies. The distribution curves of the color coat values on the primary structure peds in the subhorizons of the B horizon, shown in Figure XX, are characterized in Table 16. From the distribution curves and from the analyses made of them, relationships between the color coat development and the macroclimate can be shown.

As shown in Figure XX, the maximum color coat development on the primary peds in the subhorizons of the leached B2 horizon appears to be stratified with the macroclimate across the general soil-climosequence. In five out of the six profiles studied, the maximum color coat development in the profile occurs in the horizon immediately underlying the A1 horizon. Organic staining appears to be the most effective agent of color coat development in this area of the profile, and as a result the color coat maximum is strongly related to the characteristics of the transition between the A1 and B2 horizons.

The maximum color coat development in the soil-climosequence occurs in profile T-5. As the precipitation increases or decreases across the soil-climosequence from that representative for profile T-5, the color coat development in the leached B2 horizon successively becomes less pronounced. The occurrence of the highest color coat development maximum in profile T-5 is the result of, and can be explained by the presence and characteristics of the B2A1 horizon in this profile.
Figure XX. Thickness times abundance values of the color coats on the B horizon prisms by horizons for the six profiles studied.
Table 16. Characterization of the Distribution Curves of the Color Coat Development on the Primary Peds in the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Color coat values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum value</td>
</tr>
<tr>
<td></td>
<td>in the leached B2</td>
</tr>
<tr>
<td>Individual profiles</td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td>T-1 So. Moody (loess)</td>
</tr>
<tr>
<td></td>
<td>T-2 No. Moody (loess)</td>
</tr>
<tr>
<td>Aridity</td>
<td>T-4 Vienna (till)</td>
</tr>
<tr>
<td>Of the</td>
<td>T-5 Houdek (till)</td>
</tr>
<tr>
<td>Climate</td>
<td>T-6 Williams (till)</td>
</tr>
<tr>
<td>Grouped on the basis of distribution curve characteristics</td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td>T-1 So. Moody (loess)</td>
</tr>
<tr>
<td>Aridity</td>
<td>T-2 No. Moody (loess) mean</td>
</tr>
<tr>
<td>Of the</td>
<td>T-4 Vienna (till)</td>
</tr>
<tr>
<td>Climate</td>
<td>T-5 Houdek (till)</td>
</tr>
<tr>
<td></td>
<td>T-6 Williams (till) mean</td>
</tr>
<tr>
<td>Aridity</td>
<td>T-3 Agar (loess)</td>
</tr>
</tbody>
</table>

The early stages in the encroachment of an A1 horizon on a B2 horizon are expressed by the development of strong organic coatings on the faces of the primary peds in the upper portion of the otherwise little changed B2 horizon, thus forming well developed color coatings in this area of the profile. Where encroachment of the A1 horizon on the B2 horizon is more advanced, as in an A1B2 horizon, the organic staining has penetrated the ped interiors and is no longer concentrated on the ped faces as strongly developed color coatings. In profiles not having AB or BA transition horizons, encroachment of the A1 horizon on the B2 horizon either is not taking place or is incipient in nature.
In the latter condition, the color coatings are much less strongly developed. It is interesting to note that the profiles in which constructive A1 horizon processes predominate have the highest color coat development maximums in the leached B2 horizon, and conversely, those in which destructive A1 horizon processes predominate have the lowest color coat development maximums in the leached B2 horizon.

As shown in Table 16, the mean color coat development on the primary peds in the leached B2 horizon, in the total B2 horizon and in the total B horizon show a similar pattern of stratification with the macroclimate across the soil-climosequence as that shown by the maximum color coat development on the primary peds in the subhorizons of the leached B2 horizon, although somewhat less complete than that of the latter.

Soil Structure

The graphic presentation of the structure phases of the soil morphology studies are shown in Figures XXI through XXVI.

Structure grade. The structure grade values of the strongest primary (primary or subprimary) peds and of the strongest secondary (secondary or subsecondary) peds in the subhorizons of the B horizon for the six profiles studied are shown in Figures XXI and XXII respectively. The plotted values of structure grade were computed using the procedures developed and reported in the earlier phases of the field morphology studies. The mean structure grade values of the subhorizons of the B horizon for the six profiles studied are shown in Figure XXIII. The
Figure XXI. Structure grade values of the primary prisms in the B horizon by horizons for the six profiles studied.
plotted values are the mean values of the structure grade values of
the primary and secondary pads shown in Figures XXI and XXII respectively. The distribution curves of the structure grade values of the
primary pads, the secondary pads and of the mean horizon structure,
shown in Figures XXI, XXII and XXIII are characterized in Tables 17
and 18. From the distribution curves per se and from the analyses made
of them, relationships of the structure grade with the macroclimate and
with the parent material can be shown.

Structure grade of the primary pads. The distribution curves of
the structure grade values of the strongest primary prisms in the sub-
horizons of the B horizon, as shown in Figure XXI, can be grouped on
the basis of their general shape and position characteristics into four
groups.

The distribution curve for profile T-1 shows that the most
strongly developed primary prisms occur in the third subhorizon of the
leached B2 horizon. This is in contrast to profiles T-2 and T-4, in
which the most strongly developed primary prisms occur in both the
second and third subhorizons of the leached B2 horizon, and to profiles
T-5, T-6 and T-3, in which the most strongly developed primary prisms
occur in the second subhorizon of the leached B2 horizon. This rela-
tionship is of interest from the standpoint of the evolution of the
structure B2 horizon across the soil-climosequence.

Profiles T-6 and T-3 comprise one group and are the most arid
members of the soil-climosequence. They lack the transition horizon
between the A1 and B2 horizons that is indicative of the encroachment
of the A1 horizon on the B2 horizon. The strongest-grade primary prisms are developed in the second subhorizon of the leached B2 horizon and this horizon is comparatively thin in those profiles.

Profile T-5 comprises another group and is developing in a somewhat less arid climatic environment than that representative of profiles T-6 and T-3. Profile T-5 has a B2A1 transition horizon between the A1 and the B2 horizons that is indicative of the encroachment of the A1 horizon on the B2 horizon, but like profiles T-6 and T-3, it has the strongest-grade primary prisms in the second subhorizon of the leached B2 horizon which immediately underlies the B2A1 horizon. The horizon in which the strongest-grade primary prisms are developed is thicker than are the horizons in which the maximum-grade primary prisms occur in profiles T-6 and T-3. This increased thickness appears to be an expression of the beginning of a downward migration of the maximum structure development in the B2 horizons as the result of and accompanying the destruction of the B horizon characteristics in the overlying B2A1 horizon resulting from the active encroachment of the A1 horizon onto what once had been the uppermost subhorizon of the B2 horizon.

Profiles T-4 and T-2 comprise the third group. These profiles occur in somewhat more humid climatic environments than that representative of profile T-5. Profile T-4 has an A1B2 transition horizon between the A1 horizon and the B2 horizon that is indicative of an advanced stage of the encroachment of the A1 horizon onto the B2 horizon. The strongest-grade primary prisms occur in the two subhorizons of the leached B2 horizon immediately underlying the A1B2 horizon and are the
second and third subhorizons of the leached B2 horizon. This appears
to be indicative of a more advanced stage in the downward migration
of the zone of maximum structure development in the B2 horizon as the
result of and accompanying the destruction of the B horizon character-
istics in the overlying A1B2 horizon by the nearly complete superim-
position of the A1 horizon over what once had been the uppermost sub-
horizon of the leached B2 horizon. Profile T-2 is very similar to
profile T-4 in this respect; however, because it has developed in a
slightly more humid climatic environment than that representative of
profile T-4, the A1B2 transition horizon of profile T-4 has become an
A12 horizon in profile T-2 to complete the evolution of B2 to A1 in
this area of the profile. As in profile T-4, the strongest-grade pri-
mary prisms in profile T-2 occur in the second and third subhorizons
of the leached B2 horizon. The uppermost subhorizon of the B2 hori-
zon in profile T-2 shows a slight deterioration in the structure grade
of the primary prisms is taking place that cannot be attributed to A1
horizon encroachment because the micromorphologic features indicative
of an actively encroaching A1 horizon are lacking in this horizon.
This deterioration in structure grade of the primary prisms in the
upper subhorizons of the leached B2 horizon, although evident in pro-
file T-2, becomes more pronounced in profile T-4.

Profile T-1 comprises the fourth group and is developing in the
warmest and most humid climatic environment of the general soil-climo-
sequence. Profile T-4 has a B2A1 transition horizon between the A1 and
the B2 horizons having micromorphologic characteristics indicative of
Table 17. Characterization of the Distribution Curves of the Structure Grade Values of the Primary Prisms in the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Maximum structure grade in the leached B2</th>
<th>Mean structure grade of the leached B2</th>
<th>Mean structure grade of the leached B2 including AB transition horizons</th>
<th>Depth to the max. structure grade in the B2 horizon in inches</th>
<th>Depth of the midpoint of the maximum structure grade in the B2 horizon in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increasing aridity</strong></td>
<td><strong>So. Moody (loess)</strong> 10.0</td>
<td><strong>No. Moody (loess)</strong> 10.0</td>
<td><strong>Vienna (till)</strong> 11.0</td>
<td><strong>Houdek (till)</strong> 11.0</td>
<td><strong>Agar (loess)</strong> 12.0</td>
</tr>
<tr>
<td>So. Moody</td>
<td>8.75</td>
<td>8.20</td>
<td>17.0</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>No. Moody</td>
<td>9.65</td>
<td>9.65</td>
<td>16.0</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td>Vienna</td>
<td>11.00</td>
<td>10.50</td>
<td>12.0</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>Houdek</td>
<td>11.0</td>
<td>9.50</td>
<td>6.0</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>Williams</td>
<td>12.0</td>
<td>11.50</td>
<td>8.5</td>
<td>10.8</td>
<td></td>
</tr>
<tr>
<td>Agar</td>
<td>12.0</td>
<td>10.50</td>
<td>8.25</td>
<td>11.6</td>
<td></td>
</tr>
</tbody>
</table>

**Profiles grouped on the basis of distribution curve similarities**

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Maximum structure grade in the leached B2</th>
<th>Mean structure grade of the leached B2</th>
<th>Mean structure grade of the leached B2 including AB transition horizons</th>
<th>Depth to the max. structure grade in the B2 horizon in inches</th>
<th>Depth of the midpoint of the maximum structure grade in the B2 horizon in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increasing aridity</strong></td>
<td><strong>So. Moody (loess)</strong> 10.0</td>
<td><strong>No. Moody (loess)</strong> mean</td>
<td><strong>Vienna (till)</strong> 10.5</td>
<td><strong>Houdek (till)</strong> mean</td>
<td><strong>Agar (loess)</strong> mean</td>
</tr>
<tr>
<td>So. Moody</td>
<td>8.75</td>
<td>mean</td>
<td>8.20</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>No. Moody</td>
<td>mean</td>
<td>mean</td>
<td>8.20</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Vienna</td>
<td>mean</td>
<td>mean</td>
<td>10.08</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Houdek</td>
<td>11.0</td>
<td>11.0</td>
<td>9.50</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Williams</td>
<td>12.0</td>
<td>11.0</td>
<td>8.25</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Agar</td>
<td>12.0</td>
<td>11.0</td>
<td>11.6</td>
<td>mean</td>
<td>mean</td>
</tr>
</tbody>
</table>
destructive A1 horizon processes and of deteriorating or degradational structure B2 horizon processes. The strongest-grade primary prisms occur in the third subhorizon of the leached B2 horizon. This appears to indicate an even more advanced stage in the downward movement of the zone of maximum structure development in the B2 horizon than that shown in profile T-2. The deterioration or degradation of the structure grade in the first and second subhorizons of the leached B2 horizon, which overlie the subhorizon of maximum structure development, is considerably more advanced than that shown in profile T-2. The degradation of the prismatic structure B in this area of the profile appears to add to the evidence favoring the concept of incipient A1 horizon formation in this area of the profile in profile T-1.

As shown in Table 17, the strength of the maximum structure grade of the primary prisms developed in the leached B2 horizons of the six profiles studied appears to be stratified with the macroclimate across the general soil-climosequence, increasing in the direction of increasing aridity of the macroclimate. The stronger grade of the primary prisms can be attributed to the increasing thickness and continuity of clay skin development on the primary peds with increasing aridity of the macroclimate which will be established later. When the profiles are grouped on the basis of the characteristics of the distribution curves and the grouped profiles are averaged, as in the lower bracket of table 17, the maximum structure grade of the primary prisms developed in the leached B2 horizon is strongly stratified with the macroclimate, increasing with increasing aridity across the soil-climosequence.
of the grouped profiles.

As shown in both the upper and lower brackets of Table 17, the mean structure grades of the primary prisms of the leached B2 horizon, and of the leached B2 including the AB and BC transition horizons, show a tendency toward climatic stratification that parallels that shown by the maximum structure grade in the leached B2 horizon, but they do not appear to be strongly stratified with the macroclimate across the soil-climosequence.

The depth in the profile to the strongest-grade primary prisms in the B2 horizon and the depth in the profile to the midpoint of the strongest grade development of the primary prisms in the B2 horizon, as shown in both the upper and lower brackets of Table 17, appear to be quite strongly stratified with the macroclimate, becoming shallower in the direction of increasing aridity across the soil-climosequence of the individual profiles and across the soil-climosequence of the grouped profiles.

**Structure grade of the secondary pedes.** The distribution curves of the structure grade values of the strongest secondary blocks in the subhorizons of the B horizon, as shown in Figure XXII, can be grouped on the basis of their general shape and position characteristics into three groups.

The distribution curve for profile T-1 shows that the most strongly developed secondary blocks occur in the first and second subhorizons of the leached B2 horizon. This is in contrast to profiles T-2, T-6 and T-3, in which the most strongly developed secondary blocks
Figure XXII. Structure grade values of the secondary blocks in the B horizon by horizons for the six profiles studied.
occur in the first subhorizon of the leached B2 horizon, and to profiles T-4 and T-5 in which the most strongly developed secondary blocks occur in the second subhorizon of the leached B2 horizon. This relationship is of interest from the standpoint of the evolution of the structure B2 horizon across the soil-climosequence.

Profiles T-6 and T-3 comprise one group and are the most arid members of the soil-climosequence. The strongest-grade secondary blocks in these profiles are developed in the first subhorizon of the leached B2 horizon which immediately overlies the subhorizon of the leached B2 in which the strongest-grade primary prisms are developed. The strongest-grade secondary blocks occur at a shallower depth in the profile in profiles T-6 and T-3 than they do in the other profiles of the soil-climosequence.

Profiles T-5 and T-4 comprise the second group and are developing under somewhat more humid climatic environments than that representative of profiles T-6 and T-3. The strongest-grade secondary blocks are developed in the second subhorizon of the leached B2 horizon which immediately underlies the AB or BA transition horizons occurring in these profiles. The zone of maximum development of the secondary blocks overlaps all or part of the zone of maximum development of the primary prisms. The maximum-grade values of the secondary blocks in the B horizon of profiles T-5 and T-4 are considerably lower than are those in the other profiles in the soil-climosequence.
Profiles T-2 and T-1 comprise the third group and are developing under the most humid climatic environments in the soil-climosequence. The strongest-grade secondary blocks are developed in the first subhorizon of the B2 horizon in profile T-2 and in the first and second subhorizons of the B2 horizon in profile T-1, and in both cases immediately overlie the subhorizon of the B2 horizon in which the maximum development of the primary prism occurs.

As shown in Table 18, the strength of the maximum structure grade of the secondary blocks developed in the leached B2 horizon of the six profiles studied appears to be stratified with the macroclimate across the general soil-climosequence.

The lowest maximum grade values of the secondary blocks in the leached B2 horizon are developed in profiles T-4 and T-5. Both of these profiles have either an A1B2 or a B2A1 transition horizon between the A1 and B2 horizons that is indicative of the encroachment of the A1 onto the B2 horizon. Both of these profiles also have the subhorizon of maximum secondary block development coincident with a part or all of the zone of maximum primary prism development, which in part would explain the lower maximum grade values of the secondary blocks in the leached B2 horizons of these profiles.

As the precipitation decreases across the soil-climosequence, as in profiles T-6 and T-3, or as the precipitation and temperature increase together across the soil-climosequence, as in profiles T-2 and T-1, the maximum grade of the secondary blocks developed in the leached B2 horizon becomes stronger. Profiles T-6, T-3, T-2 and T-1
do not have transition horizons between the A1 and B2 horizons that are indicative of the encroachment of the A1 horizon onto the B2 horizon. These profiles do not have the subhorizon of maximum secondary block development coincident with any part of the zone of maximum primary prism development, which in part explains the higher maximum grade values of the secondary blocks in these profiles. The subhorizon or subhorizons of the leached B2 horizon in which the maximum secondary block development occurs immediately overlies the subhorizon or subhorizons of the leached B2 horizon in which the maximum primary prisms are developed.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 18, the same relationships are evident between the maximum grade values of the secondary blocks developed in the leached B2 horizon and the microclimate, as were shown in the individual profile sequence in the upper bracket of Table 18.

The relationships between the maximum grades of the primary prisms and the maximum grades of the secondary blocks in the leached B2 horizons of the profiles studied also are of interest. In profiles T-6 and T-3 the developed maximum grades of the primary prisms in the leached B2 horizons are essentially the same as the developed maximum grades of the secondary blocks in the leached B2 horizons. In profiles T-4 and T-5 the developed maximum grades of the primary prisms in the leached B2 horizons are considerably stronger than are those of the secondary blocks. In profiles T-2 and T-1 the developed maximum grades
Table 18. Characterization of the Distribution Curves of the Structure Grade Values of the Secondary Blocks in the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Maximum structure grade in the leached B2</th>
<th>Mean structure grade of the leached B2</th>
<th>Mean structure grade of the leached B2 including AB transition horizons</th>
<th>Depth to the max. structure grade in the B2 horizon in inches</th>
<th>Depth of the midpoint of the maximum structure grade in the B2 horizon in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>11.0</td>
<td>9.00</td>
<td>9.40</td>
<td>6.0</td>
<td>11.50</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>11.0</td>
<td>9.25</td>
<td>9.40</td>
<td>9.0</td>
<td>12.00</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>9.0</td>
<td>7.50</td>
<td>7.60</td>
<td>12.0</td>
<td>13.00</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>9.0</td>
<td>9.00</td>
<td>7.20</td>
<td>6.0</td>
<td>12.00</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>12.0</td>
<td>11.50</td>
<td>11.50</td>
<td>4.0</td>
<td>6.25</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>11.0</td>
<td>10.00</td>
<td>10.00</td>
<td>3.0</td>
<td>5.50</td>
</tr>
</tbody>
</table>

Profiles grouped on the basis of distribution curve characteristics

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Maximum</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
</tbody>
</table>
of the primary prisms in the leached B2 horizons are weaker than are those of the secondary blocks.

As shown in both the upper and lower brackets of Table 18, the mean structure grades of the secondary blocks of the leached B2 horizon and of the leached B2 horizon including the AB and BA transition horizons, show the same degree and pattern of stratification with the macroclimate as that shown by the maximum grade of the secondary blocks developed in the leached B2 horizon.

The depth in the profile to the strongest-grade secondary blocks in the B2 horizon and the depth in the profile to the midpoint of the strongest grade development of the secondary blocks in the B2 horizon, as shown in the upper bracket of Table 18, appears to be strongly stratified with the macroclimate across the soil-climosequence. The strongest-grade secondary blocks in the B2 horizon are developed at the greatest depth in the profile in profile T-4. As the precipitation decreases and the temperature increases or as the temperature and precipitation increase together from that representative of profile T-4, the depths in the profile at which the strongest-grade secondary blocks are developed become shallower. When the profiles are grouped on the basis of the distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 18, similar relationships are evident between the depth in the profile of the strongest-grade secondary blocks and the macroclimate as shown by the individual profiles in the upper bracket of Table 18.
Mean structure grade of peds. The distribution curves of the mean structure grade values of the strongest grade peds in the subhorizons of the B horizon, as shown in Figure XXIII, can be grouped on the basis of their general shape and position characteristics into four groups. (a) Profile T-1: The distribution curve for profile T-1 shows a greater depth to the maximum mean structure grade development in the leached B2 horizon than do the other profiles in the soil-climosequence. The greater depth to the maximum structure development in profile T-1 appears to be the result of the structure B deterioration taking place in the upper subhorizons of the leached B2 under the more intensive weathering activity in this zone of the profile induced by the greater weathering potential of the macroclimate. (b) Profiles T-2 and T-4: The distribution curves for profiles T-2 and T-4 show more shallowly developed mean structure grade maximums in the leached B2 horizons of these profiles than that in profile T-1, although the maximums per se are of nearly the same magnitude in all three profiles. This difference in developmental depth appears to reflect less intensive weathering activity in this zone of the profile than that represented in profile T-1. (c) Profile T-5: The distribution curve for profile T-5 is distinguished from those of the other profiles in the soil-climosequence in having the lowest mean structure grade maximum in the leached B2 horizon. The comparatively low mean structure grade maximum in profile T-5 appears to be the result of the destructional effect on the structure grade of the active A1 horizon encroachment on the B2 horizon. (d) Profiles T-6 and T-3: The distribution curves for profiles T-6 and
Figure XXIII. Mean structure grade values in the B horizon by horizons for the six profiles studied.
T-3 are differentiated from those of the other profiles in the soil-climosequences by having stronger and more shallowly developed mean structure grade maximums than do the other profiles in the soil-climosequence.

Structure class. The structure class values of the strongest-grade primary (primary or subprimary) peds and of the strongest-grade secondary (secondary or subsecondary) peds in the subhorizons of the B horizon for the six profiles studied are shown in Figures XXIV and XXV respectively. The plotted values of structure class were computed using the procedures developed and reported in the earlier phases of the field morphology studies. The mean structure class values of the subhorizons of the B horizon for the six profiles studied are shown in Figure XXVI. The plotted values are the means of the structure class values of the primary and secondary peds shown in Figures XXIV and XXV respectively. The distribution curves of the structure class values of the primary peds, the secondary peds and of the mean horizon structure shown in Figures XXIV, XXV and XXVI, are characterized in Tables 19, 20 and 21. From the distribution curves themselves and from the analyses made of them, relationships of the structure class with the macroclimate and with the parent material can be shown.

Structure class of the primary peds. The distribution curves of the structure class values of the strongest-grade primary prisms in the subhorizons of the B horizon, as shown in Figure XXIV, can be grouped on the basis of their general shape and position characteristics into
Figure XXIV. Structure class values of the primary prisms in the B horizon by horizons for the six profiles studied.
Table 19. Characterization of the Distribution Curves of the Structure Class Values of the Primary Prisms in the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Structure class values</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Range within B horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B21 horizon</td>
<td>Mean of leached B2</td>
<td>Mean of total B2</td>
<td>Mean of total B horizon</td>
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</tr>
<tr>
<td>Individual profiles</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of the climate</td>
<td>T-1 So. Moody (loess)</td>
<td>2.20</td>
<td>1.80</td>
<td>2.23</td>
<td>2.23</td>
<td>2.80</td>
</tr>
<tr>
<td>aridity</td>
<td>T-2 Moody (loess)</td>
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<td>2.90</td>
<td>3.17</td>
<td>1.70</td>
</tr>
<tr>
<td></td>
<td>T-4 Vienna (till)</td>
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<td>3.00</td>
<td>3.00</td>
<td>3.48</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>T-5 Houdek (till)</td>
<td>2.00</td>
<td>2.00</td>
<td>2.10</td>
<td>3.00</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
<td>T-6 Williams (till)</td>
<td>1.40</td>
<td>1.40</td>
<td>1.67</td>
<td>2.68</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>T-3 Agar (loess)</td>
<td>0.40</td>
<td>1.20</td>
<td>1.80</td>
<td>2.56</td>
<td>3.80</td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
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</tr>
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<td>1.80</td>
<td>2.33</td>
<td>2.23</td>
<td>2.80</td>
</tr>
<tr>
<td>aridity</td>
<td>T-2 Moody (loess)</td>
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<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
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<td>T-4 Vienna (till)</td>
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<td>2.95</td>
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<td>1.45</td>
</tr>
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<td>climate</td>
<td>T-5 Houdek (till)</td>
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<td>2.10</td>
<td>3.00</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
<td>T-6 Williams (till)</td>
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<td>mean</td>
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<td>mean</td>
</tr>
<tr>
<td></td>
<td>T-3 Agar (loess)</td>
<td>0.9</td>
<td>1.30</td>
<td>1.74</td>
<td>2.62</td>
<td>3.30</td>
</tr>
</tbody>
</table>
the four groups shown in the lower bracket of Table 19.

As shown in Table 19, the structure class values of the primary prisms in the B21 horizon appear to be stratified with the macroclimate across the general soil-climosequence. The coarsest prisms in the B21 horizon occur in profiles T-2 and T-4. As the precipitation decreases or as the precipitation and temperature increase together from that representative of profiles T-2 and T-4, the prisms in the B21 horizon successively decrease in size. The decreasing size of the prisms in the B2 horizon accompanying the decreasing precipitation for profiles T-5, T-6 and T-3 appears to be a reflection of greater periodicity in the wetting and drying, and swelling and shrinking cycles as a result of the increasing continentality characteristic of the climate. The slight decrease in the size of the prisms in the B2 horizon of profile T-1 appears to be the result of the degradational modification of the structure that also is expressed in the structure grade component in the horizon, induced by the greater intensity of weathering in this portion of the profile.

When the profiles are grouped on the basis of the characteristics of the distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 19, the same relationships are evident between the structure class values of the primary prisms in the B21 horizon and the macroclimate as were shown in the individual profile sequence in the upper bracket of Table 19.

It is of interest to note that the finest prisms in the B2 horizon occur in the B21 horizon in profiles T-4, T-5, T-6 and T-3, but
in profiles T-2 and T-1 the finest prisms in the B2 horizon occur in subhorizons below the B21. The range in the size of the prisms between the B21 and B22 horizons is greater in profile T-1 than in profile T-2 and appears to represent an evolutionary sequence.

As shown in Table 19, the mean structure class values of the primary prisms in the leached B2 horizon, in the total B2 horizon and in the total B horizon all show nearly the same kind and degree of climatic stratification as that shown by the structure class values of the primary prisms in the B21 horizon. In all cases the highest class values occur in profile T-4 and as the precipitation and temperature increase together or as the precipitation decreases from that representative of profile T-4, the class values decrease.

When the profiles are grouped on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 19, the same relationships are evident between these features and the macroclimate as were shown in the individual profile sequence in the upper bracket of Table 19.

The range in the size of the prisms in the B horizon, as shown in Table 19, also appears to be stratified with the macroclimate across the general soil-climosequence and across the soil-climosequence of the grouped profiles.

Structure class of the secondary peds. The distribution curves of the structure class values of the strongest-grade secondary peds in the subhorizons of the B horizon, as shown in Figure XXV, are characterized in Table 20. The relatively inextensive occurrence of secondary
blocks in some of the profiles precludes the grouping of the distribution curves for this feature.

Table 20. Characterization of the Distribution Curves of the Structure Class Values of the Secondary Blocks in the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Structure class values</th>
<th>Mean of the leached horizon</th>
<th>Mean of the total horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual profiles</td>
<td></td>
<td>B21</td>
<td>B2</td>
</tr>
<tr>
<td>Increasing aridity</td>
<td>T-1 So. Moody (loess)</td>
<td>0.10</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>T-2 No. Moody (loess)</td>
<td>0.25</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>T-4 Vienna (till)</td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>decreasing aridity</td>
<td>T-5 Houdek (till)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>T-6 Williams (till)</td>
<td>0.45</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>T-7 Agar (loess)</td>
<td>0.33</td>
<td>0.66</td>
</tr>
</tbody>
</table>

As shown in Table 20, the structure class values of the secondary blocks in the B21 horizon appear to be stratified with the macroclimate across the general soil-climosequence. The coarsest blocks in the B21 horizon occur in profile T-4. As the precipitation decreases or as the precipitation and temperature increase together from that representative of profile T-4, the blocks in the B21 horizon successively decrease in size. The decreasing size of the blocks in the B2 horizon accompanying the decreasing precipitation in profiles T-5, T-6 and T-3, like that of the prisms, appears to be a reflection of greater periodicity in the wetting and drying, and swelling and shrinking cycles as a result of the increasing continentality characteristic of the climate.
Figure XXV. Structure class values of the secondary blocks in the B horizon by horizons for the six profiles studied
The relatively great decrease in the size of the blocks of the B21 horizon of profile T-1, like that of the prisms, appears to be the result of the degradational modification of the structure that also is expressed in the structure grade component in this horizon, and is induced by the greater intensity of weathering in this profile. It is of interest that the finest blocks in the B2 horizon occur in the B21 horizon in all the profiles studied.

As shown in Table 20, the mean structure class values of the secondary blocks in the leached B2 horizon, in the total B2 horizon and in the total B horizon all show approximately the same kind and degree of climatic stratification as that shown by the structure class values of the secondary blocks in the B21 horizon. In all cases the highest class values occur in profile T-4 and as the precipitation and temperature increase together or as the precipitation decreases from that representative of profile T-4, the class values of the secondary blocks decrease.

**Mean structure class of peds.** The distribution curves of the mean structure class values in the subhorizons of the B horizon, as shown in Figure XXVI, can be grouped on the basis of their general shape and position characteristics into four groups, as shown in the lower bracket of Table 21.

As shown in Table 21, the mean structure class values of the B21 horizon, the leached B2 horizon, the total B2 horizon and the total B horizon all appear to be stratified with the macroclimate across the soil-climosequence. The highest mean structure class values
occur in profile T-4 in all instances. As the precipitation and temperature increase together or as the precipitation decreases and the temperature increases from that representative of profile T-4, the mean structure class values decrease. When the profiles are grouped on the basis of their distribution curve similarities, as in the lower bracket of Table 21, the same relationships between these features and the macroclimate are evident as were shown by the ungrouped profiles in the upper bracket of Table 21.

The range in the structure class values within the B horizons of the profiles, as shown in Table 21, also appears to be stratified with the macroclimate across the general soil-climosequence. The lowest range occurs in profile T-4 and as the precipitation and temperature increases from that representative of profile T-4, the range in the structure class values within the B horizon successively increase. When the profiles are grouped on the basis of their distribution curve similarities, as in the lower bracket of Table 21, the same relationship between this feature and the macroclimate is evident that was shown by the individual profiles in the upper bracket of Table 21.

Clay Skin Development

The graphic presentation of the clay skin development phase of the soil morphology studies is shown in Figures XXVII through XXIX.

Clay skin values. The values of the clay skins on the strongest-grade primary (primary or subprimary) peds and on the strongest-grade secondary peds (secondary or subsecondary) peds in the subhorizons of the
Figure XXVI. Mean structure class values in the B horizon by horizons for the six profiles studied.
Table 21. Characterization of the Distribution Curves of the Mean Structure Class Values in the Subhorizons of the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Individual profiles</th>
<th>Structure class values</th>
<th>Range within B horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B21 horizon</td>
<td>Leached B2 horizon</td>
</tr>
<tr>
<td>Increasing aridity of the climate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td></td>
<td>1.15</td>
<td>1.12</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td></td>
<td>1.72</td>
<td>1.34</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td></td>
<td>2.00</td>
<td>2.20</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td></td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td></td>
<td>0.93</td>
<td>1.06</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td></td>
<td>0.37</td>
<td>0.95</td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity of the climate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td></td>
<td>1.15</td>
<td>1.12</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td></td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td></td>
<td>1.96</td>
<td>2.02</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td></td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td></td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td></td>
<td>0.65</td>
<td>1.01</td>
</tr>
</tbody>
</table>
B horizon for the six profiles studied are shown in Figures XXVII and XXVIII respectively. The plotted clay skin values were computed using the procedures developed and reported in the earlier phases of the field morphology studies. The total clay skin values of the subhorizons of the B horizon for the six profiles studied are shown in Figure XXIX. The plotted values are the sums of the clay skin values on the primary and secondary peds shown in Figures XXVII and XXVIII respectively. The distribution curves of the values of the clay skins on the primary and secondary peds and of the total clay skin values of the horizons shown in Figures XXVII, XXVIII and XXIX, are characterized in Tables 22, 23 and 24. From the distribution curves themselves and from the analyses made of them, relationships of the clay skin development with the macroclimate can be shown.

Clay skin development on the primary peds. The distribution curves of the clay skin values on the strongest-grade primary prisms in the subhorizons of the B horizon, as shown in Figure XXVII, can be grouped on the basis of their general shape and position characteristics into three groups.

The distribution curves of the clay skin values on the primary prisms in the B horizon in profiles T-1 and T-2 indicate that the clay skin development on the prisms is very weak in these profiles. Although slight developmental clay skin maxima on the prisms occur in the second or third subhorizon of the B2 horizon in these profiles, these developmental maxima do not coincide with the horizon of maximum clay accumulation in the profile.
Figure XXVII. Clay skin values on the primary prisms in the B horizon by horizons for the six profiles studied.
The distribution curves of the clay skin values on the primary prisms in the B horizon in profiles T-4 and T-5 show more pronounced developmental clay skin maximums. The developmental clay skin maximums on the prisms occur in the second subhorizon of the B horizon in these profiles and the developmental maximums coincide, or occur in close association with the horizon of maximum clay accumulation.

The distribution curves of the clay skin values on the primary prisms in the B horizon in profiles T-6 and T-3 show the strongest developmental clay skin maximums of the six profiles studied. The developmental clay skin maximums on the prisms occur in the first and second subhorizons of the B horizon in these profiles and the developmental maximums coincide or occur in close association with the horizon of maximum clay accumulation.

As shown in Table 22, the maximum clay skin values on the prisms in the B2 horizon, the mean clay skin values on the prisms in the leached B2 horizon, the mean clay skin values on the prisms in the total B2 horizon and the mean clay skin values on the prisms in the total B horizon all appear to be stratified with the macroclimate, increasing with increasing aridity of the climate across the general soil-climosequence. It is also of interest that as the clay skin values on the prisms increase, the accumulation of clay in the B2 horizon over that of the A horizon also increases.

When the profiles are grouped on the basis of their distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 22, similar relationships are shown between the
clay skin values on the prisms and the macroclimate as were shown by the individual profiles in the upper bracket of Table 22.

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Clay skin values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td></td>
<td>in B2</td>
</tr>
<tr>
<td>Increasing</td>
<td>T-1 So. Moody (loess)</td>
</tr>
<tr>
<td></td>
<td>T-2 No. Moody (loess)</td>
</tr>
<tr>
<td>Aridity of Climate</td>
<td>T-4 Vienna (till)</td>
</tr>
<tr>
<td></td>
<td>T-5 Houdek (till)</td>
</tr>
<tr>
<td></td>
<td>T-6 Williams (till)</td>
</tr>
<tr>
<td></td>
<td>T-3 Agar (loess)</td>
</tr>
</tbody>
</table>

Clay skin development on the secondary peds. The distribution curves of the clay skin values on the strongest-grade secondary peds in the subhorizons of the B horizon, as shown in Figure XXVIII, are characterized in Table 23. The relatively inextensive occurrence of secondary blocks in some of the profiles precludes the grouping of the distribution curves for this feature.

As shown in Table 23, the maximum clay skin values on the blocks in the B2 horizon, the mean clay skin values on the blocks in the leached B2 horizon, the mean clay skin values on the blocks in the
Figure XXVIII. Clay skin values of the secondary blocks in the B horizon by horizons for the six profiles studied.
total B2 horizon and the mean clay skin values on the blocks in the
total B horizon all appear to be stratified with the macroclimate,
tending to increase with increasing aridity of the climate across the
general soil-climosequence. As the clay skin values on the blocks in-
crease, the accumulation of clay in the B2 horizon over that of the A
horizon also increases, although this correlation is not as strongly
expressed in the case of the blocks as it was with the prisms.

Table 23. Characterization of the Distribution Curves of the
Clay Skin Values on the Secondary Blocks in the
B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Maximum in B2 horizon</th>
<th>Mean of leached B2 horizon</th>
<th>Mean of total B2 horizon</th>
<th>Mean of total B2 horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual profiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>0.034</td>
<td>0.019</td>
<td>0.019</td>
<td>0.019</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>0.100</td>
<td>0.067</td>
<td>0.053</td>
<td>0.040</td>
</tr>
<tr>
<td>T-2 Agar (loess)</td>
<td>0.034</td>
<td>0.034</td>
<td>0.034</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Total clay skin development in the horizon. The distribution
curves of the total clay skin values of the subhorizons of the A and B
horizons, as shown in Figure XXIX, can be grouped on the basis of their
general shape and position characteristics into four groups.

The distribution curves of the total clay skin values in the
subhorizons of the B horizon in profiles T-1 and T-2 indicate that the
clay skin development is very weak in these profiles. Although very
weak developmental clay skin maximums do occur in the second or third
Figure XXIX. Total clay skin values for the subhorizons of the A and B horizons by horizons for the six profiles studied.
subhorizon of the B2 horizon in these profiles, these developmental maximums do not coincide with the horizon of maximum clay accumulation in the profile, which in these profiles is the A1 horizon. This relationship would seem to indicate that the accumulation of clay in these profiles is not the result of clay movement involved in an eluvial-illuvial sequence, but rather that it is primarily the result of clay formation in situ induced by the more intensive weathering activity associated with the warm, humid climatic environments under which these profiles are developing.

The distribution curves of the total clay skin values of the subhorizons of the B horizon in profiles T-4 and T-5 show more pronounced developmental clay skin maxima. The higher maximum developed in profile T-5, shows profile T-5 to be intergradational between profile T-4 and profiles T-6 and T-3 relative to this feature. Profiles T-4 and T-5 each were maintained as a separate group as a result of this differential between the maxima. The developmental clay skin maxima occur in the second subhorizon of the B horizon in profiles T-4 and T-5 and the developmental maxima either coincide with, or occur in close approximation to, the horizon of maximum clay accumulation in the profile. This relationship would seem to indicate that the clay accumulation in these profiles is the result of sequential eluvial-illuvial clay movement out of the A horizon and into the B2 horizon.

The distribution curves of the total clay skin values of the subhorizons of the B horizon in profiles T-6 and T-3 show the strongest
developmental clay skin maxima of the six profiles studied. The developmental clay skin maxima occur in the first, or uppermost, subhorizon of the B horizon in these profiles and the developmental maxima either coincide with, or occur in close approximation to, the horizon of maximum clay accumulation in the profile. The clay accumulation in these profiles also appears to be the result of sequential eluvial-illuvial clay movement out of the A horizon and into the B2 horizon.

As the total clay skin values in the B2 horizon successively increase across the soil-climosequence, the accumulation or build-up of clay in the B2 horizon over that of the A1 horizon also successively increases.

As shown in Table 24, the maximum total clay skin values in the B2 horizon, the mean total clay skin values in the leached B2 horizon, the mean total clay skin values in the total B2 horizon and the mean total clay skin values in the total B horizon all appear to be stratified with the macroclimate, increasing with increasing aridity of the climate across the general soil-climosequence.

When the profiles are grouped on the basis of the characteristics of their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 24, similar relationships are shown between the total clay skin values in the subhorizons of the B horizon and the macroclimate as were shown by the individual profiles in the upper bracket of Table 24.
Table 24. Characterization of the Distribution Curves of the Total Clay Skin Values in the Subhorizons of the B Horizon for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Clay skin values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum in B2</td>
</tr>
<tr>
<td>Individual profiles</td>
<td></td>
</tr>
<tr>
<td>Increasing</td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>0.010</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>0.009</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>0.029</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>0.071</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>0.200</td>
</tr>
<tr>
<td>T-7 Agar (loess)</td>
<td>0.115</td>
</tr>
</tbody>
</table>

Profiles grouped on the basis of distribution curve characteristics

Increasing
T-1 So. Moody (loess) mean 0.010 mean 0.006 mean 0.006 mean 0.004
T-2 No. Moody (loess) mean 0.009 mean 0.005 mean 0.004 mean 0.004
T-4 Vienna (till) mean 0.029 mean 0.022 mean 0.019 mean 0.012
T-5 Houdek (till) mean 0.071 mean 0.071 mean 0.044 mean 0.022
T-6 Williams (till) mean 0.200 mean 0.167 mean 0.127 mean 0.081
T-7 Agar (loess) mean 0.115 mean 0.110 mean 0.076 mean 0.046

Calcium Carbonate Equivalent Development

The graphic presentation of the distribution of the calcium carbonate equivalent phase of the soil morphology studies is shown in Figures XXX through XXXII.

Calcium carbonate equivalent values. The values of the calcium carbonate equivalent in the mass of the ped interiors and of that oriented on the ped faces in the horizons of the profile containing free carbonates are shown in Figures XXX and XXXII respectively for the six profiles studied. The plotted calcium carbonate equivalent values were calculated using the procedures developed and reported in the earlier phases of the field morphology studies. The total calcium carbonate equivalent
values of the horizons of the profile containing free carbonates are shown in Figure XXXII for the six profiles studied. The plotted values are the sums of the calcium carbonate equivalent values of the ped interiors and of the ped faces shown in Figures XXX and XXXI, respectively. The distribution curves of the calcium carbonate equivalent values of the ped interiors and the ped faces and of the total calcium carbonate equivalent values of the horizons shown in Figures XXX, XXXI and XXXII, are characterized in Tables 25, 26 and 27. From the distribution curves per se and from the analyses made of them, relationships between the calcium carbonate equivalent values in the mass of the ped interiors, on the ped faces and of the total horizon values can be shown. Relationships of the calcium carbonate equivalent values with the macroclimate and with the parent material also can be shown.

**Calcium carbonate equivalent values in the ped interiors.** The distribution curves of the calcium carbonate equivalent values in the mass of the ped interiors in the profile, as shown in Figure XXX, can be grouped on the basis of their general shape and position characteristics into four groups. The factors exerting the strongest influence on this grouping are the depth to free carbonates in the profile and the depth in the profile of the midpoint of the developmental maximum calcium carbonate equivalent values. The shape characteristics of the distribution curves serve to indicate the evolutionary nature of the distribution of the calcium carbonate equivalent values in the profile across the general soil-climosequence.
Figure XXX. Calculated CaCO₃ equivalent values of the ped interiors by horizons for the six profiles studied.
The distribution curve of the calcium carbonate equivalent values in the mass of the ped interiors in profile T-1 indicates that in this orientation the greatest depth in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values in the profiles of the soil-climosequence occur in this profile. The shape characteristic of the distribution curve would seem to indicate that the maximum calcium carbonate equivalent value in the profile occurs below the five-foot profile depth.

The distribution curves of the calcium-carbonate equivalent values in the mass of the ped interiors in profiles T-2 and T-4 show that in this orientation the depths in the profiles to free carbonates and to the developmental maximum calcium carbonate equivalent values are not as deep as they are in profile T-1. The shape characteristics of the distribution curves for profiles T-2 and T-4 are very similar and seem to indicate the occurrence of comparatively stable developmental maximums within the five-foot profile.

The distribution curve of the calcium carbonate equivalent values in the mass of the ped interiors in profile T-5 shows that in this orientation the depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent value are not as deep as they are in profiles T-2 and T-4. The shape characteristic of the distribution curve for profile T-5 seems to indicate active evolution in the depth of the developmental maximum in the profile. The shift in the depth of the developmental maximum appears to be away from the more shalllowly positioned maximums, like those occurring in profiles
T-6 and T-3, and toward the more deeply positioned maxima, like those occurring in profiles T-4 and T-2.

The distribution curves of the calcium carbonate equivalent values in the mass of the ped interiors in profiles T-6 and T-3 show that in this orientation the depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values in the profile are shallower in these profiles than they are in the other profiles in the soil-climosequence. The distribution curves for profiles T-6 and T-5 show different shape characteristics. Profile T-6, developed in glacial till, has a distribution curve with a single maximum that appears to be relatively stable. Profile T-3, developed in loess-sial materials, has a double-maximum distribution curve similar to that of profile T-5, and like that of profile T-5 appears to indicate active evolution in the depth of the developmental maximum in the profile. This difference in the shape characteristic between the distribution curves for profiles T-6 and T-3 appears to be the result of the effect of the difference in the permeability factor of the parent material on the leaching of carbonates under similar macroclimatic environments.

As shown in Table 25, the depth in the profile to free carbonates in the mass of the ped interiors appears to be stratified with the macroclimate, becoming increasingly more shallow with increasing aridity across the general soil-climosequence. The stratification of this factor with the macroclimate is even more striking when the parent materials are held constant, as in the case of the loess soil-climosequence and the glacial till soil-climosequence. When the profiles are grouped
Table 25. Characterization of the Distribution Curves of the Calcium Carbonate Equivalent Values in the Ped Interiors for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Depth to CaCO$_3$ in inches</th>
<th>Maximum CaCO$_3$ equiv. value</th>
<th>Depth to max. CaCO$_3$ equiv. value in inches</th>
<th>Midpoint depth of max. CaCO$_3$ equiv. value in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual profiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0</td>
<td>4.0</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>30.0</td>
<td>11.0</td>
<td>30.0</td>
<td>36.0</td>
</tr>
<tr>
<td>T-3 Vienna (till)</td>
<td>26.0</td>
<td>10.4</td>
<td>27.0</td>
<td>32.0</td>
</tr>
<tr>
<td>T-4 Houdek (till)</td>
<td>18.0</td>
<td>14.5</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>T-5 Williams (till)</td>
<td>13.0</td>
<td>15.0</td>
<td>13.0</td>
<td>17.0</td>
</tr>
<tr>
<td>T-6 Agar (loess)</td>
<td>17.0</td>
<td>11.0</td>
<td>17.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0</td>
<td>4.0</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Vienna (till)</td>
<td>24.5</td>
<td>10.8</td>
<td>28.5</td>
<td>34.0</td>
</tr>
<tr>
<td>T-4 Houdek (till)</td>
<td>18.0</td>
<td>14.5</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>T-5 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-6 Agar (loess)</td>
<td>15.0</td>
<td>13.0</td>
<td>15.0</td>
<td>18.0</td>
</tr>
</tbody>
</table>
on the basis of the similarities in their distribution curves and the grouped profiles are averaged, as in the lower bracket of Table 25, the same relationships between this feature and the macroclimate are shown as were shown by the individual profile sequence in the upper bracket of Table 25.

The maximum calcium carbonate equivalent values in the mass of the ped interiors, as shown in Table 25, do not appear to be stratified with the macroclimate across either the general soil-climosequence or across the climosequence of the grouped profiles.

As shown in Table 25, the depths to the developmental maximum calcium carbonate equivalent values and the midpoint depths of the maximum calcium carbonate equivalent values in the mass of the ped interiors, appear to be stratified with the macroclimate, becoming increasingly more shallow with increasing aridity across the general soil-climosequence. When the profiles are grouped on the basis of their distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 25, the same relationships between these features and the macroclimate are shown as were evident in the individual profile sequence in the upper bracket of Table 25.

**Calcium carbonate equivalent values on the ped faces.** The distribution curves of the calcium carbonate equivalent values on the ped faces in the profile, as shown in Figure XXXI, can be grouped on the basis of the general shape and position characteristics into four groups. The factors exerting the strongest influence in this grouping are the depth to free carbonates in the profile and the depth in the profile
of the midpoint of the developmental maximum calcium carbonate equivalent values. The shape characteristic of the distribution curves serve to indicate the evolutionary nature of the distribution of the calcium carbonate equivalent values in the profile across the general soil-climosequence.

The distribution curve of the calcium carbonate equivalent values on the ped faces in profile T-1 indicates that in this orientation, the greatest depth in the profile to the free carbonates and to the developmental maximum calcium carbonate equivalent values in the profiles of the soil-climosequence occur in this profile. The shape characteristic of the distribution curve would seem to indicate that the maximum calcium carbonate equivalent value in the profile occurs below the five-foot profile depth.

The distribution curves of the calcium carbonate equivalent values on the ped faces in profiles T-2 and T-4 show that in this orientation the depths in the profiles to free carbonates and to the developmental maximum calcium carbonate equivalent values are not as deep as in profile T-1. The shape characteristic of the distribution curves for profiles T-2 and T-4 are very similar and seem to indicate comparatively stable developmental maximums occurring within the five-foot profile in this orientation.

The distribution curve of the calcium carbonate equivalent values on the ped faces in profile T-5 shows that in this orientation the depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values are not as deep as in profiles
Figure XXXI. Calculated CaCO₃ equivalent values of the ped faces by horizons for the six profiles studied.
T-2 and T-4. The shape characteristic of the distribution curve for profile T-5 seems to indicate active evolution in the depth of the developmental maximum in the profile and the evolution appears to be more advanced on the ped faces than it is in the mass of the ped interiors. The shift in the depth of the developmental maximum appears to be away from the more shallowly positioned maximums, like those occurring in profiles T-6 and T-3, and toward the more deeply positioned maximums, like those occurring in profiles T-4 and T-2.

The distribution curves of the calcium carbonate equivalent values on the ped faces in profiles T-6 and T-3 show that in this orientation the shallowest depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values in the profiles of the soil-climosequence occur in these profiles. The shape characteristics of the distribution curves for profiles T-6 and T-3 seem to indicate active evolution in the depth of the developmental maximums in this orientation in the profiles, and the evolution appears to be more advanced in the ped face orientation than it is in the mass of the ped interiors. The evolution within this feature is neither as advanced nor as pronounced in these profiles as it is in profile T-5.

As shown in Table 26, the depth in the profile to free carbonates on the ped faces appears to be stratified with the macroclimate, becoming shallower with increasing aridity across the general soil-climosequence. The stratification of this factor with the macroclimate is even more striking when the parent materials are held constant, as in the cases of the loess soil-climosequence and the glacial till soil-
Table 26. Characterization of the Distribution Curves of the Calcium Carbonate Equivalent Values on the Ped Faces for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Depth to CaCO₃ in inches</th>
<th>Maximum CaCO₃ equiv. value</th>
<th>Depth to max. CaCO₃ equiv. value in inches</th>
<th>Midpoint depth of max. CaCO₃ equiv. value in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual profiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0</td>
<td>4.0</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>26.0</td>
<td>16.5</td>
<td>30.0</td>
<td>27.0</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>23.0</td>
<td>6.0</td>
<td>27.0</td>
<td>26.0</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>18.0</td>
<td>8.5</td>
<td>33.0</td>
<td>37.5</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>13.0</td>
<td>5.5</td>
<td>13.0</td>
<td>21.0</td>
</tr>
<tr>
<td>T-7 Agar (loess)</td>
<td>17.0</td>
<td>8.0</td>
<td>21.0</td>
<td>25.5</td>
</tr>
<tr>
<td>Profiles grouped on the basis of distribution curve characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0 mean</td>
<td>4.0 mean</td>
<td>46.0 mean</td>
<td>53.0 mean</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>24.5 mean</td>
<td>8.2 mean</td>
<td>28.5 mean</td>
<td>36.0 mean</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>18.0 mean</td>
<td>8.5 mean</td>
<td>33.0 mean</td>
<td>37.5 mean</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-7 Agar (loess)</td>
<td>15.0 mean</td>
<td>6.5 mean</td>
<td>17.0 mean</td>
<td>22.8 mean</td>
</tr>
</tbody>
</table>
climosequence. When the profiles are grouped on the basis of their distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 26, the same relationships between this feature and the macroclimate are shown as were shown by the individual profile sequence in the upper bracket of Table 26.

The depths in the profile to free carbonates, as shown in Tables 25 and 26, are the same in both the ped face and ped interior orientations.

The maximum calcium carbonate equivalent values on the ped faces, as shown in Table 26, like those in the mass of the ped interiors, do not appear to be stratified with the macroclimate across either the general soil-climosequence or across the climosequence of the grouped profiles.

The maximum calcium carbonate equivalent values, as shown in Tables 25 and 26, are higher in the mass of the ped interiors than they are on the ped faces in all the profiles studied, with the exception of profile T-1, where profiles developing in loess and profiles developing in glacial till occur in the same or very similar macroclimatic environments, as in the cases of profiles T-2 and T-4, and T-6 and T-3, the maximum calcium carbonate equivalent value differentials between the ped faces and the ped interiors are greater in the profiles developed in glacial till than they are in the profiles developed in loessial materials. This would appear to indicate that the distribution of calcium carbonate is more strongly ped oriented in profiles developing in relatively-low permeability materials than it is in profiles developing
in relatively-high permeability materials.

As shown in Table 26, the depths to the developmental maximum calcium carbonate equivalent values on the ped faces, although showing a tendency toward climatic stratification, do not appear to be as strongly stratified with the macroclimate as were the depths of this feature in the mass of the ped interiors. When the profiles are grouped on the basis of the distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 26, the same relationships between this feature and the macroclimate are shown as were evident in the individual profile sequence in the upper bracket of Table 26.

It is of interest however, that in profiles T-5 and T-3, the two profiles in which active evolution of the depths of the developmental maximum appears to be taking place, the developmental maximum on the ped faces occurs at a greater depth in the profile than it does in the mass of the ped interiors. In profiles T-1, T-2, T-4 and T-6 the developmental maximums in the mass of the ped interiors and on the ped faces occur at the same depth in the profile.

As shown in Table 26, the midpoint depths of the developmental maximum calcium carbonate equivalent values on the ped faces, although showing a tendency toward climatic stratification, do not appear to be as strongly stratified with the macroclimate as were the depths of this feature in the mass of the ped interiors. When the profiles are grouped on the basis of their distribution curve characteristics and the profiles are averaged, as in the lower bracket of Table 26, the
same relationship between this feature and the macroclimate are shown as were evident in the individual profile sequence in the upper bracket of Table 26.

The midpoint depths of the developmental maximum calcium carbonate equivalent values on the ped faces are deeper in the profile than are the midpoint depths for this feature in the mass of the ped interiors in profiles T-4, T-5, T-6 and T-3. This relationship appears to indicate that some active evolution in the depth of the developmental maximum calcium carbonate equivalent values is taking place in all of these profiles. This evolution is less pronounced however, in profiles T-6 and T-4 than it is in profiles T-5 and T-3. Profiles T-1 and T-2 appear to have comparatively stable developmental maximums.

Calcium carbonate equivalent values of horizons. The distribution curves of the total calcium carbonate equivalent values of the horizons in the profile, as shown in Figure XXII, can be grouped on the basis of their general shape and position characteristics into four groups. The factors exerting the strongest influence on this grouping are the depth to free carbonates in the profile and the depth in the profile of the midpoint of the developmental maximum calcium carbonate equivalent values.

The shape characteristics of the distribution curves serve to indicate the evolutionary nature of the distribution of the calcium carbonate equivalent values in the profile across the general soil-climosequence.
Figure XXXII. Calculated CaCO$_3$ equivalent values for horizons by horizons for six profiles studied.
The distribution curve of the total calcium carbonate equivalent values by horizons in profile T-1 indicates that the greatest depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values in the profiles of the soil-climosequence occur in this profile. It would appear that the true developmental maximum calcium carbonate equivalent value occurs below the five-foot profile depth in profile T-1.

The distribution curves of the total calcium carbonate equivalent values by horizons in profiles T-2 and T-4 show the depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values to be considerably shallower in these profiles than they are in profile T-1. It would appear that the developmental calcium carbonate equivalent value maximums occur well within the five-foot profile in profiles T-2 and T-4.

The distribution curve of the total calcium carbonate equivalent values by horizons in profile T-5 shows the depth in the profile to free carbonates to be similar to that in profiles T-6 and T-3 and the depth in the profile to the developmental maximum calcium carbonate equivalent value to be similar to that in profiles T-4 and T-2. It appears that the developmental calcium carbonate equivalent value maximum occurs well within the five-foot profile in profile T-5.

The distribution curves of the total calcium carbonate equivalent values by horizons in profiles T-6 and T-3 show the depths in the profile to free carbonates and to the developmental maximum calcium carbonate equivalent values to be shallower in these profiles than
Table 27. Characterization of the Distribution Curves of the Total Calcium Carbonate Equivalent Values of the Horizons for the Six Profiles Studied

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Depth to CaCO₃ in inches</th>
<th>Maximum CaCO₃ equiv. value</th>
<th>Depth to max. CaCO₃ equiv. value in inches</th>
<th>Midpoint depth of max. CaCO₃ equiv. value in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual profiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing aridity of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0</td>
<td>8.0</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>26.0</td>
<td>21.5</td>
<td>30.0</td>
<td>36.0</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>23.0</td>
<td>16.5</td>
<td>27.0</td>
<td>32.0</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>18.0</td>
<td>19.5</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>13.0</td>
<td>20.0</td>
<td>13.0</td>
<td>17.0</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>17.0</td>
<td>17.0</td>
<td>21.0</td>
<td>25.5</td>
</tr>
</tbody>
</table>

Profiles grouped on the basis of distribution curve characteristics

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Depth to CaCO₃ in inches</th>
<th>Maximum CaCO₃ equiv. value</th>
<th>Depth to max. CaCO₃ equiv. value in inches</th>
<th>Midpoint depth of max. CaCO₃ equiv. value in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing aridity of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1 So. Moody (loess)</td>
<td>46.0</td>
<td>8.0</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>T-2 No. Moody (loess)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-4 Vienna (till)</td>
<td>24.5</td>
<td>19.0</td>
<td>28.5</td>
<td>34.0</td>
</tr>
<tr>
<td>T-5 Houdek (till)</td>
<td>18.0</td>
<td>19.5</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>T-6 Williams (till)</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>T-3 Agar (loess)</td>
<td>15.0</td>
<td>18.5</td>
<td>17.0</td>
<td>21.2</td>
</tr>
</tbody>
</table>
they are in the other profiles in the soil-climosequence. The developmental calcium carbonate equivalent value maximums occur well within the five-foot profile in profiles T-6 and T-3.

The overall thickness of the calcium carbonate equivalent build-up as shown in the distribution curves of the horizons is an indication of the degree of evolution taking place in the depth in the profile of the developmental calcium carbonate equivalent value maximums. The thicker zones of accumulation appear to be indicative of a greater degree of active evolution than do the thinner zones of accumulation.

As shown in Table 27, the depth in the profile to free carbonates in the horizons of the profile appears to be stratified with the macroclimate, becoming shallower with increasing aridity across the general soil-climosequence. The stratification of this factor with the macroclimate is even more striking when the parent materials are held constant as in the cases of the loess soil-climosequence and the glacial till soil-climosequence. When the profiles are grouped on the basis of their distribution curve characteristics and the grouped profiles are averaged, as in the lower bracket of Table 27, the same relationships between this feature and the macroclimate are shown as were shown by the individual profile sequence in the upper bracket of Table 27.

The maximum calcium carbonate equivalent values in the horizons, as shown in Table 27, like those in the mass of the ped interiors and those on the ped faces, do not appear to be stratified with the macroclimate either across the general soil-climosequence or across the
climosequence of the grouped profiles.

As shown in Table 27, the depths to the horizons of maximum developmental calcium carbonate equivalent values and to the midpoints of the horizons in which the developmental maxima occur, appear to be strongly stratified with the macroclimate, becoming progressively more shallow in the profile with increasing aridity across the general soil-climosequence and across the climosequence of the grouped profiles.

The close agreement between the total calcium carbonate equivalent values of the horizons for profiles T-1, T-2 and T-3, as calculated from the field observations and shown in Figure XXXII, and the analyzed calcium carbonate equivalent percentages for the same horizons in these profiles as reported in Figure XXXIX in the discussions of the laboratory data, is of interest from the standpoint of another aspect of quantitativeness with which this study is concerned and which will be discussed later in the thesis.

Laboratory Studies

Results of the Laboratory Studies

The results of the laboratory studies of the six profiles investigated are presented graphically in Figures XXXII through XXXVIII which are included within the following section of the thesis. The laboratory data also are presented in tabular form in Tables 1 through 6 in Appendix C.

Discussion of the Laboratory Studies

Although the main emphasis of this study is centered around the
morphologic approach to the study of soils, the laboratory character-
ization of the profiles also was necessary before the profiles studied
could be placed in the 7th approximation of the proposed new system of
soil classification (59). Because of the supplementary nature of the
laboratory aspects to the overall study and because of their use pri-
marily as data necessary to the placement of the profiles studied into
the proposed system, the results of the laboratory investigations per
se are not discussed in the same degree of detail as were those of the
morphologic phases.

Particle Size Distribution

The results of the particle size distribution analyses for the
six profiles investigated are shown in their entirety in Tables 1
through 6 in Appendix C. The sand and silt fractions, although re-
ported, do not appear to merit further attention. In light of the
genetic implications attached to the distribution of clay in the pro-
file, a discussion of the characteristics of the distribution of clay
in the profiles studied would seem to be pertinent. The distribution
of clay by horizons for the six profiles studied is shown in Figure
XXXIII.

The distribution curves of the percent clay by horizons for the
six profiles studied, as shown in Figure XXXIII, can be grouped on the
basis of their general shape and position characteristics into three
groups.

In profiles T-1 and T-2, the greatest accumulation of clay occurs
in the A1 horizon. This is in contrast to profiles T-4, T-5, T-6 and
Figure XXXIII. Percent clay by horizons for the six profiles studied.
I-3 in which the greatest accumulation of clay occurs in one of the subhorizons of the B2 horizon. It appears that more clay has accumulated in the A1 horizon of profile T-1 than in the A1 horizon of profile T-2. The near absence of clay skins on these profiles in combination with the gradual decrease in clay with increasing profile depth suggests that the accumulated clay involved in profiles T-1 and T-2 primarily is the result of clay formation in place.

In profile T-4, the accumulation of clay in the B2 horizon over that present in the A1 horizon, although evident, is not as great as that in profiles T-5, T-6 and T-3. The accumulation of clay in the B2 horizons is substantially greater than that present in the A1 horizons in profiles T-5, T-6 and T-3. The presence of well developed clay skins in these profiles and the pronounced clay build-up in the B2 horizons suggests that the accumulated clay involved in profiles T-5, T-6 and T-3 is primarily the result of clay movement.

The origin, amount and location of the clay accumulation in the profile appear to be stratified with the macroclimate across the soil-climosequence.

pH Determinations

The results of the pH determinations for the six profiles investigated are shown in their entirety in Tables 1 through 6 in Appendix C. The distribution of the pH values by horizons for the six profiles investigated is shown in Figure XXXIV.

The distribution curves of the pH values at 1:1 and 1:10 dilutions by horizons for the six profiles investigated, as shown in Figure
Figure XXXIV. pH by horizons for the six profiles studied
XXXIV, cannot be grouped on the basis of their general shape and position characteristics.

The characteristics of the parent material appear to strongly affect the distribution of the pH values in the profile, and as a result, the distribution of the pH values in the profile does not appear to be stratified with the macroclimate across the general soil-climosequence. However, when the parent material factor is held constant, as it is in the case of the loess soil-climosequence or the glacial till soil-climosequence, the distribution of the pH values in the profile appears to be strongly stratified with the macroclimate; the pH values at equivalent depths in the profile becoming higher with increasing aridity across the soil-climosequence.

The pH differences between adjacent profiles in the soil-climosequence appear to be expressed through the full depth of the profile in the loess soil-climosequence. This is in contrast to the profiles in the glacial till soil-climosequence in which pH differences of consequence between adjacent profiles in the soil-climosequence appear to be limited to the A1 and B2 horizons in the profile.

Organic Carbon and Total Nitrogen

The distribution of organic carbon and total nitrogen by horizons for the six profiles studied is shown in Figures XXXV and XXXVI respectively and the C/N ratios for these profiles are shown in Figure XXXVII. The same data are shown in tabular form in Tables 1 through 6 in Appendix C.
Figure XXXV. Percent organic carbon by horizons for the six profiles studied.
Figure XXXVI. Percent nitrogen by horizons for the six profiles studied.
The distribution curves of the organic carbon by horizons for the six profiles investigated, as shown in Figure XXXV, can be grouped on the basis of their general shape and position characteristics into two groups.

The distribution curves for profiles T-2 and T-4 have distinctly different shape characteristics when compared with those of the other profiles. The upper portions of the curves are concave in contrast to the convex aspect of the upper portions of the curves representing profiles T-1, T-5, T-6 and T-3. The deeper distribution of the relatively high organic carbon values in profiles T-4 and T-2 appears to be consistent with the thicker A1 horizons formed in these profiles and appears to reflect the effect of constructional A1 horizon processes.

The percent organic carbon in the A1 horizon appears to be stratified with the macroclimate across the general soil-climosequence. The highest organic carbon value in the A1 horizon occurs in profile T-4. As the temperature and precipitation increase together or as the temperature increases and the precipitation decreases from that representative of profile T-4, the percent organic carbon in the A1 horizon decreases.

The distribution curves of the total nitrogen by horizons for the six profiles investigated, shown in Figure XXXVI, as would be expected, have similar shape and position characteristics to those shown by the distribution curves of the organic carbon.

The percent total nitrogen in the A1 horizon appears to be stratified with the macroclimate across the general soil-climosequence. The
Figure XXXVII. C/N ratios by horizons for five of the profiles studied.
highest total nitrogen value in the A1 horizon occurs in profile T-4. As the temperature and precipitation increase together or as the temperature increases and the precipitation decreases from that representative of profile T-4, the percent total nitrogen in the A1 horizon decreases.

The distribution curves of the C/N ratios by horizons for five of the six profiles investigated are shown in Figure XXXVII. The evolutionary nature of the shape and position characteristics of the distribution curves of the C/N ratios from profile to profile across the general soil-climosequence precludes grouping the curves. The pattern of this evolution is illustrated by the C/N ratios of the A1 and B21 horizons in the profiles studied shown in Table 28.

Table 28. C/N Ratios of the A1 and B21 Horizons

<table>
<thead>
<tr>
<th>Horizon</th>
<th>So. Moody T-1</th>
<th>No. Moody T-2</th>
<th>Vienna T-4</th>
<th>Houndek T-5</th>
<th>Williams T-6</th>
<th>Agar T-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>11.3</td>
<td>11.5</td>
<td>12.0</td>
<td>--*</td>
<td>12.0</td>
<td>11.6</td>
</tr>
<tr>
<td>B21</td>
<td>16.0</td>
<td>12.1</td>
<td>11.0</td>
<td>--*</td>
<td>9.2</td>
<td>10.6</td>
</tr>
</tbody>
</table>

* Missing data

As shown in Table 28, the C/N ratios of the A1 horizons appear to be stratified with the macroclimate. The highest C/N ratio in the A1 horizon occurs in profile T-4. As the temperature and precipitation increase together or as the temperature increases and the precipitation decreases, the C/N ratios of the A1 horizon become smaller.
Figure XXXVIII. Electrical conductivity by horizons for five of the profiles studied.
This relationship appears to reflect the direct influence of temperature on the accumulation of organic matter and the effect of relatively high organic matter accumulation on the C/N ratio.

The C/N ratios of the B21 horizons, as shown in Table 25, also appear to be stratified with the macroclimate; however, the pattern of stratification is not the same as that shown by the C/N ratios of the A1 horizons. The highest C/N ratio in the B21 horizon occurs in profile T-1. As the precipitation decreases from that representative of profile T-1, the C/N ratios of the B21 horizons become smaller. This relationship appears to reflect the direct influence of increasing precipitation on the loss of nitrogen, through leaching, from materials that are relatively low in organic matter.

The C/N ratios of the A1 horizons are lower than are those of the B21 horizons in profiles T-1 and T-2, and are higher than are those of the B21 horizons in profiles T-4, T-6 and T-3.

Electrical conductivity

The results of the electrical conductivity determinations for five of the six profiles investigated are shown in Tables 1 through 6 in Appendix C. The distribution of the electrical conductivity values by horizons for the five profiles investigated is shown in Figure XXXVIII.

The distribution curves of the electrical conductivity values by horizons for five of the six profiles investigated, as shown in Figure XXXVIII, can be grouped on the basis of their general shape and position characteristics into two groups. This grouping appears to be
a reflection of the parent material factor.

The characteristics of the parent material, and especially that of permeability, appear to strongly effect the distribution of the electrical conductivity values in the profile. As a consequence, the distribution of the electrical conductivity values does not appear to be stratified with the macroclimate across the general soil-climosequence. However, when the parent material factor is held constant, as it is in the case of the loess soil-climosequence or the glacial till soil-climosequence, the distribution of the electrical conductivity values in the profile appears to be weakly stratified with the macroclimate, except in the substratum, where it appears to be strongly stratified with the macroclimate. When the parent material is held constant, the electrical conductivity values in the profile substrata increase with increasing aridity across the soil-climosequence.

Calcium Carbonate Equivalent

The results of the calcium carbonate equivalent determinations for the six profiles investigated are shown in Tables 1 through 6 in Appendix C. The distribution of the percent calcium carbonate equivalent by horizons for the six profiles studied is shown in Figure XXXIX.

The distribution curves of the percent calcium carbonate equivalent by horizons for the six profiles investigated are shown in Figure XXXIX.

The distribution of calcium carbonate in the six profiles investigated was discussed at length in the discussion of the morphologic phases of this study and therefore will not be discussed in this section.
Figure XXXIX. Percent CaCO₃ equivalent by horizons for the six profiles studied.
Analyzed versus calculated calcium carbonate equivalent values. The calcium carbonate equivalent values of the 10 calcaeous horizons in profiles T-1, T-2 and T-3 as calculated from the field observations following the procedures developed and reported in the earlier phases of the morphology studies are compared in Table 29 with the percent calcium carbonate equivalent figures obtained by laboratory analysis of the same 10 horizons.

Table 29. Comparison of the Calculated and Analyzed Calcium Carbonate Equivalent Values

<table>
<thead>
<tr>
<th>Profile</th>
<th>Horizon</th>
<th>Depth in inches</th>
<th>Percent calcium carbonate equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calculated</td>
</tr>
<tr>
<td>T-1 So. Moody</td>
<td>C1ca</td>
<td>46-60</td>
<td>8.0</td>
</tr>
<tr>
<td>T-2 No. Moody</td>
<td>B2ca</td>
<td>26-60</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>B3ca</td>
<td>30-42</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>D1ca</td>
<td>42-49</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>D2ca</td>
<td>49-60</td>
<td>12.0</td>
</tr>
<tr>
<td>T-3 Agar</td>
<td>B2ca</td>
<td>17-21</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>B3ica</td>
<td>21-30</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>B32ca</td>
<td>30-39</td>
<td>16.0</td>
</tr>
<tr>
<td></td>
<td>C1ca</td>
<td>39-48</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>D1ca</td>
<td>48-60</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Correlation of the calculated with the analyzed percent calcium carbonate equivalent, as shown in Table 29, gave an r value of 0.956. This value of r is highly significant at the 1 percent level. It therefore would appear that the percent calcium carbonate equivalent of soil materials can be determined with an acceptable degree of quantitative- ness using the field methods outlined in this study.
Figure XXXI. Cation exchange capacity by horizons for the six profiles studied.
Cation Exchange Capacity

The results of the cation exchange capacity determinations for the six profiles investigated are shown in Tables 1 through 6 in Appendix C. The distribution of cation exchange capacity by horizons for the six profiles studied is shown in Figure XXX.

The distribution curves of the cation exchange capacity values by horizons for the six profiles investigated, as shown in Figure XXX, can be grouped on the basis of their general shape and position characteristics into two groups.

The cation exchange capacity of the A1 horizon is higher than that of the B21 horizon in profiles T-1, T-2 and T-4. In profiles T-5, T-6 and T-3 the cation exchange capacity of the A1 horizon is lower than that of the B21 horizon.

The above relationships are explainable on the basis of the amount and distribution of organic matter and of clay in these profiles. The maximum clay content in the profile occurs in the A1 horizons of profiles T-1 and T-2. The A1 horizons of profiles T-2 and T-4 have a considerably higher organic matter content than do the A1 horizons of the other profiles in the soil-climosequence. Profiles T-1 and T-2 do not have a build-up of clay in the B2 horizon. Profile T-4 has a weak build-up of clay in the B2 horizon. The A1 horizons of profiles T-5, T-6 and T-3 have only moderate amounts of organic matter. Profiles T-5, T-6 and T-3 have a pronounced build-up of clay in the B2 horizon.

Extractable Cations

The results of the extractable cation determinations for five of
Figure XXXI. Extractable calcium by horizons for five of the profiles studied
Figure XXXII. Extractable magnesium by horizons for five of the profiles studied
the six profiles investigated are shown in Tables 1 through 6 in Appendix C. The distribution of the extractable calcium, magnesium, sodium, potassium and hydrogen by horizons for these five profiles is shown in Figures XXXI through XXXV respectively.

The distribution curves of the extractable calcium by horizons for five of the six profiles studied are shown in Figure XXXI. The evolutionary nature of the shape and position characteristics of the distribution curves of the extractable calcium from profile to profile across the general soil-climosequence precludes grouping of the curves.

The amount of extractable calcium in the leached portion of the solon appears to be stratified with the macroclimate, especially when the parent material is held constant, as within the loess soil-climosequence or within the glacial till soil-climosequence. As the precipitation increases across the soil-climosequence the amount of extractable calcium in the horizons in the leached portion of the solon increases. The successive increase of extractable calcium in the horizons in the leached portion of the solon appears to reflect the increased weathering of the less easily weathered calcium bearing minerals, such as Andesine, Oligoclase, Hornblende and Albite, in addition to those that are more easily weathered, such as Anorthite, Bytownite, Labradorite and Augite and that are probably the primary source of the extractable calcium in the profiles in the more arid range of the soil-climosequence.

The extractable calcium does not appear to follow the same increase pattern as that of the cation exchange capacity. The increase
Figure XXXIII. Extractable sodium by horizons for the six profiles studied.
in extractable calcium therefore does not appear to be the direct result of an increase in the cation exchange capacity.

The distribution curves of the extractable magnesium values by horizons for five of the six profiles studied are shown in Figure XXXII.

The amount of extractable magnesium in the A1 and B21 horizons appears to follow the same increase pattern as that of the cation exchange capacity in these horizons. This relationship appears to indicate that the amount of extractable magnesium in these horizons is directly related to the cation exchange capacity.

The extractable magnesium values in the A1 and B21 horizons appears to be stratified with the parent material, being higher in the loess derived profiles than in those derived from glacial till.

The extractable magnesium values in the horizons in the leached portion of the solon do not appear to be stratified with the macroclimate across the general soil-climosequence, the loess soil-climosequence or the glacial till soil-climosequence.

The distribution curves of the extractable sodium values by horizons for the six profiles studied are shown in Figure XXXII.

Only trace amounts of extractable sodium occur in the A1 horizons of the profiles across the soil-climosequence.

The amount of extractable sodium in the B21 horizon appears to be stratified with the macroclimate, increasing slightly with increasing precipitation across the soil-climosequence. The successive increase in the B21 horizon, although slight, appears to reflect the
Figure XXXIV. Extractable potassium by horizons for the six profiles studied
increased weathering in the B21 horizon of the less easily weathered sodium bearing minerals, such as Andesine, Oligoclase, Hornblende, Albite and Anorthoclase, in addition to those that are more easily weathered such as Bytownite and Labradorite. The extractable sodium in the B21 horizon does not appear to follow the same increase pattern as that of the cation exchange capacity.

The amount of extractable sodium in the substrata of the profiles appears to be stratified with the macroclimate, especially when the parent material factor is held constant, as within the loess soil-climosequence or within the glacial till soil-climosequence. As the precipitation decreases across the soil-climosequence the amount of extractable sodium in the substratum materials rapidly increases. This represents a reversal of the trend shown in the B21 horizon. The extractable sodium in the substratum materials, like that in the B21 horizon, does not appear to follow the same increase pattern as that of the cation exchange capacity.

The distribution curves of the extractable potassium values by horizons for the six profiles investigated are shown in Figure XXXIV.

The amount of extractable potassium in the A1 horizon appears to be stratified with the macroclimate across the general soil-climosequence. The smallest amount of extractable potassium in the A1 horizon occur in profiles T-4 and T-2. As the precipitation and temperature increase together or as the precipitation decreases from that representative of these profiles, the extractable potassium in the A1 horizon increases. The extractable potassium in the A1 horizon does
Figure XXXV. Extractable hydrogen by horizons for five of the profiles studied.
not appear to follow the same increase pattern as that of the cation exchange capacity.

The amount of extractable potassium in the B21 horizon appears to be stratified with the macroclimate across the general soil-climosequence. The smallest amount of extractable potassium in the B21 horizon occurs in profile T-4. As the precipitation and temperature increase together or as the temperature increases and the precipitation decreases from that representative of profile T-4, the extractable potassium in profiles T-1 and T-2, the warmest, most humid and most strongly leached members of the soil-climosequence, over that of profile T-4, would seem to indicate tighter bonding of the potassium in the exchange complex which suggests the presence of illitic clays in the upper horizons of these profiles. The extractable potassium in the B21 horizon does not appear to follow the same increase pattern as that of the cation exchange capacity.

The amount of extractable potassium in the substratum appears to follow the same increase pattern as that of the cation exchange capacity of the substratum materials. This relationship appears to indicate that the amount of extractable potassium in the substratum materials is directly related to the cation exchange capacity.

The distribution curves of the extractable hydrogen values by horizons for five of the six profiles investigated are shown in Figure XXXXV.

The amount of extractable hydrogen by horizons in the profiles studied does not appear to be stratified with the macroclimate across
the general soil-climosequence. However, when the parent material factor is held constant, as within the loess soil-climosequence and within the glacial till soil-climosequence, the amount of extractable hydrogen present by horizons appears to be strongly stratified with the macroclimate, decreasing with increasing aridity across the loess soil-climosequence and across the glacial till soil-climosequence.

Saturation Extract Soluble Cations

The results of the determination of the saturation extract soluble cations for four of the six profiles investigated are shown in Tables 1 through 6 in Appendix C. The distribution of the saturation extract soluble calcium, magnesium, sodium and potassium by horizons for these four profiles is shown in Figures XXXVI and XXXVII.

The distribution curves of the soluble calcium by horizons for four of the six profiles investigated are shown in Figure XXXVI.

The amount of soluble calcium present by horizons in the leached subsoil appears to be strongly stratified with the macroclimate, increasing with increasing aridity across the general soil-climosequence. In profiles T-3 and T-6, the two most arid members of the soil-climosequence, the highest amount of soluble calcium occurs in the A1 horizon and decreases with increasing depth in the profile. In profiles T-1 and T-2, the two most humid members of the soil-climosequence, the highest amount of soluble calcium occurs at a considerable depth in the profile and decreases with decreasing depth in the profile. The above relationships, along with the general shape and position characteristics of the distribution curves per se, indicate the effects of progressively
Figure XXXVI. Soluble calcium and magnesium by horizons for four profiles studied
Figure XXXVII. Soluble potassium and sodium by horizons for four profiles studied.
increasing precipitation on the evolitional leaching of soluble calcium from the soil profile.

The distribution curves of the soluble magnesium by horizons for four of the six profiles investigated are shown in Figure XXXXVI.

The amount and distribution of soluble magnesium in the profiles studied does not appear to show any apparent relationships between individual profiles or to any other factor or feature common to the profiles or to their laboratory characterization.

The distribution curves of the soluble sodium by horizons for four of the six profiles investigated are shown in Figure XXXXVII.

The amount of soluble sodium present by horizons in the upper 20 inches of the solum is nearly the same in all profiles. The amount of soluble sodium in the solum and substratum below 20 inches appears to be strongly stratified with the macroclimate, increasing with increasing aridity across the general soil-climosequence.

The distribution curves of the soluble potassium by horizons for four of the six profiles investigated are shown in Figure XXXXVII.

The amount of soluble potassium present in the A1 and B21 horizons appears to be strongly stratified with the macroclimate, increasing with increasing aridity across the general soil-climosequence. The amount of soluble potassium in the lower solum and in the substratum materials appears to be nearly the same for all the profiles.

Percent Base Saturation

The results of the determinations of the percent base saturation by horizons for five of the six profiles studied are shown in Tables
Figure XXXVIII. Percent base saturation by horizons for five profiles studied.
1 through 6 in Appendix C. The distribution curves of the percent base saturation by horizons for these five profiles are shown in Figure XXXVIII.

The percent base saturation by horizons in the profiles studied does not appear to be strongly stratified with the macroclimate across the general soil-climosequence. However, when the parent material factor is held constant, as within the loess soil-climosequence and within the glacial till soil-climosequence, the percent base saturation by horizons appears to be strongly stratified with the macroclimate, increasing with increasing aridity across the soil-climosequence.

The depth in the profile to a base saturation percentage of 100, appears to be strongly stratified with the macroclimate, becoming shallower in the profile with increasing aridity across the general soil-climosequence.
CONCLUSIONS

The material presented in this thesis is not meant to represent a completed study. This thesis is the 4th approximation in the development of a continuing study, the objectives of which coincide with the stated objectives of the thesis. The dynamic nature of the morphologic features of the soil precludes the finality implied by a completed study of them.

The following are the conclusions drawn with respect to the quantitative methods of soil study proposed and reported in this thesis.

(a) The quantitative standards and recording methods developed and presented in this study appear to be well adapted to the consistent field observation and characterization of the morphologic features of the soil.

(b) The quantitative standards and values developed and used in this study appear to be sensitive to, and capable of showing, the micro as well as the macro changes in the progression of the genetic morphology of soils.

(c) The quantitative standards and values developed and used in this study are useful in locating natural breaks in the continuums of individual morphologic entities, thus providing a basis within the soil itself for the quantitative differentiation and characterization of classificational units.

(d) The use of the quantitative standards and values developed and reported in this study makes possible the graphic portrayal of all morphologic features of the soil.
(e) A graphic presentation of the morphologic features of the soil facilitates the recognition and characterization of the evolutionary nature of the morphologic and genetic transitions between adjacent profiles in the continuum of soils.

(f) The use of the quantitative standards and values developed and reported in this study appears to make possible the field determination of certain soil properties with a degree of quantitiveness presently obtainable only through laboratory analysis.

The following are the conclusions drawn from the results of this study relative to the classification of the six profiles investigated.

(a) The classification of the six profiles studied, at the Great Soil Group level in the framework of the classification system currently in use in the United States (66, 64, 54), is as follows:

Profile T-1, Moody silty clay loam, is a Brunizem having similar general profile characteristics to those of the Brunizems reported in adjacent states (35, 45).

Profile T-2, Moody silty clay loam, is a Chernozem intergrading to Brunizem (63).

Profile T-4, Vienna loam, is a Chernozem (68) having similar general profile characteristics to those of the Chernozems reported in adjacent states (35, 37, 45).

Profile T-5, Houdak loam, is a Chestnut intergrading to Chernozem and has general profile characteristics similar
similar to those of the Chernozems intergrading to Chestnuts reported in North Dakota (39).

Profile T-6, Williams loam, and profile T-7, Agar loam, are Chestnuts (63) having similar general profile characteristics to those of the Chestnuts reported in adjacent states (35, 37, 45).

(b) The classification of the six profiles studied, at the Great Group and Subgroup levels in the framework of the 7th approximation of the proposed new classification system (59), is as follows:

Profile T-1, Moody silty clay loam: Hapludoll (5.52), Typic Hapludoll (5.520). This placement is in accord with that made by the Soil Scientists Conference (57).

Profile T-2, Moody silty clay loam: Haploboroll (5.42), Udollic Haploboroll (5.42-5.5). Soils of the Moody series were classified as Typic Hapludolls (5.420) by the Soil Scientists Conference (57).

Profile T-4, Vienna loam: Haploboroll (5.42), Typic Haploboroll (5.420). This placement is in accord with that made by the Soil Scientists Conference (57).

Profile T-5, Houdek loam: Argiboroll (5.43), Ustollic Argiboroll (5.43-5.6). Soils of the Houdek series were classified as Typic Argiborolls (5.430) by the Soil Scientists Conference (57).
Profile T-6, Williams loam and profile T-3 Agar silt loam: Argustoll (5.63), Roric Argustoll (5.63-5.4). This placement is in accord with that made by the Soil Scientists Conference (57).


**APPENDIX A**

Figure I. Front of the soil profile description card developed

<table>
<thead>
<tr>
<th>Field Legend Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Condition</td>
<td>Date</td>
</tr>
<tr>
<td>Inorganic lanthanide</td>
<td>Date</td>
</tr>
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</table>

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<th>Mapping Unit Number</th>
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<td>Field Number</td>
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<tr>
<td>Trip</td>
<td>Climate</td>
<td>Macro-Climatic</td>
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<tr>
<td>County</td>
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<tr>
<td>Location</td>
<td>Natural Vegetation</td>
<td>Region</td>
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<tr>
<td></td>
<td>or Crop</td>
<td>Site</td>
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</table>

<table>
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<th>Shading</th>
<th>Drainage</th>
<th>Pedology</th>
<th>Agronomic</th>
<th>Weathrable</th>
<th>Profile Water Table</th>
<th>Rend Distribution</th>
<th>Soil Profile Activity</th>
<th>Basalt Or Rocks</th>
<th>Coarsest</th>
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</thead>
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<td></td>
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<td>Ave. Ann. inches</td>
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<td>Inc. Zone</td>
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<td></td>
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<td>Inc. On %</td>
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<td>Inc. Off %</td>
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<td>Profile</td>
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<td>Profile H2O Budget</td>
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</tbody>
</table>

Classification and Genetic Discussion
Figure II. Back of the soil profile
description card developed
APPENDIX B

The field symbolization developed and used in this study for recording the morphologic features of the soil on the field description cards developed and used in this study is as follows.

**Soil Color**

**Color notations:**

The soil color notations used on the field description cards are taken directly from the Munsell Soil Color Charts (40) and are in accord with notations set forth in that publication. The decimal system is used for recording color readings that are interpolations between the existing Hue, Value, and Chroma notations.

**Example:**

\[10\text{YR} \, 6/2\]

Hue Value Chroma

**Color coatings:**

**Color coat abundance patterns:**
- EFC Extremely patchy color coats
- VPC Very patchy color coats
- MPC Moderately patchy color coats
- SPC Slightly patchy color coats
- NCC Nearly continuous color coats
- CC Continuous color coats

**Color coat thickness:**
1. Thin color coats
2. Moderately thick color coats
3. Thick color coats
4. Very thick color coats

**Color coat placement or orientation:**
- Color coats on vertical faces of peds
- Color coats on horizontal faces of peds
- Color coats on both vertical and horizontal faces of peds
- P Color coats on primary peds
- SP Color coats on subprimary peds
- S Color coats on secondary peds
- SS Color coats on subsecondary peds

**Causative agents of color coats and mottlings:**
- OM Organic matter
- O Oxidation
- R Reduction
Carbonates
Salts
Iron
Manganese
Bleached silica

Example: 2-MPC-10YR 2/1-0M-# P

2/1) Organically stained coatings on both the vertical and horizontal faces of the primary peds.

Color mottlings or stains:

Abundance of mottles or stains:
F Few mottles or stains
C Common mottles or stains
M Many mottles or stains

Size of mottles or stains:
F Fine mottles or stains
M Medium mottles or stains
C Coarse mottles or stains

Contrast or distinctness of mottles:
VF Very faint mottles or stains
F Faint mottles or stains
D Distinct mottles or stains
P Prominent mottles or stains
VF Very prominent mottles or stains

Boundary characteristic of mottles:
A Abrupt-boundary mottles or stains
S Sharp-boundary mottles or stains
C Clear-boundary mottles or stains
D Diffuse-boundary mottles or stains

Placement or orientation of mottles:
I In the interiors of the peds
F On the faces of the peds

Example: FFPS 10YR 5/3 Fe

Few, fine, prominent, sharp boundary, yellowish-brown (10YR 5/3) iron stains.

Soil Structure
Structure types (kind of peds)

Pristatic structure:
$: Rough-surface, subangular prisms
$: Rough-surface, angular prisms
Rough-surface, subangular-angular prisms; unoriented

Rough-surface, subangular-angular prisms; oriented

Irregular-surface, subangular prisms
Irregular-surface, angular prisms
Irregular-surface, subangular-angular prisms; unoriented
Irregular-surface, subangular-angular prisms; oriented

Smooth-surface, subangular prisms
Smooth-surface, angular prisms
Smooth-surface, subangular-angular prisms; unoriented
Smooth-surface, subangular-angular prisms; oriented

Short vertical axis prismatic structure
Rough-surface, short, subangular prisms
Rough-surface, short, angular prisms
Rough-surface, short, subangular-angular prisms; unoriented
Rough-surface, short, subangular-angular prisms; oriented

Irregular-surface, short, subangular prisms
Irregular-surface, short, angular prisms
Irregular-surface, short, subangular-angular prisms; unoriented
Irregular-surface, short, subangular-angular prisms; oriented

Smooth-surface, short, subangular prisms
Smooth-surface, short, angular prisms
Smooth-surface, short, subangular-angular prisms; unoriented
Smooth-surface, short, subangular-angular prisms; oriented

Columnar structure (round-tops)
Rough-surface, subangular, round-topped columns
Rough-surface, angular, round-topped columns
Rough-surface, subangular-angular, round-topped columns; unoriented
Rough-surface, subangular-angular, round-topped columns; oriented
Irregular-surface, subangular, round-topped columns
Irregular-surface, angular, round-topped columns
Irregular-surface, subangular-angular, round-topped columns; unoriented
Irregular-surface, subangular-angular, round-topped columns; oriented
Smooth-surface, subangular, round-topped columns
Smooth-surface, angular, round-topped columns
Smooth-surface, subangular-angular, round-topped columns; unoriented
Smooth-surface, subangular-angular, round-topped columns; oriented

Short vertical axis columnar structure (round-tops):
Rough-surface, short, subangular, round-topped columns
Rough-surface, short, angular, round-topped columns
Rough-surface, short, subangular-angular, round-topped columns; unoriented
Rough-surface, short, subangular-angular, round-topped columns; oriented
Irregular-surface, short, subangular, round-topped columns
Irregular-surface, short, angular, round-topped columns
Irregular-surface, short, subangular-angular, round-topped columns; unoriented
Irregular-surface, short, subangular-angular, round-topped columns; oriented
Smooth-surface, short, subangular, round-topped columns
Smooth-surface, short, angular, round-topped columns
Smooth-surface, short, subangular-angular, round-topped columns; unoriented
Smooth-surface, short, subangular-angular, round-topped columns; oriented

Columnar structure (flat-tops):
Rough-surface, subangular, flat-topped columns
Rough-surface, angular, flat-topped columns
| Rough-surface, subangular-angular, flat-topped columns; unoriented |
| Rough-surface, subangular-angular, flat-topped columns; oriented |
| Irregular-surface, subangular, flat-topped columns |
| Irregular-surface, angular, flat-topped columns |
| Irregular-surface, subangular-angular, flat-topped columns; unoriented |
| Irregular-surface, subangular-angular, flat-topped columns; oriented |
| Smooth-surface, subangular, flat-topped columns |
| Smooth-surface, angular, flat-topped columns |
| Smooth-surface, subangular-angular, flat-topped columns; unoriented |
| Smooth-surface, subangular-angular, flat-topped columns; oriented |

**Short vertical axis columnar structure (flat-tops):**

| Rough-surface, short, subangular, flat-topped columns |
| Rough-surface, short, angular, flat-topped columns |
| Rough-surface, short, subangular-angular, flat-topped columns; unoriented |
| Rough-surface, short, subangular-angular, flat-topped columns; oriented |
| Irregular-surface, short, subangular-angular, flat-topped columns |
| Irregular-surface, short, angular, flat-topped columns |
| Irregular-surface, short, subangular-angular, flat-topped columns; unoriented |
| Irregular-surface, short, subangular-angular, flat-topped columns; oriented |
| Smooth-surface, short, subangular, flat-topped columns |
| Smooth-surface, short, angular, flat-topped columns |
| Smooth-surface, short, subangular-angular, flat-topped columns; unoriented |
| Smooth-surface, short, subangular-angular, flat-topped columns; oriented |
Blocky structure:

1. Rough-surface, subangular blocks
2. Rough-surface, angular blocks
3. Rough-surface, subangular-angular blocks; unoriented
4. Rough-surface, subangular-angular blocks; oriented
5. Irregular-surface, subangular blocks
6. Irregular-surface, angular blocks
7. Irregular-surface, subangular-angular blocks; unoriented
8. Irregular-surface, subangular-angular blocks; oriented
9. Smooth-surface, subangular blocks
10. Smooth-surface, angular blocks
11. Smooth-surface, subangular-angular blocks; unoriented
12. Smooth-surface, subangular-angular blocks; oriented

Platy structure:

- Rough-surface plates
- Irregular-surface plates
- Smooth-surface plates
- Rough-surface platelets
- Irregular-surface platelets
- Smooth-surface platelets

Granular structure:

- Rough-surface granules
- Irregular-surface granules
- Smooth-surface granules

Structureless:

Ma Massive (coherent)
S,g Single grain (noncoherent)

Miscellaneous structures of geologic rather than pedologic origin:

6. Precedes all grade notations for structure of geologic origin
≠ Horizontal blocky structure
≠ R Rough-surface horizontal blocks
≠ I Irregular-surface horizontal blocks
≠ S Smooth-surface horizontal blocks
Laminations

Varves

Stratification

Bedded, unweathered

Bedded, partially weathered

**Structure class (size of peds):**
- va Very fine peds
- a Fine peds
- b Medium peds
- c Coarse peds
- vc Very coarse peds

**Structure grade (strength of ped development):**
- 0 Massive-no peds
- 3 Low-very weak peds
- 4 Ortho-very weak peds
- 5 High-very weak peds
- 6 Low-weak peds
- 7 Ortho-weak peds
- 8 High-weak peds
- 9 Low-moderate peds
- 10 Ortho-moderate peds
- 11 Ortho-moderate peds
- 12 High-moderate peds
- 13 Low-strong peds
- 14 Ortho-strong peds
- 15 High-strong peds
- 16 Low-very strong peds
- 17 Ortho-very strong peds
- 18 High-very strong peds

Example: 13b 7a 4. 

Primary peds are low-strong, medium, smooth-surface, short, subangular, flat-topped columns separating into secondary peds that are ortho-weak, fine, subangular blocks.

**Clay skins**

Clay skin abundance or pattern:
- Extremely patchy clay skins
- Very patchy clay skins
- Moderately patchy clay skins
- Slightly patchy clay skins
- Nearly continuous clay skins
Clay skin placement or orientation:

- Clay skins on the vertical faces of peds
- Clay skins on the horizontal faces of peds
- Clay skins on both the vertical and horizontal faces of the peds

The above symbols are used in conjunction with the following ped symbols:

P Primary peds
SP Subprimary peds
S Secondary peds
SS Subsecondary peds

- Clay skins lining root channels
- Clay skins lining tubular pores
- Clay skins lining stone pockets
- Clay skins lining worm cavities
- Clay skins lining worm channels
- Clay bridges between sand grains
- Clay films showing ridging

Example: —P (S ⇒ P
Thin, very patchy and moderately thick, extremely patchy clay films on both the vertical and horizontal faces of the primary peds and lining root channels and vertical tubular pores.

Disseminated carbonates or calcareousness:

Types of effervescence:

IVLH Instantaneous, very long-duration, high bubble-up action
IVLF Instantaneous, very long-duration, low-fizz action
ILH Instantaneous, long-duration, high bubble-up action
ILF Instantaneous, long-duration, low-fizz action
ISH Instantaneous, short-duration, high bubble-up action
ISF Instantaneous, short-duration, low-fizz action
DVLH Delayed, very long-duration, high bubble-up action
DVLF Delayed, very long-duration, low-fizz action
DLH Delayed, long-duration, high bubble-up action
DLF Delayed, long-duration, low-fizz action
DSH  Delayed, short-duration, high bubble-up action
DSF  Delayed, short-duration, low-fizz action

Strength of effervescence or degree of calcarceousness:
V1  Very weak effervescence or very weakly calcarceous
1   Weak effervescence or weakly calcarceous
2   Moderate effervescence or moderately calcarceous
3   Strong effervescence or strongly calcarceous
V3  Violent effervescence or very strongly calcarceous

Placement or orientation of effervescence or degree of calcarceousness:
P   Primary peds
SP  Subprimary peds
S   Secondary peds
SS  Subsecondary peds
I   In the interiors of peds
F   On the faces of peds

Example: 2-ILH-PI/1-ISH-PF
Moderately calcarceous with instantaneous, long duration, high bubble-up effervescence in the interiors of the primary peds and weakly calcarceous with instantaneous, short duration, high bubble-up effervescence on the faces of the primary peds.

Segregated and concretionary carbonates
Segregation and concretion size:
V3  Very small segregations or concretions
S   Small segregations or concretions
M   Medium segregations or concretions
L   Large segregations or concretions
VL  Very large segregations or concretions

Segregation and concretion abundance:
V1  Very few segregations or concretions
1   Few segregations or concretions
2   Common segregations or concretions
3   Many segregations or concretions
V3  Very many segregations or concretions

Segregations and concretion shape:
R   Round segregations or concretions
I   Irregular segregations or concretions

Segregation and concretion boundary characteristic:
a  Abrupt-boundary segregations or concretions
s  Sharp-boundary segregations or concretions
c  Clear-boundary segregations or concretions
d  Diffuse-boundary segregations or concretions

...
Placement or orientation of segregations and concretions:

- P Primary peds
- SP Subprimary peds
- S Secondary peds
- SS Subsecondary peds
- I In the interiors of the peds
- F On the faces of the peds

Example: 2-M-R-s-PI, V1-VS-R-d-PO

Common, medium, round, abrupt-boundary carbonate segregations in the interiors of the primary peds and a very few, very small, round, diffuse-boundary carbonate segregations on the faces of the primary peds.

Salts other than calcium and magnesium carbonates

Kind of salts:

- cs Gypsum
- sa Soluble salts other than gypsum

Size of salt segregations (SG) or nests of salt crystals (SN):

- VS Very small segregations or nests of crystals
- S Small segregations or nests of crystals
- M Medium segregations or nests of crystals
- L Large segregations or nests of crystals
- VL Very large segregations or nests of crystals

Abundance of segregations or nests of salt crystals:

- V1 Very few segregations or nests of crystals
- 1 Few segregations or nests of crystals
- 2 Common segregations or nests of crystals
- 3 Many segregations or nests of crystals
- V3 Very many segregations or nests of crystals

Boundary characteristic of salt segregations:

- a Abrupt-boundary segregations
- s Sharp-boundary segregations
- c Clear-boundary segregations
- d Diffuse-boundary segregations

Placement or orientation of salt segregations and nests of salt crystals:

- P Primary peds
- SP Subprimary peds
- S Secondary peds
- SS Subsecondary peds
- I In the interiors of the peds
- F On the faces of the peds
Example: V1-V3-e-sa-sa-PI, 3-3-a-mi-oc-s-PI
Very few, very small, sharp-boundary salt segregations
and many, small, abrupt boundary, nests of gypsum crystals in
the interiors of the primary peds.

Biological features
Worm casts, channels, and cavities:

\[\text{\textbullet} \quad \text{Worm casts}\]
\[\ast \quad \text{Worm channels; unfilled}\]
\[\ast \quad \text{Worm channels; filled}\]
\[\circ \quad \text{Worm cavities; unfilled}\]
\[\circ \quad \text{Worm cavities; filled}\]

Abundance of worm casts, channels, and cavities:

\(V1\) Very few worm casts or channels
\(1\) Few worm casts or channels
\(2\) Common worm casts or channels
\(3\) Many worm casts or channels
\(V3\) Very many worm casts or channels

Size of worm casts and channels:

\(va\) Very small worm casts or channels
\(a\) Small worm casts or channels
\(b\) Medium worm casts or channels
\(c\) Large worm casts or channels
\(vs\) Very large worm casts or channels

Size of worm cavities:

\(va\) Very small worm cavities
\(a\) Small worm cavities
\(b\) Medium worm cavities
\(c\) Large worm cavities
\(vs\) Very large worm cavities

Krotovinas:

\(K\) Krotovinas

Abundance of krotovinas:

Actual number

Size of krotovinas:

\(va\) Very small krotovinas
\(a\) Small krotovinas
\(b\) Medium krotovinas
\(c\) Large krotovinas
\(vs\) Very large krotovinas

Examples: V1-va\(\ast\), 3b\(\circ\)
Very few, very small worm casts and unfilled worm
channels, and many, medium, filled worm cavities.

la, 2b K
One small and two medium krotovinas

Quartz grains
Shape of quartz grains:
- Round quartz grains
- Subangular quartz grains
- Angular quartz grains
- Same as the above three, but showing percussion marks
  - P Few percussion scars
  - P Common percussion scars
  +P Many percussion scars

Condition of quartz grains:
- Unstained, transparent quartz grains
- Unstained, translucent quartz grains
- Lightly stained, transparent quartz grains
- Lightly stained, translucent quartz grains
- Darkly stained, transparent quartz grains
- Darkly stained, translucent quartz grains

Agents involved in staining of quartz grains:
- OM Organic matter
- Fe Iron
- Mn Manganese

Size of quartz grains:
- VF Very fine quartz grains
- F Fine quartz grains
- M Medium quartz grains
- C Coarse quartz grains
- VC Very coarse quartz grains

Abundance of quartz grains:
If not oriented as coats on pedes:
- VF Very few quartz grains
- F Few quartz grains
- C Common quartz grains
- M Many quartz grains
- VM Very many quartz grains

If as oriented coats on pedes:
- EPC Extremely patchy quartz grain coats
- VPC Very patchy quartz grain coats
- MPC Moderately patchy quartz grain coats
- SPC Slightly patchy quartz grain coats
- NCC Nearly continuous quartz grain coats
CC Continuous quartz grain coats

Thickness of oriented quartz grain coatings:
1 Thin coating of quartz grains
2 Moderately thick coating of quartz grains
3 Thick coating of quartz grains
4 Very thick coating of quartz grains

Placement or orientation of quartz grains:
P Primary peds
SP Subprimary peds
S Secondary peds
SS Subsecondary peds
I In the interiors of peds
F On the faces of peds

Example: VF=Fe, M=Fe, 1-VPC=VF, P
A very few, fine and medium, lightly iron stained, translucent, subangular quartz grains throughout and with thin, very patchy coatings of very fine, unstained, translucent, subangular quartz grains on the vertical faces of the primary peds.

Dark minerals and feldspars
Kind of minerals:
DM Dark minerals
F Feldspars

Shape of mineral grains:
∩ Round mineral grains
◇ Subangular mineral grains
□ Angular mineral grains

Abundance of mineral grains:
VF Very few mineral grains
F Few mineral grains
C Common mineral grains
M Many mineral grains
VM Very many mineral grains

Size of mineral grains:
VF Very fine mineral grains
F Fine mineral grains
M Medium mineral grains
C Coarse mineral grains
VC Very coarse mineral grains

Placement or orientation of mineral grains:
P Primary peds
SP Subprimary peds
Tubular pores

Abundance of tubular pores:
VF Very few tubular pores
F Few tubular pores
C Common tubular pores
M Many tubular pores
VM Very many tubular pores

Size of tubular pores:
Cross sectional size of tubular pores:
VF Very fine tubular pores
F Fine tubular pores
M Medium tubular pores
L Large tubular pores
VL Very large tubular pores

Length of tubular pores:
VS Very short tubular pores
S Short tubular pores
M Moderately long tubular pores
L Long tubular pores
VL Very long tubular pores

Shape of tubular pores:
Cross sectional shape of tubular pores:
• Round tubular pores
• Oblong tubular pores

Transverse sectional shape of tubular pores:
○ Linear tubular pores
○ Curved tubular pores
○ Complex tubular pores

Direction of tubular pores:
↓ Vertical tubular pores
→ Horizontal tubular pores
↑ Angular tubular pores
← Multidirectional tubular pores
Pattern of tubular pores:
- Simple or unbranched tubular pores
- Compound or branched tubular pores

Internal condition of tubular pores:
- Unobstructed tubular pores
- Tubular pores obstructed with roots
- Tubular pores obstructed with clay

Placement or orientation of tubular pores:
- In the interiors of peds (I)
- On the faces of peds (F)

Example: M-VF-SØ, VF-H-MLØ, I

Consistency of moist soil:
- Loose moist consistency (L)
- Very friable moist consistency (VFR)
- Friable moist consistency (FR)
- Firm moist consistency (F)
- Very firm moist consistency (VF)
- Extremely firm moist consistency (EF)

Consistency of dry soil:
- Loose dry consistency (L)
- Soft dry consistency (S)
- Slightly hard dry consistency (SH)
- Hard dry consistency (H)
- Very hard dry consistency (VH)
- Extremely hard dry consistency (EH)

Horizon boundaries

Distinctness of boundary:
- Abrupt horizon boundary (a)
- Clear horizon boundary (c)
- Gradual horizon boundary (g)
- Diffuse horizon boundary (d)

Topography of boundary:
- Smooth horizon boundary (s)
- Wavy horizon boundary (w)
1 Irregular horizon boundary
2 Broken horizon boundary

Example: aw
This changes abruptly with a wavy boundary to:
### Table 1. Laboratory Data for Profile T-1

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth in inches</th>
<th>Particle size distribution</th>
<th>pH</th>
<th>Percent organic carbon</th>
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<td>Percent sand</td>
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<td>Percent clay</td>
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### Percent nitrogen C/N ratio

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<tr>
<th>Percent nitrogen</th>
<th>C/N ratio</th>
<th>Percent moisture at saturation</th>
<th>Percent CaCO₃ equiv.</th>
<th>Gypsum me./100 gm. soil</th>
<th>EC x 10² millimhos per cm. at 25°C</th>
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--- Determination not made.
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--- Determination not made.
Tr. Determination made but amount determined was below minimum reportable value.
### Table 2. Laboratory Data for Profile T-2

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### Percent C/N ratio

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<th>C/N moisture at saturation</th>
<th>Percent CaO3</th>
<th>Percent gypsum</th>
<th>Electro conductivity</th>
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<td></td>
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<td></td>
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<td>EC x 10³ millimhos</td>
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*Tr. Determination made, but the amount determined was below the minimum reportable value.*
Table 2. (Continued)

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<th>Cation exchange capacity me./100 gm. soil</th>
<th>Extractable cations miliequivalents per 100 gm. of soil</th>
<th>Base saturation percentage on sum + H</th>
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<table>
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--- Determination not made.
Tr. Determination made but amount determined was below minimum reportable value.
### Table 3. Laboratory Data for Profile T-3

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<th>Percent silt</th>
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<th>pH 1:1</th>
<th>pH 1:5</th>
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### Table 3. (Continued)

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<th>Percent moisture at saturation</th>
<th>Percent CaCO₃</th>
<th>Gypsum me./100 gm. soil</th>
<th>Electric conductivity EC x 10⁻³ millimhos per cm. @ 25°C</th>
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* Determination not made.*
Table 3. (Continued)

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<th>Cation exchange capacity m.e./100 gm. soil</th>
<th>Extractable cations miliequivalents per 100 gm. of soil</th>
<th>Base saturation percentage on sum + H</th>
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--- Determination not made.
Tr. Determination made but amount determined was below minimum reportable value.
Table 4. Laboratory Data for Profile T-4

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<th>Percent clay</th>
<th>Percent paste</th>
<th>pH</th>
<th>Percent organic carbon</th>
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<th>Percent nitrogen</th>
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<th>Percent moisture at saturation</th>
<th>Percent CaCO₃</th>
<th>me./100 gm.</th>
<th>Elect. conductivity EC x 10³ millimhos per cm. @ 25°C</th>
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-- Determination not made.
Tr. Determination made but the amount determined was below the minimum reportable value.
Table 4. (Continued)

<table>
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<th>Cation exchange capacity me./100 gm. soil</th>
<th>Extractable cations millequivalents per 100 gm. of soil</th>
<th>Base saturation percentage on sum + H</th>
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--- Determination not made.
Tr. Determination made but amount determined was below the minimum reportable value.

Saturation extract soluble cations millequivalents per liter

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Percent exchangeable cations

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<td>--</td>
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<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

--- Determination not made.
### Table 5. Laboratory Data for Profile T-5

<table>
<thead>
<tr>
<th>T-5</th>
<th>S-59-SD-59-11</th>
<th>Particle size distribution</th>
<th>Percent organic carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizon Depth in inches</td>
<td>Horizon Depth in inches</td>
<td>sand</td>
<td>silt</td>
</tr>
<tr>
<td>A1</td>
<td>0-3</td>
<td>A1 0-7</td>
<td>34.5</td>
</tr>
<tr>
<td>B2A1</td>
<td>3-6</td>
<td>B2 7-14</td>
<td>37.8</td>
</tr>
<tr>
<td>B2</td>
<td>6-13</td>
<td>B3 14-18</td>
<td>34.8</td>
</tr>
<tr>
<td>B2ca</td>
<td>18-21</td>
<td>Cca 18-42</td>
<td>45.4</td>
</tr>
<tr>
<td>B31ca</td>
<td>21-25</td>
<td>C1 42-53</td>
<td>43.6</td>
</tr>
<tr>
<td>B32ca</td>
<td>25-33</td>
<td>C2 53-60</td>
<td>47.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>**</th>
<th>Percent moisture of CaCO₃ equiv. per cm 3 25° C.</th>
<th>Electrical conductivity EC x 10⁻³ millimhos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat. 1:5 1:10 paste</td>
<td>Percent nitrogen ratio</td>
<td>C/N</td>
<td>Percent saturation</td>
</tr>
<tr>
<td></td>
<td>Determinations made by this study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Determinations made by this study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>** Calculated from organic carbon.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- Determination not made.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tr. Determination made but the amount determined was below the minimum reportable value.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| pH | 5.9 | 6.2 | 6.7 | 0.226 | -- | -- | Tr. | 0.7 |
|    | 6.8 | 6.9 | 7.3 | 0.076 | -- | -- | Tr. | 0.3 |
|    | 7.1 | 7.4 | 8.0 | 0.071 | -- | -- | Tr. | 1.0 |
|    | 7.7 | 8.1 | 8.9 | 0.034 | -- | -- | 17  | 1.4 |
|    | 7.9 | 8.2 | 9.1 | --   | -- | 12 | 4.0 |
|    | 7.9 | 8.3 | 9.2 | --   | -- | 13 | 5.0 |
Table 5. (Continued)

<table>
<thead>
<tr>
<th>Cation exchange capacity me./100 gm. soil</th>
<th>Extractable cations millequivalents per 100 gm. of soil</th>
<th>Base saturation percentage on sum + H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca  Mg  Na  K  H</td>
<td></td>
</tr>
<tr>
<td>22.8</td>
<td>--  --  0.1  1.2  --</td>
<td>--</td>
</tr>
<tr>
<td>23.6</td>
<td>--  --  0.1  0.7  --</td>
<td>--</td>
</tr>
<tr>
<td>23.0</td>
<td>--  --  0.1  0.7  --</td>
<td>--</td>
</tr>
<tr>
<td>13.8</td>
<td>--  --  0.6  0.2  --</td>
<td>--</td>
</tr>
<tr>
<td>13.6</td>
<td>--  --  1.8  0.2  --</td>
<td>--</td>
</tr>
<tr>
<td>12.8</td>
<td>--  --  1.9  0.2  --</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saturation extract soluble cations millequivalents per liter</th>
<th>Percent exchangeable cations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca  Mg  Na  K</td>
<td>Ca  Mg  Na  K</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  Tr.  --</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  Tr.  --</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  Tr.  --</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  --  --</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  --  --</td>
</tr>
<tr>
<td>--  --  --  --</td>
<td>--  --  --  --</td>
</tr>
</tbody>
</table>

-- Determination not made.
Tr. Determination made but amount determined was below minimum reportable value.
Table 6. Laboratory Data for Profile T-6

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth in inches</th>
<th>Particle size distribution</th>
<th>Percent</th>
<th>Percent</th>
<th>Percent</th>
<th>pH</th>
<th>sat. 1:5</th>
<th>1:10 organic carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0-4</td>
<td></td>
<td>31.9</td>
<td>46.4</td>
<td>21.7</td>
<td></td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>B21</td>
<td>4-8¾</td>
<td></td>
<td>36.7</td>
<td>35.7</td>
<td>27.6</td>
<td></td>
<td>6.4</td>
<td>6.8</td>
</tr>
<tr>
<td>B22</td>
<td>8¾-13</td>
<td></td>
<td>33.6</td>
<td>35.3</td>
<td>31.1</td>
<td></td>
<td>7.0</td>
<td>7.2</td>
</tr>
<tr>
<td>B2ca</td>
<td>13-21</td>
<td></td>
<td>30.7</td>
<td>35.5</td>
<td>33.8</td>
<td></td>
<td>7.7</td>
<td>8.2</td>
</tr>
<tr>
<td>B31caes</td>
<td>21-27</td>
<td></td>
<td>35.6</td>
<td>37.5</td>
<td>26.9</td>
<td></td>
<td>7.9</td>
<td>8.7</td>
</tr>
<tr>
<td>B32caes</td>
<td>27-36</td>
<td></td>
<td>40.3</td>
<td>39.2</td>
<td>20.5</td>
<td></td>
<td>8.2</td>
<td>9.0</td>
</tr>
<tr>
<td>C1caes</td>
<td>36-46</td>
<td></td>
<td>39.8</td>
<td>37.7</td>
<td>22.5</td>
<td></td>
<td>8.3</td>
<td>9.0</td>
</tr>
<tr>
<td>C2ccs</td>
<td>46-60+</td>
<td></td>
<td>39.1</td>
<td>39.5</td>
<td>21.5</td>
<td></td>
<td>8.0</td>
<td>8.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent nitrogen</th>
<th>C/N ratio</th>
<th>Percent moisture at saturation</th>
<th>Percent CaCO₃</th>
<th>Percent gypsum</th>
<th>%</th>
<th>Electric conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>sat.</td>
<td>equiv.</td>
<td>soil</td>
<td></td>
<td>per cm. @ 25°C</td>
</tr>
<tr>
<td>.216</td>
<td>12.0</td>
<td>50.3</td>
<td>Tr.</td>
<td>0</td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>.134</td>
<td>9.2</td>
<td>47.9</td>
<td>Tr.</td>
<td>0</td>
<td></td>
<td>0.6</td>
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<tr>
<td>.104</td>
<td>9.5</td>
<td>50.7</td>
<td>Tr.</td>
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<td>0.8</td>
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<tr>
<td>.076</td>
<td>9.7</td>
<td>52.2</td>
<td>21</td>
<td>Tr.</td>
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<td>0.6</td>
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<tr>
<td>.044</td>
<td>9.3</td>
<td>44.1</td>
<td>17</td>
<td>Tr.</td>
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<td>0.7</td>
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<td>--</td>
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<td>44.6</td>
<td>14</td>
<td>Tr.</td>
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<td>--</td>
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<td>51.2</td>
<td>14</td>
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<td>2.2</td>
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<tr>
<td>--</td>
<td></td>
<td>48.0</td>
<td>12</td>
<td>Tr.</td>
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<td>3.6</td>
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</tbody>
</table>

-- Determination not made.
Tr. Determination made but the amount determined was below the minimum reportable value.
Table 6. (Continued)

<table>
<thead>
<tr>
<th>Cation exchange capacity me./100 gm. soil</th>
<th>Extractable cations millequivalents per 100 gm. of soil</th>
<th>Base saturation percentage on sum + H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca</td>
<td>Mg</td>
</tr>
<tr>
<td>20.2</td>
<td>13.4</td>
<td>4.7</td>
</tr>
<tr>
<td>22.1</td>
<td>14.6</td>
<td>6.7</td>
</tr>
<tr>
<td>23.3</td>
<td>17.8</td>
<td>7.8</td>
</tr>
<tr>
<td>17.3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>14.8</td>
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<td>--</td>
</tr>
<tr>
<td>13.3</td>
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<td>15.1</td>
<td>--</td>
<td>--</td>
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<tr>
<td>14.9</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saturation extract soluble cations millequivalents per liter</th>
<th>Percent exchangeable cations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>Mg</td>
</tr>
<tr>
<td>4.8</td>
<td>2.8</td>
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<tr>
<td>3.3</td>
<td>2.5</td>
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</tr>
<tr>
<td>0.7</td>
<td>1.9</td>
</tr>
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<td>1.0</td>
<td>3.2</td>
</tr>
<tr>
<td>6.8</td>
<td>20.8</td>
</tr>
</tbody>
</table>

-- Determination not made.
Tr. Determination made but the amount determined was below the minimum reportable value.