Soil classification in Polk County, Iowa

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SOIL CLASSIFICATION IN POLK COUNTY, IOWA

by

Ralph Joseph McCracken

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major Subject: Soil Morphology and Genesis

Approved:

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1956
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INTRODUCTION

Soil classification has as its immediate objectives organization of knowledge about soils, helping to remember soil properties, bringing out soil relationships and differences, and provision of units for predictive statements. Ideally, these objectives seem best met by a natural or scientific system of soil classification. This implies classification of soils according to those properties about which the greatest possible number of statements can be made. Because knowledge of soil is yet very incomplete and new knowledge is continually being gained, it seems desirable that soil classification should evolve through a series of approximations. This evolution should be guided by theory and principles in order that the criteria and classes be as objective as possible.

First published attempts at systematic soil classification were by European workers in the nineteenth century. These classifications were for the most part based on a single soil property important to agriculture or geologic origin. At the end of the nineteenth century and the start of the twentieth century, Russian soil scientists developed the concept of soil as a natural body and classified soils according to soil-forming factors. Soil classification and mapping in the United States commenced about 1900.
A geologic definition of soil as a surficial material was accepted by most of the early American investigators, consequently soil map units coincided with geologic or physiographic units for the most part. A few years later, C. F. Marbut was largely responsible for a shift by most American soil scientists to a concept of soil as a natural body and to classification by soil profile properties. Marbut (1927, 1935) emphasized the soil profile as the fundamental unit of study and developed a multiscategorical classification scheme.

The present generally accepted soil classification scheme, as outlined in the 1938 U. S. Department of Agriculture Yearbook (Baldwin, Kellogg, and Thorp, 1938) with modifications suggested in 1949 (Thorp and Smith, 1949; Riecken and Smith, 1949) is essentially that developed by Marbut with certain modifications.

Evolution of the concept of the soil series as a basic mapping and taxonomic unit in Polk County and central Iowa can be seen in soil maps and reports prepared during the past 50 years in this area. Graphic illustration in terms of numbers of soil series, types, and total map units is shown in Figure 1. (Only the northern portion of Polk County has been included in order that areas of similar soil patterns could be compared.) The greatly increased number of soil series and map units is a reflection of the narrowing of the definition of the series and increasing use of subdivisions.
Figure 1. Increase in numbers of soil series, types and map units in 50 years of soil studies in central Iowa.
of soil series in order to increase the number of predictive statements that can be made. The increased number is also a reflection of increased knowledge about soil properties and soil behavior, and the desire to more adequately express theories of soil genesis. Increases in number have been accompanied by shifts in nomenclature.

As an example of nomenclature and concept shift, seven of 14 soil series recognized in the 1921 Polk County soil survey (Smies, Corson, and Meister, 1921) were recognized in the recently completed Polk County soil survey (McCracken, McClelland, and others, 1953). All seven had been redefined in soil surveys since 1921 such that their range of properties is much narrower in the newer Polk County investigation. The seven series dropped from the 1921 list have been redefined such that their area of occurrence no longer includes Polk County. Discussion of the historical development of concepts of specific soil series is beyond the scope of the present study, however.

Very few published statements have been made concerning the rationale of the shifts in concepts of soil series and of broader soil taxonomic units. The county soil survey reports, for example, have not indicated the logic for redefinition and subdivision of soil series and for the shifts in nomenclature which have occurred.

Basic theory and logic of the present U. S. Department of
Agriculture multiclassification soil taxonomic scheme needs to be critically examined, as has been pointed out by Thorp and Smith (1949). Postulation of complementary and perhaps alternative approaches to soil classification (Jenny, 1941, 1946) and questioning of the basis of the multiclassification taxonomic approach (Crocker, 1952) indicate the need for study of the theoretical background of soil classification and the need for testing other approaches.

In the present study, the U. S. Department of Agriculture multiclassification taxonomic scheme is evaluated and improvements are suggested in relation to classification of soils of Polk County, Iowa, with the view of increasing objectivity, predictive power, and organization of soil knowledge. General genetic trends of soils in this county are indicated, though soil genetic studies are beyond the scope of the study. Role of the functional, factorial approach and of the soil sequence (Jenny, 1941, 1946) is tested. Some of the general trends and problems in soil taxonomy are summarized.

This study has been delimited to Polk County, Iowa for a number of reasons. The magnitude of the problem is decreased. The writer is familiar with the soils of the area through field mapping (McCraeken, McClelland, and others, 1956). There is a multiplicity of soil-forming factors in the county, including several kinds of parent material, which has made several classification problems.
Location of Polk County and the soil patterns within it are shown in Figure 2.
Figure 2. Location of Polk County and principal soil association areas
PRINCIPAL SOIL ASSOCIATION AREAS IN IOWA

- Principal Soil Associations:
  - SSW: Shelby, Sharpsburg, and Winterset
  - F: Fayette
  - GPS: Galva, Primghar, and Buxton
  - SC: Grundy and Haig
  - M: Marshall
  - Mo: Moody
  - MI: Monona and Hamburg
  - MPS: Marcus, Primghar, and Cal
  - ST: Storer, Clarion, and Webster
  - SSW: Shelby, Grundy, and Haig
  - SSE: Shelby, Seymour, and Edina
  - WL: Weller and Lindley

- New Names Not on County Soil Maps:
  - SSW: Shelby, Sharpsburg, and Winterset
  - F: Fayette
  - GPS: Galva, Primghar, and Buxton
  - SC: Grundy and Haig
  - MPS: Marcus, Primghar, and Cal
  - ST: Storer, Clarion, and Webster
  - SSW: Shelby, Grundy, and Haig
  - SSE: Shelby, Seymour, and Edina
  - WL: Weller and Lindley

- Map Symbols:
  - Abrupt Boundary
  - Tentative Boundary
  - Gradational Boundary

- Scale: 24 Miles, approx.
Development of the Concept of Soil and Soil Units

Concept of Soil

Concept of soil held by those making the first published attempts at soil classification was either of soil as a natural medium for plant growth or as a surficial geologic material. Consequently these late nineteenth century soil workers classed soil either according to its productivity or some property related to productivity (Thaer, cited in Glinka, 1927) or according to origin of the geologic parent material (Fallou, 1862; Richtofen, 1886). Factors probably involved in this agricultural and geologic bias of these western European workers were the intensive cultivation of western European soils, the rather wide range of geologic material under similar climate in western Europe, and the relatively high degree of advancement of geology during this period.

Concept of soil as a natural independent body was developed by Russian soil investigators during the period 1870-1915 (Afanasiev, 1927; Wilde, 1946; Crocker, 1952). Dokuchaiev (1879) has been credited with first developing the concept of soil as a dynamic natural body formed by the soil forming factors of climate, vegetation, time, parent
material and topography. For this reason, Dokuchalev can be considered the founder of modern soil classification. Sibirtsiev (1890, 1898), a student of Dokuchalev, emphasized the development of different soil properties under different climatic regimes. Glinka (1914) developed and emphasized the concept of the soil profile, consisting of horizons, or genetically-produced layers, formed by soil development. Glinka also emphasized the role of moisture in soil development.

Concept of soil held by most of the early American soil scientists interested in soil genesis and classification was essentially that of soil as a surficial geologic material which differed in suitability for plant growth due to differences in texture, or particle size distribution (U. S. Department of Agriculture, 1899; Whitney, 1908; Simonson, 1952). Exceptions were Shaler (1891) and Hilgard (1906). Shaler defined soil as a natural body; Hilgard pointed out property differences between soils of humid and arid regions. This strong geologic bias in early American soil classification began with the first field mapping of soils in 1899 (U. S. Department of Agriculture, 1899) and continued until about 1920.

During this period, Coffey (1911) advocated abandonment of the concept of soil as a geologic material and acceptance of the concept of soil as a natural body functionally depend-
ent on soil-forming factors. However, Coffey seemed to have been ahead of his time, for these concepts did not become prominent in soil classification in the United States until advocated by Marbut (1921, 1922, 1927) about ten years later.

Marbut crystallized the thinking of his associates in American soil classification by de-emphasizing the strong geologic bias and drawing heavily upon earlier Russian concepts to develop a new approach to soil classification in the United States. Marbut (1927) emphasized the soil profile, the series of superimposed genetic layers in a soil, as the fundamental unit of soil study. In this 1927 paper, Marbut developed his concept of normal soil as a frame of reference. He postulated that in every region with normal relief there is a normal soil profile. Marbut's concept of normal relief was terrain with gentle or rolling slopes. Normal soils were considered to be mature in that they were postulated to be in equilibrium with their environment.

Concepts of soil developed by Marbut have been continued with but little modification in soil classification in the United States. Perhaps the greatest modification has seen development of concept of soil as a dynamic three-dimensional landscape (Ableiter, 1949; U. S. Department of Agriculture, 1951).

Concept of soil as a system with a functional relationship between soil properties and soil-defining or soil-
forming factors has been developed by Jenny (1941). Concept of soil as a function of soil-forming factors was first formulated by Dokuchaiev (1879), though not in quantitative terms. Considering the soil-defining factors as independent variables, Jenny has derived a relationship denoted by him as the fundamental equation:

\[ S = f(c_1, o, p, r, t \ldots) \]

where \( S \) = any soil property, \( c_1 \) = climate (environmental), \( o \) = organisms, \( p \) = parent material (defined as state of the soil system at time zero of soil formation), \( r \) = relief (topography), \( t \) = period of soil formation ("age" of soil) and the dots represent any additional factors which should be considered.

Full implications of this functional, factorial definition and concept of soil for soil taxonomy have not yet been evaluated.

**Broad soil units, higher levels of generalization**

Broad soil units, both taxonomic and cartographic, were developed by the early Russian students of soil on the basis of differing genesis of soils in accordance with their concept of soil. Dokuchaiev (1879) distinguished "normal" soils and "extranormal" soils as primary broad classes, substratified into broad groups of soils with similar profiles.
Dokuchaiev's normal soils (from which Marbut developed his concept of normal soils) were those produced by soil-forming processes; extranormal soils were eroded or freshly deposited soils. Sibirtsev (1895) gave primary emphasis to climate, consequently proposed three very broad groups of zonal, intrazonal, and azonal soils. Sibirtsev conceived zonal soils as "wholly developed" and occurring in zones corresponding to climatic zones. Intrazonal soils were defined as having formed where local soil forming forces such as relief (topography) and parent material have predominated over the zonal or climatic forces. Sibirtsev defined azonal soils as those on borders of soil zones and not confined to any one zone. These broad classes are essentially comparable to those of the highest level of generalization in the present U. S. Department of Agriculture soil classification outline (Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949).

Glinka (1914, 1927) postulated a somewhat different approach. His broadest units or primary differentiation consisted of two classes, one of which consisted of soils influenced in development by internal factors, primarily nature of the parent rock, and the second developed under influence of external soil formational factors. Glinka's second level of generalization recognized classes according to moisture content (optimum, average, excessive, insufficient). His third highest level of generalization consisted of soils with
broadly similar profiles and assigned folk names. These concepts have been continued with some modification in the presently recognized great soil groups (Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949). Glinka placed more emphasis on differentiating broad groups according to soil characteristics than did Dokuchaiev or Sibirtsev.

In summary, it seems that these early Russian workers placed too much emphasis on one or two soil-forming factors, such as Sibirtsev's emphasis of climate and Glinka's emphasis on parent material and moisture. Also, their broad groups were differentiated largely on measured or assumed variations in the genetic factors themselves rather than by the soil profile properties resulting from influence of these factors, which means that soils cannot be classified until their genesis is known.

Many of the concepts of broad soil units developed by these early Russian workers have been made a part of the present U. S. Department of Agriculture soil classification with some modification.

Concept of broad soil units in the early days of soil classification in the United States was that of soil provinces essentially comparable to physiographic provinces, as described by Whitney (1908). Thirteen great soil provinces within the United States were established, described by Whitney as broad groupings of certain soil similarities due in
part to character of the geologic parent material and in part
to the dominant agencies responsible for the character of the
province (such as metamorphism, regional uplift, and glacia-
tion). Inspection of Whitney's map of soil provinces shows
Iowa entirely within the "glacial and loessial" soil province.

Inadequacies of the soil province as a broad soil unit
were soon realized due to the finding of greatly different
soil profiles within a given soil province. Modification of
soil provinces to groups based on soil properties was advo-
cated at an early date by Coffey (1911). He distinguished
major soil groups of the United States based upon soil differ-
ences "due to variations in the processes of formation result-
ing from dissimilar climatic conditions." Coffey established
a number of broad soil units which were forerunners of present
day great soil groups, as defined by Baldwin, Kellogg, and
Thorp (1938). Distribution of "dark-colored prairie soils"
and "light-colored timbered soils" in Iowa as defined by
Coffey and shown on his map of soils of the United States is
shown in Figure 3. Boundary between the substratification
of prairie soils from till and those from loess extends
across Polk County on this map.

Concepts of broad soil units based upon soil differ-
ences reflecting differences in soil-forming factors as adva-
ced by Coffey apparently did not meet with general accep-
tance in soil classification in the United States until
Figure 3. Broad soil units in Iowa as conceived by Coffey (1912)

PG: dark-colored prairie soils from ice-laid deposits (glacial)

PW: dark-colored prairie soils from wind-laid deposits (aeolian)

TWMi: light-colored timbered soils from wind-laid deposits (aeolian, Mississippi loess)
restated several years later by Marbut (1922, 1927). For example, in the Polk County soil report of 1921 (Smies, Corson, and Meister, 1921), soils were placed in three broad groups according to the nature of the geologic material from which they developed. Differences between soils developed under forest as compared to soils formed under prairie vegetation were largely attributed to more active erosion preventing accumulation of organic matter in the former soils, a rather different concept than that of Coffey. Study of published soil survey reports for Iowa counties indicates that it was not until 1925 that soils were grouped into "light-colored timbered" and "dark-colored prairie" broad soil units, with de-emphasis of geological materials.

Increasing realization by American soil survey workers of the inadequacy of the concepts and definitions of soil units led C. F. Marbut, chief of Soil Survey in the U. S. Department of Agriculture, 1913-1935, to develop a comprehensive multicategorical soil classification system, drawing heavily upon the earlier Russian works (Marbut, 1927, 1935). Marbut laid down the principle that the broad soil classes in the higher categories, the higher levels of generalization, should be based on features of fully developed and mature or normal soil profiles since normal soil was his frame of reference. Consequently, wet soils, "young" soils without complete profiles, alkali soils, and soils with
genetic layers of induration or compaction ("pan" soils) were not classed in the broad units of the higher levels of generalization of Marbut's classification. His reasoning was that soil classification should be based on "stable, permanent features," comparable to classification in biological sciences based on mature individuals.

Criterion selected by Marbut (1927) for the primary stratification of all normal soils into two broad units or classes was presence or absence of a calcium carbonate accumulation zone in higher amounts than in the parent material in some horizon of the true soil, independent of the nature of the parent material. These were designated as Pedocals and Pedalfers, respectively. An accessory feature of the Pedalfers was postulated to be either a shifting or an accumulation of sesquioxide, or both, in the solum (A and B horizons). Marbut (1935) drew a line through the central United States, west of which were Pedocals and east of which were Pedalfers. All of Iowa except the northwest corner is east of this line. Thus, according to Marbut's criterion and demarcation, all normal soils of Polk County are Pedalfers.

The generalization level below that of Pedocals and Pedalfers was designated as consisting of inorganic colloid composition groups by Marbut (1927, 1935). These classes were differentiated on basis of decomposition products of parent material, presumed to correlate with climatic differ-
ences. The next lower category was defined by Marbut as consisting of great soil groups, or classes of normal soils of regions of similar environment. These great soil groups were defined somewhat narrower than by Coffey (1912) or by the earlier Russian workers in soil classification.

Impact of Marbut's work can readily be seen in a study of Iowa county soil survey reports published during this period. The soil survey report for Union County, Iowa published in 1927 (Elwell and Moran, 1927) included for the first time in an Iowa county soil report (more than 25 had been previously published) a discussion of soil-forming factors other than geological parent material, a soil profile description of major soils, and the use of the term regional profile. The term regional profile is a synonym for the normal profile concept of Marbut. Iowa county soil survey reports following this date have shown much redefinition of soil map units according to the concept of differentiation according to soil profile properties, give some description of soil-forming factors, and show placement of map units in broader soil units.

Though Marbut's approach constituted a major advance, need for a number of improvements and re-evaluations can be shown. Failure to classify soils other than normal soils at the higher categorical levels is a serious theoretical weakness, as pointed out by Cline (1949a). Concept of Pedalfers
and Pedocals has not proved useful in soil classification. Soils with Pedalfer-like profiles in the Pedalfer zone have been found to have lime accumulations. It is not possible to judge in many soils whether presence or absence of a calcium carbonate accumulation zone is pedogenic or inherited from the parent material. Bias of the normal soils as a frame of reference in classification seems too strong.

The multicategorical soil classification scheme developed by Marbut and his associates has been modified to comprise the present official U. S. Department of Agriculture soil classification. The major part of these revisions was presented by Baldwin, Kellogg and Thorp (1938) in the 1938 Yearbook of Agriculture. Some recent revisions have been discussed by Thorp and Smith (1949). Modifications in the Marbut classification introduced in the 1938 Yearbook of Agriculture (Baldwin, Kellogg, and Thorp, 1938) were:

a. Dropping of the concept of Pedalfers and Pedocals as the primary classification and substitution of the concept of zonality essentially as first outlined by Sibirteev (1895, 1897). This highest category was named the "order". Three classes were established - zonal, interzonal, and azonal soils.

b. The inorganic colloid composition groups of the second highest categorical level were dropped and
soil "suborders" were substituted.

c. All soils were classified at all categories.

The revisions published by Thorp and Smith (1949) included redefinition of some of the great soil groups.

Some questions concerning this multicategorical classification scheme and some suggested improvements are presented in a later section dealing with placement of Polk County soils in the classification.

Soil units of lower levels of generalization

Development of concepts of soil units of lower levels of generalization as they relate to Polk County soil classification can best be illustrated by tracing the evolution of soil units during soil mapping of Polk County and adjoining Story County (Figure 1) within the past 50 years as a reflection of changes in concepts. Special emphasis is placed on the soil series, since it is the basic unit of soil mapping and of predictive statements.

Soil series as a term for a soil unit was developed by Whitney (1908) and co-workers in the early days of soil classification in the United States. Whitney described soil series as soils "alike in all respects except in texture and in such physical properties as texture determines." Soil series were defined on the basis of similarity in origin of
material and to a limited extent natural drainage and color were considered. Because soil series were assumed correlated with geologic formations or physiographic units, they were assumed to display a series of textures (particle size distribution) associated with the range in textures of the geologic unit or the physiographic area, hence the name "series". Soil types within the series were defined by Whitney as soils "alike in all respects." Consequently, soil series were very much broader in early American soil classification than in present usage, as has been pointed out by Simonson (1952).

Examples of the early concepts of soil series can be seen in the soil map and report for Story County, Iowa, published in 1904 (Marean and Jones, 1904). Story County is immediately north of Polk County and has a soil pattern comparable to that of the northern four-fifths of Polk County (Figure 2). A total of two soil series and five types were recognized. The Marshall soil series was mapped in the areas with original prairie vegetation, with soil types of loam, fine sand, and clay loam. Miami soil series was mapped not only in the areas of original forest cover as Miami clay loam, but also on the floodplains for rather recently deposited dark and clayey soil material as Miami black clay loam. Other areas of alluvial soil material were simply designated as Meadow.
The soil map and report for Polk County published in 1921 (Smiles, Corson, and Meister, 1921) illustrates much narrowing of the soil series concept and many shifts in nomenclature since the Story County report was published. This Polk report listed 11 soil series and 27 soil types for the area with soil pattern comparable to that of Story County. Neither the Marshall nor Miami series was recognized in this survey. The Marshall series concept apparently had been shifted to something near its present concept of a loess-derived prairie soil of medial horizon development in western Iowa (Simonson, Riecken, and Smith, 1952) and the Miami had apparently been narrowed to a till-derived forested soil in the eastern Corn Belt (Brown and Thorp, 1942). Soil series recognized on the prairie-covered portion of the Late Wisconsin till plain were Carrington loam and fine sandy loam, Shelby loam, and Webster clay loam and silty clay loam. The Webster soil was described as having poor natural drainage, indicating a trend to series differentiation, according to profile properties.

The Lindley series was recognized in the forested areas on the basis of soil properties. In southern Polk County, the loess-derived soils were differentiated into the Tama soil series for those formed under prairie vegetation and the Clinton for those formed under forest vegetation. A large number of soil series were recognized on the outwash terraces.
and flood plains partly on the basis of their physiographical position and partly on the basis of broad textural differences.

In summary, by this period till-derived soils were differentiated from loess-derived soils, soil profile properties were recognized in that soils with unique features due to wetness and poor aeration were differentiated as distinct soil series and soils with features due to forest vegetation influence were differentiated. No discussion of the basis for these shifts from previously published concepts are given. Also, no discussion of theories or assumed principles of soil genesis and classification is given.

Further narrowing of concepts of the soil series and of soil types and further shifts in nomenclature are reflected in a soil survey report and map for Story County issued in 1941 based upon a re-survey of Story County (Meldrum, Perfect, and Mogen, 1941). The earlier soil survey with its broad soil units had not proven adequate for predictive statements. In this 1941 Story report Clarion loam and fine sandy loam soil types have replaced the Carrington and Shelby series recognized in the 1921 Polk County survey. Apparently by this period, the definition of the Carrington soil series had been narrowed to its present concept of soils developed from Iowan till under prairie vegetation (evolution of the Carrington series has been traced by White, 1950) and the Shelby series had been narrowed to a concept of soils of medium texture.
formed from Kansan till under prairie vegetation.

The Dickinson and Thurman soil series formed from sandy loam and loamy sand soil material, respectively, under prairie vegetation were also recognized on the Late Wisconsin till plain in the 1941 Story report. This is an example of narrowing of the textural range of a soil series which was taking place during this period. This step is also an example of the redefinition of the soil type as a soil unit, restricting it to subdivisions of the soil series according to differences in texture of the surface horizon only, rather than for subdivisions according to textural differences of the entire soil as in the earlier concept of soil type.

Another modification in the 1941 Story survey was the recognition of the Ames soil, developed under forests with poor aeration. Lindley soil series was defined and used in this survey much as in the 1921 Polk survey except that the wet areas were recognized as the Ames soil series.

Phases of soil types defined according to degree of erosion and of slope were employed in the 1941 Story County survey for the first time in an Iowa county soil survey.

Influence of Marbut's work can be seen in the Story report. Detailed profile descriptions of the major soils are given, and soil series are grouped in the broader units of great soil groups. However, no discussion of the shifts in series concepts and nomenclature is given, nor is there a
discussion of the principles followed and criteria used in placing the soils in the various soil series.

Soils of Polk County were recently remapped due to the inadequacies of the soil units and of the small map scale of the 1921 survey for detailed predictive statements concerning farm fields and for land evaluation purposes (McCracken, McClelland and others, 1956). As a result of the continuing trend in narrowing of soil series, increasing subdivision of series and types into phases, and the use of large scale air-photos for base maps, the total number of map units of this survey is well over 200. A total of 164 map units, 41 types and 36 series were recognized in the northern portion of Polk County, comparable in soil pattern to Story County. This is roughly an increase of about five times in total map units and nearly a tripling of soil series over the 1941 Story soil survey (Figure 1).

Some of the major shifts from the 1941 survey are the restriction of Lindley soils to forested soils from Kansan till and introduction of the Hayden series for a portion of their former range, introduction of a number of soil series for the soils of the prairie-forest border transitional between darker prairie soils and lighter-colored forested soils, recognition of a number of soils intermediate in aeration and degree of wetness, further narrowing of the Clarion series by introduction of the Storden soils for those soils from
Late Wisconsin till without complete profile development, and introduction of a large number of soil phases as subdivisions of soil types.

This increase in numbers of soil series through narrowing of their definition and the great increase in number of total map units is typical of the situation in soil classification elsewhere in Iowa and in the United States. Need for evaluation and testing of present principles and procedures in soil classification seems indicated.
Development of Soil Classification Theory

**General logic of categorical soil classification**

First logical development of the basis and principles of taxonomic soil classification was by Merbut (1922, 1927). Merbut's concepts of the proper basis for soil classification are summarized:

1. Soil classification is necessary for effective use of soil knowledge, though the classification process does not contribute to knowledge of the things classified.
2. Soil classification must be scientific, with no deviations for the sake of practical uses of the soil.
3. Basis of the grouping should be characteristics of the objects grouped.
4. The soil profile is the most convenient method for expressing soil characteristics.
5. Any complete classification scheme should include a series of categories ranging from the highest with the smallest possible number of groups to the lowest which includes units only, not groups.
6. Higher categories must be entirely based on properties of those soils with normal or mature profiles.
7. Characteristics of the soil on which soil classification should be based are:
a. With regard to soil horizons - number in the profile, color, texture, structure, relative arrangement, chemical composition, and thickness.
b. With regard to the soil material: character and geology.
c. Thickness of the true soil.

A detailed analysis of basic soil classification principles has been presented by Cline (1949a). This analysis is based in part on adaptations of the general logic and theory of classification of Mill (1863) to soil classification. Cline defined and discussed classes, categories, the principles of differentiation as they relate to classes and categories, and the criteria of classification and their sources. A summary of Cline’s discussion is presented in the following paragraphs.

A class is defined by Cline as "a group of individuals, or of other classes, similar in selected properties and distinguished from all other classes of the same population by differences in these properties." He advances the concept of the modal individual, or central nucleus of a class, which has the modal properties of the class. A class is assumed or postulated to have a frequency distribution of values of a certain characteristic - the maximum of this distribution defines the modal individual. All individuals in a class are assumed to be more similar to the modal individual of that
class than the modal individual of any other class; the test
for class placement is similarity to the modal individual,
according to Cline.

A differentiating characteristic is the property chosen
as the basis for grouping into classes. This differentiating
characteristic should be important for the objective of the
classification and carry the greatest possible number of co-
varying accessory characteristics.

In a large and varying population such as soils, classes
must be subdivided to show more of the desired relationships,
thus establishing more categories, according to Cline. A
category, then, is a series of classes formed by stratifying
the population by a single set of criteria.

Cline has outlined the principles of differentiation as
they affect classes, indicating that a differentiating charac-
teristic must be important for the objective, and be a
property of the things classified (or a direct interpretation
for the objective). Also, it should carry as many accessory
properties as possible.

As to criteria for classification, Cline stated that no
one had yet improved upon the ten criteria proposed by Marbut
for differentiation among soils at the categorical level of
the soil type. He postulated that these criteria are acces-
sory characteristics of properties which should be used for
differentiating characteristics at higher categorical levels
but soil scientists are not yet sufficiently aware of broader relationships among soils so that these can be adequately selected.

**Functional, factorial approach to soil taxonomy**

An approach to soil genesis and classification in terms of quantitative study of soil properties as functions of soil-forming or soil-defining factors has been suggested by Jenny (1941, 1946). Dokuchaiev (1879) first formulated the approach of soil as a function of soil-forming factors, though not in quantitative manner. Stephens (1947) has used such an approach in a "functional synthesis". Crocker (1952) has presented a critical discussion of Jenny's approach, and suggested that discrete soil classes and multieategorical soil classification are invalid as a result of implications of the functional analyses.

A functional relationship between soil properties and soil-defining or soil-forming factors has been derived by Jenny (1941) which he has called the fundamental equation:

\[ S = f (cl, o, p, r, t, \ldots) \]  

(1)

where \( S \) = any soil property, \( cl \) = climate (environmental), \( o \) = organisms, \( p \) = parent material (defined as state of the soil system at time zero of soil formation), \( r \) = topography (relief), \( t \) = period of soil formation ("age" of soil), and
the dots represent any additional factors which should be considered.

Stephens (1947) has contended that the soil formers considered independent variables by Jenny are not actually independent. However, as pointed out by Crocker (1952), Jenny intended the variables to be considered independent in functional analyses but did not deny that they are sometimes functionally interrelated.

Derivations of five single-factor functions from the fundamental equation (1) by alternately considering each of the soil-formers as variable with the others held constant have been called by Jenny (1946) the "canonical functions" of quantitative analyses of soils. Soils displaying an array of properties as functions of differing values of the one variable not held or assumed constant were described as soil sequences. Jenny assigned distinct names to each of the five sequences and defined them as follows.

The **climosequence** is defined by the functional relationship:

\[ \Sigma S = f (cl) o, p, r, t, \ldots \]  

(2)

where symbols have the same meaning as in (1), and \( \Sigma S \) represents summation of soil properties in a soil profile.

Thus a climosequence is a grouping or array of soils differing in properties due chiefly to differences in climate, and other soil-forming factors are considered as constant or
contributing only negligibly to the observed differences in properties.

Similarly, a biosequence was defined as an array of soils with properties differing largely due to differences in the organism factor, in accordance with the relationship:

$$\Sigma S = f(c)_{1}, p, r, t, \ldots$$  \hspace{1cm} (3)

Lithosequences may be assembled from the relationship:

$$\Sigma S = f(p)_{1}, c, r, t, \ldots$$  \hspace{1cm} (4)

Toposequences of soils may be developed from the functional expression:

$$\Sigma S = f(r)_{1}, c, p, t, \ldots$$  \hspace{1cm} (5)

Chronosequences of soils are based on the single-factor function:

$$\Sigma S = f(t)_{1}, c, p, r, \ldots$$  \hspace{1cm} (6)

Concept of the soil catena (a widely used grouping in American soil survey) as described by Bushnell (1943, 1945) seems similar to that of the toposequence, as pointed out by Jenny (1946). Bushnell (1945) apparently has considered this functional approach as complementary to the presently accepted taxonomic soil classification system.

Some of the exponents of the functional, factorial approach seem to regard it as an alternative and competitive approach to soil taxonomy, especially Crocker (1952). As suggested by Crocker, this approach should be extensively tried and tested to determine if its role is that of a
complementary or subsidiary approach to soil taxonomy, or whether it is truly an alternative, competitive approach.

Uniqueness of Soil Taxonomy

Soil classification must deal with a number of taxonomic problems unique to soils as a population of natural objects. Some soil taxonomic problems are not unique to soil classifications but are of different degree than in classification of biological populations.

One unique problem is that soils are not controlled by hereditary factors, as are plants and animals. Though plants and animals are dependent on favorable environment for existence, and the degree of expression of their properties is related to environmental factors, they do have certain gene and chromosome patterns which impose developmental limits, as pointed out by Robinson (1951). For example, the species category in plant and animal taxonomy seems nearly comparable in level of generalization to that of the series in soil taxonomy. In a description of the nature and properties of species, Huxley (1940) stated that they have such characteristics as "self-perpetuating as groups" and "normally do not interbreed with related groups", in addition to characteristics comparable with the nature of soil series, as "morphologically distinguishable from other related groups" and
"have a geographical distribution area".

Soils have many properties resulting from action of biologic agencies which distinguish them from rock and mineral groups and makes for different classification problems. Pettijohn (1949) has stated that composition and texture are the properties of most significance for a petrographic classification, and that the test for significance of characteristics proposed for rock classification is whether they are basic to understanding of origin.

Another problem inherent in soil classification not present in plant and animal taxonomy is that soils are parts of multidimensional continua, and are not discrete individuals as are members of purely biologic populations. This problem is not unique to soil taxonomy since it is inherent in rock classification and in classifying ecologic groups of biologic individuals. Crocker (1952) considered this problem of the soil body as a geographic continuum so basic and important that he questioned the reality of a soil class with absolute limits and the validity of a multicategorical classification scheme (such as the present generally accepted basis of soil classification).

Since soils are three-dimensional parts of landscapes, taxonomic soil units must in a sense be adjectives that describe cartographic or landscape units. This type of problem is not present, or is present to much less degree, in taxonomy
of purely biological populations. Corollary to this is the problem of whether soil taxonomic units, particularly those of lower generalization levels which are widely used in field mapping, should be defined in terms of characteristics observable in the field. This problem is common to all classifications of natural objects, however.

Another problem of classification not unique to soils as a population, but perhaps true to greater degree, is that the basic agricultural importance of soils requires that some kind of units be established for statements and predictions about soils and soil behavior under man's agricultural management practices. Problems arising from this are whether or not a natural or scientific soil classification or direct interpretations therefrom can serve these requirements, or should there be a compromise or "diagnostic" (Searle, 1948) type of classification.

Philosophy of Soil Taxonomy

Fundamental bases of the multiple category classification scheme devised by Marbut (1927, 1935) and his staff seem to have been developed by inductive reasoning from study of soil relationships and by analogy from taxonomy of biological sciences. His classification study published in 1927 presented arguments for soil classification on the basis of profile
characteristics, concluding with the justifying statement that zoological and botanical bodies had been successfully defined on the basis of their characteristics. However, recent discussions of biological taxonomy indicate that this basis has not been entirely successful. Species as a taxonomic category, for example, seem best defined not only in terms of morphologic characteristics but also by geographical distribution area, properties of self-perpetuation, and lack of ability to interbreed with related groups (Huxley, 1940). It seems that genetic factors must be considered in biologic taxonomy (Darlington, 1940).

Principles of soil classification as discussed by Cline (1949a), are largely based on logic of classification as developed by Mill (1868) with the important exception of the prescription of the modal individual or modal soil as a basis for differentiation into classes.

Reality of soil classes and validity of multicategorical classification systems has been questioned by Crocker (1952) on theoretical grounds. Crocker reasoned from the functional, factorial approach derived by Jenny (1941, 1946) that the soil body occurs as a geographical continuum, therefore is unresolvable into classes.

Philosophy of soil taxonomy has been discussed by Robinson (1952) and a discussion of philosophy of biological taxonomy has been presented by Gilmour (1940). These authors
favor the concept of taxonomic classes as "clips" of sense-data or concepts framed by the reasoning mind as abstractions or constructions from impressions. Both emphasize the necessity for distinguishing between the "clipping together" of sense-data or framing of concepts in the mind and the actual sense-data or impressions themselves. Application of this philosophy to soil classification seems appropriate. This signifies that whereas soils as a population exist and are fixed, soil classes and categories are logical constructions of a reasoning mind and are arbitrary and readily subject to modification. Soil classes should be considered as groups of soils with certain properties and attributes in common. These classes can be of two kinds: natural or scientific or orthodox, as contrasted to those of a technical or subsidiary or artificial classification.

Natural classification is defined (Mill, 1868; Gilmour, 1940) as a grouping in which all attributes of the population being classified are considered; those characteristics are selected as differentiating criteria which have the greatest number of co-varying characteristics (Cline, 1949a) and which form classes about which the greatest number of statements can be made (Mill, 1868; Gilmour, 1940). In a technical or subsidiary classification only a limited number of attributes of the population are considered and differentiating characteristics are selected to form groups suitable for
specific objective of the classifier (Gilmour, 1940; Cline, 1949a). Both types of classification are products of the mind of the classifier.

The following criteria are proposed for determining, in areas of doubt, whether a proposed classification (of a soil individual into a series or of series into higher categories) is natural and thus part of the soil taxonomic scheme. If the proposed classification increases the number of statements that can be made for two or more of the likely uses of soil classification (as for agricultural predictions and highway engineering), or if it increases the number of statements that can be made for one use of the classification without decreasing the statements which can be made when the class is applied to another use, then the proposed classification is natural or scientific in nature. However, if the proposed classification decreases the statements which can be made for any of the prospective uses of the classification though it increases the number of statements that can be made for another use, then the proposed classification is technical or subsidiary in nature.

Categories or levels of generalization should be based on the degree of resemblance among classes within a given category (Gilmour, 1940). Also, members of a class within a category should resemble each other to the degree prescribed
for that category.

Acceptance of natural or scientific soil classes as having common attributes or sense-data which carry the greatest number of co-varying characteristics and that these classes are those about which the greatest number of statements can be made does not necessarily imply that each is composed of individuals developed by similar genetic factors. It is logical to expect a high correlation between natural soil classes and similarity in genetic factors. However, if it is accepted that such classes are groups of soil individuals placed in their respective classes due to their holding certain properties in common and are logical constructions of the mind, not fixed realities, then it is not necessary to postulate they have common genesis. Quite conceivably various combinations of genetic factors can produce soils with similar properties.

Development of Soil Genetic Theories

Since theories and principles of soil genesis play a large role in soil classification, a summary of soil genetic theories pertaining to the region of which Polk County is a part and their development is presented in the following paragraphs.

Marbut (1935) described those soils of Iowa and surround-
ing areas developed under prairie vegetation with good to medium aeration (named Prairie soils by him) as having dark surface horizons underlain by brown horizons little, if any, heavier in texture than the surface. He described the surface horizon as containing a high percentage of organic matter, ordinarily slightly acid, with colloids "slightly deflocculated" and with very slight eluviation. He described the lower brown horizon, the B horizon, as much lower in content of organic matter than the surface. Marbut described the lighter-colored soils formed under forest vegetation found along streams in the prairie region (named Gray-Brown Podzolic soils by him) as having developed by a leaching process primarily. He stated that in these soils there has been removal of "readily soluble salts and a considerable percentage of bases" with "an apparent accumulation of iron oxide and alumina but none of organic matter" in the lower horizons of these soils. According to Marbut, these soils have a thin, dark surface horizon rich in organic matter immediately underlain by a light-colored eluviated horizon underlain by a horizon of accumulation which is higher in content of clay. Marbut did not discuss in detail genesis of the wet soils or soils with compact layers ("pan" soils) since he considered them as not normal.

In a study of soil development from loess in central Illinois, where soil-forming factors are nearly similar to
those in Polk County, Bray (1934) concluded that two main types of secondary materials have been "produced and retained" in the soils studied — secondary silicates and concretionary material. Bray concluded that the processes of soil development in the soils studied have been in large part "a matter of the formation, breakdown to smaller sizes and movement and accumulation of the silicate colloids". He also concluded that this colloidal material starts forming early in the weathering process before carbonates have been completely leached and that its period of greatest formation and downward movement occurs before the soil has developed any marked acidity. Distribution of the "colloidal silicate" in the soil profile is a function of topography and drainage and its rate of movement in early stages varies with the type of vegetation, according to Bray. In a later paper, Bray (1935) indicated he believed this colloidal silicate to be of "beidellite-nontronite type mineral". In this later paper Bray also postulated that the mechanism for movement of the colloidal silicate is dispersion by mechanical forces associated with moving water due to these forces overcoming flocculative and sorptive forces, followed by redeposition when the mechanical forces become ineffective. Smith (1934) found evidence from laboratory study that deposition of clays in the B, or lower horizon, may be brought about by flocculation of the clay by electrolytes in the ground water or by iron
oxide colloids carrying a charge opposite that of the clay.

Conclusion that many prairie soils are not in equilibrium but are progressing in development towards claypan soils (Planosols) was drawn by Smith (1942) in a study of loess deposits in Illinois and soil development in relation to variation in the loess. Grassland soils formed from thinner loess were shown by Smith to have greater clay accumulation than grassland soils formed from thicker loess nearer the assumed river flood plain source area, and it was concluded that this could be due to differences in age of the loess.

Hutton (1947, 1948, 1950) concluded that prairie soils of southwestern Iowa formed from loess show increasing content of clay in the horizon of maximum clay accumulation and increased cation leaching as indicated by decreasing base saturation with increasing distance from the assumed Missouri River source. Hutton concluded (1947, 1950) that these differences in great part seem due to effective soil age increasing with increasing distance from the assumed source, due to assumed variation in the age of the loess deposits.

Ulrich (1949, 1950) concluded that a similar sequence of increasing clay accumulation and of cation leaching applied to the level, poorly aerated and wet soils (Wiesenboden and Planosol great soil groups) associated with the gently sloping well-aerated soils studied by Hutton.

Studies of groups of soils of central Iowa formed from
similar parent material of loess or glacial till but differing in native vegetation reported by White (1953) and White and Riecken (1956) indicate shifts in soil genesis when prairie areas are encroached by trees. (That prairies were being invaded by trees, especially on sloping areas along stream channels at the time of settlement of Iowa seems indicated by evidence presented by McComb and Loomis, 1944, and by Smith, Allaway, and Riecken, 1950). These studies indicate decreases in the content of organic matter, base saturation and clay in the upper horizons and increases in content of clay and decrease in base saturation of the lower or B horizon as forests invade prairie areas.

Clay mineralogy of soils elsewhere in Iowa belonging to the same soil series as important Polk County soils has been found by a number of studies to be predominantly montmorillonite with minor amounts of kaolinite, with some disagreement on the presence of illite.

Russell and Haddock (1940) estimated from differential thermal analyses and from analyses of potassium composition that the Clarion soil profile and the Tama surface soil which they studied (no analyses on lower portions of Tama) contains 50 to 60 percent montmorillonite, 15 to 20 percent kaolinite and 25 to 30 percent illite. No significant differences were found in clay mineralogy of the Clarion soil formed from Late Wisconsin glacial till and the Tama soil formed from loess.
Peterson (1946) concluded from differential thermal analyses, X-ray diffraction studies and cation exchange capacity determinations that Iowa soils formed from Pleistocene deposits are characteristically high in montmorillonite. He estimated that montmorillonite is relatively abundant, kaolinite present in small amounts, and illite not present in the clay fractions of the A and B horizons (upper and lower soil layers) of the Clarion Webster and Tama soil series. He found little or no difference in clay mineralogy among these soils formed from till and loess.

Lyon (1958) concluded from differential thermal and X-ray diffraction studies that the clay mineralogy of the C horizon, or parent material, of Tama and Fayette soils formed from loess in northeastern Iowa is mainly montmorillonite and illite with minor amounts of kaolinite in some samples. Lyon suggested that the illite is present as an interlayer mineral with montmorillonite.

Riggs (1963) concluded from differential thermal and X-ray diffraction studies of southern Iowa soils formed from loess and from glacial till that the dominant clay mineral is a mixed layer-illite-montmorillonite with illite also present as a distinct species and with kaolinite present in minor amount. He found similar clay mineralogy in loess and till and soils formed from these materials.

In summary, the trend in soil development in the region
of which Polk County is a part is towards development of a horizon of maximum accumulation of clay in the lower part of the true soil, or B horizon, accompanied by cation leaching, and with some accumulation of organic matter in the surface. Predominant clay mineral in the horizon of clay accumulation is of 2:1-layer lattice type. Process of clay accumulation and of leaching is accelerated under forest vegetation, accompanied by development of a light-colored subsurface horizon of eluviation.
MATERIALS AND METHODS

Descriptions of soil profiles sampled during this study are given in the Appendix. Brief profile descriptions of the remaining Polk County soil series not sampled are also given in the Appendix.

Natural Geography and Soil-forming Factors

Climate

Iowa climate has been characterized by Reed (1941) as extreme midcontinental type. Hot winds and periods of prolonged high temperature occur occasionally from May to September, though not necessarily accompanied by rainfall deficiency, according to Reed. The cold season is usually the dry season. Average annual humidity is 72 percent. These generalizations for Iowa should apply well to Polk County due to its location near the center of the state.

A summary of climatic data for Polk County is presented in Table 1. These data are abstracted from 40 years of records by the U. S. Weather Bureau at Des Moines as presented in the 1941 Yearbook of Agriculture (U. S. Department of Agriculture, 1941).
Table 1. Climatic summary, Polk County, Iowa

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<td></td>
<td>22.1</td>
<td>76.3</td>
<td>110</td>
<td>-30</td>
<td>175 days</td>
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<table>
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<th>Mean monthly precipitation, inches</th>
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<tr>
<td>Annual</td>
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<td>30.69</td>
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The above data give some picture of the modern climate in the county. But with the tip of the Mankato glacier approaching within roughly 25 miles of the northern part of the county, some climatic changes must have occurred in Polk County during this last pulsation of glaciation. The southern part of the county was doubtless subjected to climatic changes during the pre-Mankato stages of the Wisconsin glaciation. Ruhe and Scholtes (1956) cited a number of references for evidence "that at least twice during post-Mankato time temperature maxima have exceeded present conditions". They have suggested that climatic conditions have been about as now for about the past 5,000 years, with the exception of a warm period about 1,000 years ago.
Parent material

Five general kinds of soil parent material can conveniently be recognized in Polk County. Listed in order of increasing age, these are: recent alluvium, Late Wisconsin glacial till and outwash deposits, loess of Wisconsin age, Kansan glacial till, and residuum of Des Moines shale (Pennsylvanian).

Des Moines shale residuum. The Des Moines shale is the underlying bedrock of Polk County (Lees, 1908), but this formation crops out only in a few narrow bands mostly along the Des Moines River, due to the thick cover of Pleistocene deposits. Beds of the Des Moines formation, as they occur in Polk County, consist of beds of shale, fire clay, sandstone, coal, and a few thin beds of limestone, all of which are irregular in thickness and distribution (Lees, 1908). Altered silty and clay acid shales dominantly of silty clay texture form the parent soil material of soils in Polk County recognized during the survey as developing from bedrock. Petersen (1946) reported that these Des Moines beds are apparently almost pure kaolinite and that the clay fraction of the Gosport soil developed from them is dominated by kaolinite.

Kansan till. An older glacial till, presumed to be Kansan, comprises soil parent material in the southern fifth of the county in localities where it crops out below the loess
mantle (Kay and Apfel, 1929). Kansan till in Polk County where relatively unweathered except for oxidizing and leaching seems to be dominantly of clay loam texture, confirmed by particle size analysis of one profile (Prill, 1955). A few small areas of gumbotil (Kay and Apfel, 1929) were found in the area of Kansan till outcrop during the recent soil survey. Also, some evidences of translocation and reworking of the upper portion of the Kansan till sheet were observed.

Wisconsin loess. Loess of early Wisconsin age mantles the Kansan till in that portion of the county not covered by Late Wisconsin glacial till — approximately the southern fifth (Kay and Graham, 1943; Ruhe and Scholtes, 1956). The loess of southwestern and south-central Iowa is believed to have originated from the Missouri River Valley; it has been suggested that the loess in east-central Iowa had as its source the Tazewell glacial drift area to the north (Ruhe and Scholtes, 1956). Since these loess sheets blend in Polk County it seems likely that this early Wisconsin loess in Polk County originated from both sources. On the basis of a very few observations in the county and compiled loess thickness maps (Ruhe and Scholtes, 1956; Rieken and Smith, 1949), loess on the broad divides is somewhat less than 200 inches but more than 100 inches thick. Texture of the unweathered loess is silt loam. Petersen (1946) suggested that the clay fraction of this material may be high in montmorillonite.
Late Wisconsin till and outwash deposits. A very large part of the county, approximately the northern four-fifths, is covered with a rather thick deposit of Late Wisconsin glacial till (Kay and Graham, 1943) assigned by Ruhe (1952) to the Cary substage. Glacial outwash has been emplaced along the larger streams. Much of this is doubtless Cary in age, but some deposits may well be of Mankato age since streams such as the Des Moines River and the Skunk River apparently carried meltwater from the Mankato glacier which extended as far south as a few miles north of Ames (Ruhe, 1952). Some scattered patches of thin, rather coarse local loess were observed on the Cary till plain during the course of the recent soil survey. Some Late Wisconsin loess may be present as a thin increment on a few square miles of the early Wisconsin loess-covered uplands just south of Des Moines, based on observations during the recent soil survey. Average depth of leaching of calcium carbonate is about 30 inches on the Cary till plain (Kay and Graham, 1943). The Cary till is ordinarily of loam texture, as confirmed by particle size analysis of Clarion C horizon in the present study. Peterson (1946) suggested that the clay fraction of this till contains a high proportion of montmorillonite.

The Late Wisconsin outwash deposits in Polk County consist of terrace landforms composed of gravelly and cobbly sand or sandy loam, variably calcareous, overlain by about
2 to 5 feet of material of medium texture - based on field observations by the author during the county survey.

**Recent alluvium.** This material represents recently deposited stream alluvium and recent slopewash. Most of this material is on the floodplains of the larger streams.

**Relief**

The Cary till plain which occupies approximately the northern four-fifths of Polk County is slightly undulating (Kay and Graham, 1943) with the exception of strongly sloping areas along the rivers. This has been referred to as " depositional topography" by some authors, because there has been but little dissection of the original till plain.

The loess-mantled southern fifth of the county is more rugged, "erosional topography". This region is one of rolling hills with a well-oriented drainage pattern.

**Time (age)**

It is convenient to discuss time as a soil-forming factor in terms of ages of the various important parent materials of the county, the Pleistocene deposits.

The Kansan till has been assigned to the early Pleistocene (Kay and Apfel, 1929). It seems that the gumbotil (ex-
posed in a few small areas) began developing on this surface shortly after its deposition, though with a number of interventions. Due to the erosion cycles the Kansan till has undergone and its burial by loess with subsequent exhuming of a portion, an age estimate for soils formed from this till, or material derived from it, is not possible. These soil series, as presently defined, have formed from a complexity of materials.

The loessial upland landscape of southern Polk County has been postulated to be of 14,000 to 16,000 years in age by Ruhe and Scholtes (1956), reasoning from radiocarbon dates. This represents a maximum age for the early Wisconsin loess-derived soils of the county.

Ruhe and Scholtes have dated the Cary till plain landscape as 12,000 to 13,500 years in age, based on a number of radiocarbon dates obtained on wood embedded in Cary till. These figures represent the maximum age for the Cary till-derived soils.

Vegetation

Available evidence suggests that the native vegetation of Polk County was dominantly prairie with rather narrow belts of forest along the sloping sides of the river valleys (Smith, Allaway, and Riecken, 1950). Distribution of forests
in Polk County at time of settlement is shown in Figure 4. McComb and Loomis postulated (1944) that trees were invading the prairie areas before man's disturbance. In consequence, trees had begun to impress distinctive properties on prairie soils in narrow bands several hundred feet to one-fourth mile wide, as observed in the recent Polk County soil survey (McCracken, McClelland and others, 1956). Dominant prairie species was big bluestem (*Andropogon furcatus*), particularly on the sites with optimum moisture, and mid grasses were more prominent on the drier sites (Weaver, 1954). The native forests were deciduous with oak and hickory perhaps pre-dominant.

Ruhe and Scholtes (1956) cited evidence from several sources to indicate that with two Late Wisconsin glaciations in north-central Iowa, conditions seemingly were more favorable for forest vegetation in this area in the period from 16,000 to 5,000 years ago than now. They suggested that "environments of cooler, more moist forest regimes undoubtedly have been effective in the development of soils on landscapes in Iowa," though stating that the more recent prairie vegetation may have masked or obliterated these effects.
Figure 4. Original forest cover in Polk County; dark areas indicate original forest, based on data secured in the original land survey, 1832-1859 (from Iowa State Planning Board, Project 1033)
Laboratory Methods and Procedures

Physical and chemical studies

**Bulk density.** Core samples were taken in quadruplicate from selected horizons of certain soils for bulk density determinations. A Coile-type sampler with a sample holder volume of 252 cubic centimeters was used, following the procedure described by Ulrich (1950).

**Porosity and hydraulic conductivity.** Core samples were taken in quintuplicate from selected horizons of certain soils for determination of porosity. A Coile-type sampler with a sample holder of 153.6 cubic centimeters volume was used. The cores were 4.4 centimeters in diameter, and 3.8 centimeters in height. Procedure followed was similar to that described by Ulrich (1950). Capillary porosity was determined at a tension of 40 centimeters of water. Total porosity was calculated from the bulk density. Aerated porosity was calculated from the difference between total and capillary porosity. Hydraulic conductivity was determined for cores from profiles P499, P484, P481, using the procedure described by Wilson, Riecken, and Browning (1947), in which the samples are subjected to a hydrostatic head of 5 centimeters of water. Cores were those used for porosity determinations as described above.
Particle size distribution analyses. Duplicate 10 gram samples (oven-dry basis) from profiles P50C, P471, P472, P466, P470, P467, P492, P484, P499, P481, P480, P482, and P491 were subjected to particle size analyses. A sedimentation method was used with aliquots removed at calculated settling times by pipetting at 10 centimeters depth in the suspension, essentially as described by Kilmer and Alexander (1943) with minor modifications. These modifications were similar to those described by Cain (1956). No correction was made for the organic matter (destroyed by hydrogen peroxide), hence it is shown in the coarse silt fraction, which was determined by difference. Results are reported for particle size analyses of profiles P408, P404, P403, P407, and P405 performed in the Soil Survey Laboratories of the U. S. Department of Agriculture, Beltsville, Maryland.

Free iron. Analyses for "free iron" were performed on selected horizons of profiles P471, P472, P466, P470, P467, P492, P499, P481, P500, P489, P462, P408, and P407. Determinations were made on duplicate one-gram samples passed through a 40-mesh sieve, with sand caught on the screen returned to the sample, and are reported as free iron percent, oven-dry basis. Procedure used was the Swenson modification (1951) of a method developed by Jeffries (1947). In this procedure, the iron is reduced in an oxalic acid-potassium oxalate buffered solution with magnesium ribbon. Following
color development with o-phenanthroline, determinations were made colorimetrically, using an Evelyn Photoelectric Colorimeter with a 515 millimicron filter.

**Organic carbon.** Determinations were made on two-gram samples by a gravimetric dry combustion procedure (Winters and Smith, 1929). Samples were taken from selected horizons of profiles P471, P472, P466, P470, P467, P496, P494, P499, P461, P468, and P482. Also reported are organic carbon determinations for profiles P408, P406, P407, P404, and P405 by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.

**Soil reaction.** Measurements of pH were made on all horizons sampled. Determinations were made with a Beckman instrument, using a 1:1 soil-water ratio. Samples were stirred following water addition, allowed to stand 30 minutes, stirred again, and the reading made.

**Exchangeable cations and cation exchange capacity.** Determinations of exchangeable cations and of cation exchange capacity were made on selected horizons of profiles P471, P472, P466, and P482 in the North Carolina State Soil Testing Laboratory under supervision of Dr. S. L. Tissale. Exchangeable bases were extracted by leaching 20-gram duplicate subsamples with 200 milliliters of normal neutral ammonium acetate, in a modification of a procedure outlined by Peech (1945). Exchangeable potassium and calcium were determined on a Perkin-
Elmer flame photometer with lithium internal standard. Exchangeable magnesium was determined by developing color with thiazol yellow and readings on a Cenco Photometer. Total exchange capacity was determined by leaching the ammonium-saturated samples of the extraction procedure with acidified 10 percent NaCl solution, distilling the leachate into standard sulfuric acid and titrating the excess acid.

Also reported are determinations of exchangeable cations of horizons of profile P408 by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.

Soil thin section study

A study was made by means of petrographic microscope of thin sections of Clarion, Nicollet and Webster soils. A few sections of Tama and Edina soils were included in the study for comparison purposes. The Tama is a Brunizem considered to be of intermediate development; Edina is a Planosol considered to show a near maximum of B horizon development. A specific objective was to test the hypothesis that Clarion, Nicollet, and Webster soils should show evidence of clay translocation in the form of films and pore-linings if they are in a minimal stage of a developmental course a prominent feature of which is development of a horizon of silicate clay accumulation.
Undisturbed blocks of soil about three inches by three inches were collected from Clarion, Nicollet and Webster horizons designated in field study as A, B, and C. Similar samples were taken from B and C horizons of Tama soil. Sample sites are those described in the Appendix. One sample of the B horizon of an Edina soil from Wayne County, Iowa, was also collected. Orientation with respect to the soil surface was maintained by marking the blocks with drafting tape. Specific sites from which thin sections were desired were marked. Thin sections of about 0.04 millimeter in thickness were prepared by Rudolph von Huene,\footnote{Rudolph von Huene, 865 North Mentor Avenue, Pasadena, California.} using a plastic preparation to impregnate the soil before taking the section. Both longitudinal and cross sections were prepared of B horizons, all other horizon sections are cross sections.

Micromorphological studies of some Iowa soils have previously been made by Johnston (1939) and by Swanson and Peterson (1940). Johnston studied Marshall and Webster soils; Swanson and Peterson studied Shelby and Marshall soils. These workers were primarily interested in soil structure and soil particle relationships, though both these studies mention the occurrence of colloidal substances which probably are silicate clay and/or hydrous iron oxide concentrations.
Clay mineralogy study

Samples from the B2 horizons of Clarion and Tama soils were analyzed by differential thermal and X-ray spectrometric analyses\(^1\) to attempt to gain some qualitative information on clay mineralogy of a till-derived (Clarion) and of a loess-derived (Tama) soil in Polk County.

Differential thermal analyses were made of the fraction between 2 and 0.2 microns in diameter of each soil. These clays were calcium saturated and equilibrated with an atmosphere of 50 percent relative humidity. Organic matter was not removed. Heating rate was 15 degrees Centigrade per minute.

Samples were fractionated into size ranges of less than 0.2 micron, 2 to 0.2 micron, and 2 to 5 microns in diameter for X-ray diffraction studies. These fractions were glycerol solvated and mounted as oriented specimens on microscope slides. The studies were made with a North American Phillips Geiger counter X-ray spectrometer with an iron target-tube.

Fractionation into particle size ranges was according to procedures described by Jackson, Whittig, and Pennington (1949).

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\(^{1}\)Differential thermal and X-ray analyses were performed in soil laboratories of North Carolina State College under supervision of Dr. N. T. Coleman.
RESULTS AND DISCUSSION

Summary of Chemical and Physical Studies

Table 2. Bulk density and porosity of selected Polk County soils

<table>
<thead>
<tr>
<th>Horizon number</th>
<th>Depth, inches</th>
<th>Horizon designationa</th>
<th>Porosity, volume percent</th>
<th>Aeration</th>
<th>Capillary</th>
<th>Total</th>
<th>Bulk density</th>
</tr>
</thead>
<tbody>
<tr>
<td>471-1</td>
<td>0-9</td>
<td>Ah</td>
<td>15.8</td>
<td>39.5</td>
<td>55.3</td>
<td></td>
<td>1.17</td>
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<tr>
<td>1-3</td>
<td>13-17</td>
<td>B2</td>
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<td>60.0</td>
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<tr>
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<td>B2</td>
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<td>56.6</td>
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<td>1.15</td>
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<tr>
<td>-5</td>
<td>22-27</td>
<td>B3</td>
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<td>37.4</td>
<td>55.9</td>
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<td>1.17</td>
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<tr>
<td>-7</td>
<td>30-36</td>
<td>C1</td>
<td>18.0</td>
<td>35.6</td>
<td>53.6</td>
<td></td>
<td>1.23</td>
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</table>

Colo silty clay loam, P481

| 481-1          | 0-8          | Ap                  | 11.0                     | 45.9     | 56.9     |       | 1.14        |
| -3             | 14-21        | B(?)                | 12.4                     | 44.5     | 56.9     |       | 1.14        |
| -5             | 28-35        | B(?)                | 8.1                      | 43.6     | 51.7     |       | 1.28        |

Marshan silty clay loam, P467

| 467-1          | 0-13         | Ah                  | 16.2                     | 43.4     | 59.6     |       | 1.07        |
| -3             | 17-22        | B2                  | 17.4                     | 36.8     | 54.2     |       | 1.23        |
| -4             | 22-27        | B2                  | 18.5                     | 32.8     | 51.3     |       | 1.29        |
| -6             | 31-40        | C1                  | --                       | --       | --       |       | 1.30        |

Nicollet loam, P472

| 472-1          | 0-13         | Ah                  | 15.0                     | 40.1     | 55.1     |       | 1.19        |
| -3             | 17-23        | B2                  | 18.6                     | 35.0     | 53.6     |       | 1.23        |
| -4             | 23-30        | B2                  | 18.7                     | 34.9     | 53.6     |       | 1.23        |
| -5             | 30-33        | B3                  | --                       | --       | --       |       | 1.25        |
| -6             | 33-40        | C1                  | 18.4                     | 29.1     | 47.5     |       | 1.39        |

aHorizon designations other than those given in the Soil Survey Manual (U. S. Department of Agriculture, 1951) are defined in a later section.
<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth, design-</th>
<th>Porosity, volume percent</th>
<th>Aeration</th>
<th>Capillary</th>
<th>Total</th>
<th>Bulk density</th>
</tr>
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<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>466-1</td>
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<td>1.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-11 B1</td>
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<tr>
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<td>15-22 B22</td>
<td>18.7</td>
<td>34.9</td>
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<td>1.23</td>
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<tr>
<td></td>
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<th>Capillary</th>
<th>Total</th>
<th>Bulk density</th>
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</tr>
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<th>Capillary</th>
<th>Total</th>
<th>Bulk density</th>
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<td>20-24 B62</td>
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Table 2. (Continued)

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<th>Bulk density</th>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>484-1 0-8 Ap</td>
<td>10.4</td>
<td>46.5</td>
<td>56.9</td>
<td>1.12</td>
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<tr>
<td>-3 14-21 B(?)</td>
<td>8.2</td>
<td>47.2</td>
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<tr>
<td>-4 23-31 B(?)</td>
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<td>55.1</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>-6 38-50 Cg1</td>
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<td>46.8</td>
<td>53.6</td>
<td>1.23</td>
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Table 3. Hydraulic conductivity of some Polk County soils with poor natural drainage developed from alluvium

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</tr>
</thead>
<tbody>
<tr>
<td>Horizon number inches</td>
<td>co/min/cm head inches/hour</td>
</tr>
<tr>
<td>Colo silty clay loam, P481</td>
<td></td>
</tr>
<tr>
<td>481-1 0-8 Ap</td>
<td>2.84</td>
</tr>
<tr>
<td>-3 14-21 B(?)</td>
<td>1.64</td>
</tr>
<tr>
<td>-5 28-35 B(?)</td>
<td>2.30</td>
</tr>
<tr>
<td>Wabash silty clay, P499</td>
<td></td>
</tr>
<tr>
<td>499-1 0-8 Ap</td>
<td>0.74</td>
</tr>
<tr>
<td>-3 14-20 Bg1</td>
<td>0.95</td>
</tr>
<tr>
<td>-4 20-27 Bg2</td>
<td>0.12</td>
</tr>
<tr>
<td>-6 33-42 Cg1</td>
<td>0.15</td>
</tr>
<tr>
<td>Zook silty clay, P484</td>
<td></td>
</tr>
<tr>
<td>484-1 0-8 Ap</td>
<td>1.15</td>
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<tr>
<td>-4 23-31 B(?)</td>
<td>0.44</td>
</tr>
<tr>
<td>-6 38-50 Cg1</td>
<td>0.97</td>
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### Table 4. Particle size distribution and pH of some selected Polk County soil profiles

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<tr>
<th>Horizon</th>
<th>Depth, designation</th>
<th>Percent of fraction</th>
<th>Class by particle diam., microns</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;2 mm. diam.</td>
<td>Coarse sand, silt, silt, clay</td>
<td>&gt;2 mm. diam.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ph</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;50 50-20 20-2 &lt;2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth, designation</th>
<th>pH</th>
<th>Coarse</th>
<th>Fine</th>
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<td>22.8</td>
<td>23.4</td>
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<tr>
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<td>42-60</td>
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<td>25.1</td>
<td>6.8</td>
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<td>Ames loam, P500</td>
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<table>
<thead>
<tr>
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<th>Depth, designation</th>
<th>pH</th>
<th>Coarse</th>
<th>Fine</th>
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<tbody>
<tr>
<td>471-1</td>
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<td>6.7</td>
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<th>Fine</th>
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<td>&lt;1</td>
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<td>Horizon Designation</td>
<td>pH</td>
<td>Percent of Fracton &lt;2 mm. diam.</td>
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*Determinations by Soil Survey Laboratory, U.S. Department of Agriculture, Beltsville, Maryland.*
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Kato silt loam, P407

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Marshan silty clay loam, P467

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Marshan silty clay loam, 24-30 inches to sand and gravel, P492

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*Determinations by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.*
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Determiinations by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.
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Tama silt loam, P482

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Wabash silty clay, P499

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Table 5. Exchangeable cations, pH, and cation exchange capacity of some selected Polk County soil profiles

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<th>Horizon designation</th>
<th>Horizon</th>
<th>Exchangeable bases, meq./100 grams</th>
<th>Cation exchange capacity, meq./100 grams</th>
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<td>B1</td>
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aDeterminations by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.

bCation exchange capacity determined by summation of exchangeable cations.
Table 6. Organic carbon and free iron in some selected Polk County soil profiles

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<td>31-37</td>
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Table 6. (Continued)

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<th>Percent</th>
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<th>Organic carbon</th>
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Dakota loam, P405a

| 496-1          | 0-9           | Ap                  |         | 1.59      |                |
| -2             | 9-13          | AB                  |         | 1.35      |                |
| -3             | 13-17         | B1                  |         | 1.11      |                |
| -4             | 17-21         | B21                 |         | 0.84      |                |
| -5             | 21-24         | B22                 |         | 0.83      |                |

Gilbert loam, P496

| 478-1          | 0-9           | Ap                  |         | 1.45      |                |
| -2             | 9-14          | AB                  |         | 1.25      |                |
| -3             | 14-18         | B1 or C             |         | 1.90      |                |
| -4             | 18-27         | B2 or C             |         | 1.97      |                |
| -5             | 27-32         | B3 or C             |         | 1.78      |                |

Huntsville loam, P478

| 406-1          | 0-16          | Ah                  |         | 2.77      |                |
| -2             | 16-22         | B1                  |         | 2.07      |                |
| -3             | 22-36         | B2                  |         | 1.09      |                |
| -4             | 36-48         | C11                 |         | 0.48      |                |
| -5             | 48-60         | C12                 |         | 0.37      |                |

Kato loam, P406b

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aDeterminations for this profile by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.

bCarbon determinations for these profiles by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.
Table 6. (Continued)

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<th>Organic carbon</th>
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<td>B1</td>
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\*Carbon determinations for these profiles by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.
Table 6. (Continued)

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Nicollet loam, P472

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Sharpsburg silt loam, P408b

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Shelby loam, P468

\[\text{Carbon determinations for these profiles by Soil Survey Laboratory, U. S. Department of Agriculture, Beltsville, Maryland.}\]
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Tama silt loam, P482

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Wabash silty clay, P499

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Waukegan silt loam, P470

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Webster silty clay loam, P466
### General Genetic Trends in Polk County Soils

Discussion of the trends of soil genesis of Polk County soils is presented to provide a setting for the discussion of classification. This discussion as well as that of classification is presented in terms of the soil series of the county, since the soil series is the basic unit of mapping and of classification. Data presented in this study were not collected specifically to test hypotheses of soil genesis but to illustrate soil classification problems and aid in testing hypotheses concerning classification. However, sufficient data are available to indicate the general developmental course of soils of the county.

#### Table 6. (Continued)

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Clay distribution and soil development as inferred from particle size distribution analyses

Types of clay distribution in Polk County soil profiles as influenced by soil genetic processes are illustrated in Figure 5. Data for the Lindley soil are from a Polk County profile studied by Prill (1955). This soil has formed from Kansas till or translocated material derived from Kansas till. Some indication of eluviation of clay from the upper horizons, particularly from the subsurface, and a pronounced horizon of maximum clay accumulation is representative of the upland soils formed under forest vegetation and good aeration in Polk County. The Ames soil also has formed under forest vegetation but from Cary till parent material with conditions of poor aeration and wetness. Its clay distribution curve indicates marked clay translocation, particularly in comparison to the Clarion soil formed from similar Cary till parent material. This significant and relatively rapid clay translocation indicates the Ames soil is rapidly moving towards a "claypan" soil in properties. Only a few soils of the county show evidence of such rapid and extreme clay translocation.

Both the Sharpsburg and Clarion profiles illustrated in Figure 5 have formed under prairie with conditions of good aeration and oxidation. A moderate amount of illuviation into a horizon of clay accumulation without a subsurface
Figure 5. Clay distribution with depth in four Polk County soil profiles
horizon of maximum eluviation seems to have taken place in the Sharpsburg soil formed from early Wisconsin loess. This condition is representative of the upland soils of the county formed under prairie vegetation from deposits older than Late Wisconsin.

The clay distribution in the Clarion profile is representative of Polk County soils developed from Late Wisconsin deposits under prairie vegetation. Little or no evidence of clay accumulation by genetic processes is revealed by particle size distribution analyses.

Clay distribution and soil development as inferred from thin section studies

Clarion. The thin section of Clarion A horizon shows appreciable alteration of ferromagnesian minerals and of feldspars, especially plagioclase. Alteration products of feldspars are visible along edges and in embayments of grains. This is shown in the photomicrographs of Figures 6 and 7. It seems that this breakdown of primary minerals could be producing silicate clay and free iron for translocation to lower horizons. A few limonitic concentrations (tiny concretions) were noted. Structure is of moderately expressed granules. Fabric lacks the spongy feature described for the Marshall A horizon (Swanson and Peterson, 1940). Organic matter seems well decomposed and disseminated throughout in silt and colloidal size.
Figure 6. Photomicrograph of feldspar grain in Clarion A horizon showing thin coating of alteration product on edge of grain in center of picture; crossed nicols; section 6 inches below surface with plane of section parallel to surface

Figure 7. Same field as Figure 5 but with feldspar grain at extinction; note birefringent character of alteration product
The Clarion B horizon thin sections show thin and discontinuous silicate clay films, mostly as linings on pore walls rather than on aggregate faces. Photomicrograph of Figure 8 illustrates a representative clay film. These films are interpreted as silicate clay translocated from above, on the basis of their orientation and optical continuity. Their location along bays, strictures, and small pores leading off larger pores suggests mechanical emplacement. Some quartz grains have patchy, thin coatings, apparently of hydrous oxides. Limonitic blebs and amygdules (as defined by Kubiena, 1938) of silt and sand-size are common. Primary minerals show less alteration than in A horizon above. Structural aggregates are moderately well to ill-defined subangular blocks. Aggregate faces are generally "clean", lacking coatings. Fabric is of the intertextic type described by Kubiena (1938).

Clarion C1 horizon thin section (32-34 inches below surface) contains a very few thin silicate clay pore-linings. Primary minerals show little or no alteration. Several calcium carbonate concretions and sand-size limestone fragments are present. Iron concentrations are fewer than in B horizon. There is no structural aggregation, though porosity seems medium to high.

Nicollet. The thin section of the Nicollet A horizon shows appreciable alteration of ferromagnesian minerals and
Figure 8. Photomicrograph of Clarion B horizon, section taken at 20 inches below surface with plane of section parallel to surface; discontinuous clay film extends from top to bottom of picture immediately to right of center along wall of large pore (pore is dark area); granite fragment in right side of field; crossed nicols; note birefringence of clay film
feldspar. There is much silt-size and colloidal disseminated organic matter, some of which occurs as patches in "nicks" of quartz sand grains. A very few Fe amygdules are present. Structure is granular with moderately well defined aggregate faces.

Nicollet B horizon thin sections show a few thin and discontinuous clay films, assumed to be translocated silicate clay, located mostly on pore walls. Their manner of occurrence suggests mechanical emplacement according to hydrodynamic factors. A few small blebs and stringers of apparently crystal-line silicate clay are present in the groundmass, apparently not associated with a pore or structural face - a possible interpretation is clay formed in place, another is emplacement along a former structural face. There is appreciable alteration of primary minerals. Degree of alteration becomes less in the lower B horizon. Some quartz grains have patchy coatings of hydrous iron oxides in nicks and recesses but generally are clean. Concentrations of iron, limonitic in nature, in form of indescrete blebs or discrete amygdules are common. Some few show concentric pattern in cross section. Number and size of iron concentrations is greater than in Clarion B horizon, indicating more of the "free iron" is in form of concretionary concentrations than in Clarion. Structure is of subangular blocks with incompletely defined faces; structural faces generally lack coat-
ings. Fabric is of intertextic type.

The C₁ horizon thin section (36-38 inches depth) contains a very few thin continuous clay films in a few pores. Concentrations of iron seem fewer in number than in the B horizon above, with more yellowish brown hydrous iron oxide disseminated throughout the groundmass. Many large fragments of mica and feldspar are present, all relatively unaltered. Some limestone fragments and calcium carbonate concentrations are present, many of which seem to have coatings of hydrous iron oxide. There is no structural aggregation, though porosity remains high.

Nicollet C₂ horizon thin section (46-48 inches in depth) contains much calcium carbonate as a mortar cementing the material. Though some iron aggregates are present, they are yellower, less dense, and fewer in number than in B horizon above. Yellowish brown and greenish brown nearly amorphous thin films coat many limestone fragments. These are interpreted as films of rather freshly deposited hydrous iron oxides.

Webster. The thin section of Webster A horizon shows appreciable alteration of plagioclase, about comparable to that in Clarion A horizon. A very few pore linings of oriented silicate clay films are present. Some stringers of apparent silicate clay are present as small concentrations in the groundmass, not associated with present pores or structural
faces. Large dense iron segregations, limonitic in nature, are common. Many silt-sized organic matter granules and much colloidal organic matter is dispersed throughout the groundmass. Structure is of moderately developed granules and small rough subangular blocks; aggregate faces are free of coatings. Fabric is "spongy".

Webster B horizon thin sections show rather thin silicate clay films on some pore walls and a few on aggregate faces, very thin and discontinuous. Figures 9 and 10 illustrate the thin and discontinuous nature of clay films in this horizon. Degree of clay film development seems greater than in the Clarion B, but about comparable to the Nicollet B. Concentrations interpreted as silicate clay are present as small stringers and blebs in the groundmass fabric. Number of these is much greater than in Nicollet soil, whereas Clarion soil lacks them. Some of these concentrations show orientation as determined by optical character, though many are too thin and narrow for individual study. Two alternative interpretations might be made: either formation in place with some local mechanism for concentrating them, or they are translocated material emplaced along sites of former pores and aggregate faces. Number of iron concentrations is smaller than in Clarion and Nicollet soils, but average larger in diameter. These concentrations seem less dense, more bleb-like with less discrete boundaries, and are yellower than those in
Figure 9. Photomicrograph of Webster B horizon, section taken at 24 inches below surface with plane of section parallel to surface; thin discontinuous clay films along diagonal pore (pore is light area) at lower center and upper right; plane polarized light

Figure 10. Same field as Figure 9, but with crossed nicols; note birefringence of clay films
Clarion and Nicollet soils. Some show concentric cross sections. The groundmass is distinctly grayer and lighter in color than Nicollet and especially the Clarion soil. Structural aggregates tend to be subangular blocks, with faces moderately well expressed. Structural aggregation seems more pronounced than in Nicollet and Clarion B horizons.

Thin section at 42-45 inches depth in the Webster horizon designated as Cg shows the material cemented with calcite "mortar". Iron concentrations seem more numerous than in the B horizon above but not as dense and dark and consist of reddish brown sponge-like clusters. Thin deposits of hydrous iron oxide occur as coatings on the calcite mortar. There are no clay films or concentrations; primary minerals are fresh and unaltered. A number of small greenish blue to bluish green earthy clumps may be vivianite or a related mineral. There is no structural aggregation.

Tama. Tama B horizon thin sections show excellent development of oriented silicate clay films, lining most continuous pores and some aggregate faces. Figures 11 and 12 illustrate clay films in the Tama B. Some sites of occurrence of this translocated material suggest mechanical emplacement by hydrodynamic factors. Clay films are much more numerous and are thicker than in the Clarion, Nicollet, and Webster soils. Only a very few thin stringers of clay are present in the groundmass and apparently are unassociated
Figure 11. Photomicrograph of Tama B horizon, section taken at 19 inches below surface with plane of section normal to surface; top of picture corresponds to top of section; clay films along pore walls (pore is light area) with clay filling small pore extending at right angles to main pore in lower left; plane polarized light

Figure 12. Same field as above, but with crossed nicols; note birefringent character of clay films
with a pore or aggregate face. Iron concentrations are dominantly of amygdal form, dense with very discrete sharp boundaries. These concretions are distinctly denser, darker, and seem more "aged" than in Clarion and associated soils. Some have concentric configuration. All contain entrapped silt-size quartz and feldspar. Structure is moderately well-defined subangular blocks, some few have clay films on faces. Fabric is the intertextic type (Kubiena, 1938).

The thin section of the Tama C horizon (at 32-34 inches depth) shows a few thin discontinuous clay films around larger pores. This section shows more iron concentrations than B horizon above, and many are yellowish brown, sponge-like, and limonitic. They may represent relatively fresh concentrations of iron. A few structural aggregates are recognizable.

Edina. The thin section of Edina B horizon shows numerous blebs and stringers of yellowish brown material within the groundmass, interpreted as silicate clay concentrations. Photomicrographs in Figures 13 and 14 illustrate the Edina B horizon. These concentrations do not seem associated with any present pore or aggregate face and far exceed in number and amount those which are pore linings or aggregate face coatings. Large dense concretions are common in some parts of the section. Groundmass color is generally gray and light in color except for the yellowish brown clay stringers. Some zones of the section are quite gray and
Figure 13. Photomicrograph of Edina B horizon, section taken at 18 inches below surface with plane of section parallel to surface; distinct layering of clay around walls of large pore (large light area) at extreme left; stringers of clay concentration diagonally across field in left upper and right center portions, in groundmass; plane polarized light.

Figure 14. Same field as above, but crossed nicols; silt partially filling large pore obstructs clay film birefringence.
colorless; these tend to lack clay stringers. These regions contain some unidentified silt-size earthy clumps, greenish in color, which may contain a mineral of the vivianite group. Structure is rather ill-defined coarse blocks.

**Summary of thin section study**

Clarion, Nicollet, and Webster soils sampled for this micromorphological study show incipient clay translocation. Webster soils have some clay concentrations seemingly associated with the groundmass, origin of which is not clear. It seems doubtful that evidence for silicate clay translocation could be consistently found in field studies of these soils by use of hand lens. However, appearance of the clay films in thin section would seem sufficient evidence for designating those horizons below the A horizons of these soils as at least incipient B horizons, even if evidence of silicate clay translocation is to be a necessary condition for designation as a B horizon. The Tama soil sampled for thin section study showed evidence of silicate clay translocation in moderate amounts as inferred from particle size distribution analyses.

The B horizon of the Edina soil, a Planosol formed from loess in Southeastern Iowa, showed concentrations of silicate clay in stringers and blebs, seemingly unassociated with pores
or aggregate faces, origin of which is uncertain.

Clarion soil seems to contain a greater part of any hydrous iron oxides present as thin coatings or disseminations throughout the groundmass, whereas in the Webster soil most hydrous iron oxide seems to be in the form of concretionary or other concentrations. Nicollet seems intermediate between these. The Tama B horizon studied contains opaque dense concretions, but the C horizon seemed to contain less dense and opaque concretions.

**Clay mineralogy of Tama and Clarion B horizons**

Differential thermal analysis curves for fractions of Tama (loess-derived) and Clarion (till-derived) B horizons less than 2 microns in diameter are shown in Figure 15. Smoothed tracings of X-ray spectrometer curves for fractions of B horizons Clarion and Tama soils 5 to 2, and 2 to 0.2 microns in diameter are shown in Figure 16. Tracings for fractions of less than 0.2 microns in diameter are shown in Figure 17. Interpretations of these studies of clay mineralogy are summarized in Table 7.

Outstanding features of the Clarion samples are the lack of montmorillonoid clay minerals in the 5-2 micron fraction as compared to presence of a significant amount in the com-
Figure 15. Differential thermal analyses of less than 2 micron diameter fractions of B horizons of Clarion and Tama soil profiles.
Figure 16. X-ray spectrometer tracings for fractions 2 to 5 microns and 2 to 0.2 microns in diameter of B horizons of Tama and Clerion soil profiles.
Figure 17. X-ray spectrometer tracings for fractions less than 0.2 microns in diameter of B horizons of Tama and Clarion soil profiles.
Table 7. Summary of differential thermal and X-ray spectrometer studies of Clarion and Tama B horizons

<table>
<thead>
<tr>
<th>Soil</th>
<th>Fraction, diameter range, microns</th>
<th>Mineralsa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarion</td>
<td>2-5</td>
<td>quartz ++, kaolinite -, hydrous mica (?) -</td>
</tr>
<tr>
<td>Clarion</td>
<td>2-0.2</td>
<td>montmorillonoid +, quartz +, kaolinite -, illite -</td>
</tr>
<tr>
<td>Clarion</td>
<td>less than 0.2</td>
<td>(nondescript pattern - no interpretation)</td>
</tr>
<tr>
<td>Tama</td>
<td>2-5</td>
<td>quartz ++, montmorillonoid +, kaolinite -, hydrous mica (?)+</td>
</tr>
<tr>
<td>Tama</td>
<td>2-0.2</td>
<td>quartz +, montmorillonoid +, kaolinite -, illite -</td>
</tr>
<tr>
<td>Tama</td>
<td>less than 0.2</td>
<td>montmorillonoid +, illite -, kaolinite very doubtful</td>
</tr>
</tbody>
</table>

Marks after mineral indicate relative amount present:

++ = significant amount present
+ = present
- = small amount or doubtful

parable size fraction of Tama, lack of any well-defined clay mineralogy in the less than 0.2 micron fraction, and dominance of montmorillonoid clay minerals in the 2-0.2 micron fraction.

Outstanding aspects of the Tama clay mineralogy are the significant amounts of montmorillonoid clay minerals in the 5-2 micron fraction and the dominance of montmorillonoid clay minerals with small amounts of illite and possibly kaolinite.
in the less than 0.2 micron fraction.

Coarse clay fractions (2-0.2 microns) of B horizons of Tama and Clarion soils seem to have similar clay mineralogy qualitatively, though the Tama may contain a higher percentage of montmorillonoid minerals and the illite peak is somewhat broader. This is in agreement with findings of previous investigators that there are no essential qualitative differences in the clay mineralogy of loess-derived and till-derived soils of Iowa.

No evidence for random interlayering of illite and montmorillonite could be found in these samples, except for uncertainty of interpretation of the endothermic peak near 560-570 degrees in the differential thermal curves. Lyon (1955) has reported possible interlayering of illite and montmorillonite in the loessial parent material of Tama and Fayette soils in northeast Iowa and Riggs (1956) has suggested the presence of illite-montmorillonite interlayers in soils and parent materials of southwest Iowa.

Some importance might be attached to the finding of appreciable montmorillonoid mineral in the 5-2 micron fraction of the Tama sample, though highly speculative since based on only one sample. This feature may indicate some fairly stable aggregation of clay minerals in the loess, or may indicate incomplete dispersion of the sample.
Organic matter distribution

Nature of organic matter distribution in some representative Polk County soil profiles as measured by content of organic carbon in the various horizons is shown in Figure 18. Data for the Hayden profile have previously been reported by White (1953).

High content of organic matter in a thin surface layer underlain by horizons relatively low in organic matter, as in the Hayden profile in the figure, seems representative of organic matter distribution in Polk County soils formed under forest vegetation and medium to good aeration. The Hayden profile has formed from Late Wisconsin till under conditions of good aeration.

The Webster profile is illustrative of the nature of organic matter distribution in soils formed under prairie vegetation and conditions of poor aeration and natural wetness. Content of organic matter in the thick surface horizons is higher than in soils also formed under prairie but with good aeration, as the Clarion and Sharpsburg profiles illustrated here. The organic matter exhibits a diffusion characteristic with depth.

Clarion and Sharpsburg profiles exhibit organic matter distribution representative of soils formed under prairie vegetation and conditions of good to intermediate natural
Figure 18. Organic carbon distribution with depth in some Polk County soil profiles
drainage. Content of organic matter is lower in the surface horizon than in that of the forested Hayden soil, but surface horizons are thicker. Organic matter of these two profiles exhibits a diffusion versus depth characteristic. The Sharpsburg soils are assumed to be "older" than the Clarion soils, which may be an explanation for the higher content of organic matter in the upper portion of this profile.

Soil pH

Three soils which have not been limed as far as could be determined have been selected to illustrate soil pH-depth relationships in Polk County soils as related to soil genesis, as shown in Figure 19. It is assumed that soil pH roughly corresponds with the degree of leaching of the soil.

The Lindley profile (data of Prill, 1955) formed under forest from Kansan till (apparently this particular site has never been cleared) shows a higher pH in the surface than in lower horizons apparently due to return of bases by leaves. There is a slight indication of a leached eluvial layer. The pH does not increase with increasing depth in the profile until the parent material is approached. This pH-depth relationship is representative of the forested upland soils of Polk County and Iowa in general.

The condition of lowest pH values in the surface and
Figure 19. Nature of soil pH with depth in some Polk County soil profiles
Increasing pH with increasing depth in the profile as shown in the Tama profile is representative of the upland soils formed under prairie with good to medium drainage. Though the lowest pH in the soil is not always found in the surface in profiles of these soils, the general relationship of pH values increasing with depth does hold, except where leached outwash gravel underlies the profile.

Webster soil profile illustrates pH values representative of poorly aerated soils, often water saturated under natural conditions, which have formed in level or depressional areas of the Late Wisconsin till plain and outwash deposits of the northern four-fifths of Polk County. In certain areas, such soils contain free calcium carbonate throughout the soil, with pH values near 8.

Categorical Classification of Polk County Soil Series

Genetic horizon concepts

Soil horizon designations used in the morphological descriptions (Appendix) and in the following discussions of classification are discussed and defined in this section.

Soil horizon is defined as a genetic layer of the soil essentially parallel to the soil surface (U. S. Department of Agriculture, 1951). In this study, to be distinguished as a
horizon, a given layer must be distinguishable from adjacent layers by differences in one or more of such features as color, texture (particle size distribution), consistence, where these differences have been produced by soil-forming processes. First application of the term "horizon" to soil genetic layers was by early Russian workers because of lack of sharp breaks and contrasts between layers, according to a note by Marbut in his translation of Glinka (1927).

ABC horizon notations were apparently first used by Dokuchaiev (1879), though not in exactly the same sense as presently used (U. S. Department of Agriculture, 1951). As summarized by Nikiforoff (1931), Dokuchaiev defined the A horizon as the surface genetic layer, the C horizon as parent material unmodified by genetic processes, and the B horizon as the genetic layer transitional from A to C. Dokuchaiev used these notations to describe genetic layers in chernozems, or dark-colored grassland soils. These symbols soon obtained more significance as the Russians began studying forested soils, according to Nikiforoff. The A of podzolized soils (leached forested soils) became an eluvial horizon, the B an illuvial one. Nikiforoff stated that several subhorizons were introduced by the Russians, such as the A2 with the special meaning of the horizon of maximum leaching.

A departure from the ABC nomenclature was proposed by the early Russian worker Vilenski (discussed, but not cited,
by Nikiforoff, 1931). He proposed A for accumulation horizon, E for horizon of eluviation, and I for horizon of illuviation. Vilenski also proposed using small (lower case) letters as modifiers of the main horizon designations to indicate materials eluviated or illuviated, such as h for organic matter (humus) and s for soluble salts, and proposed similar letters to indicate types of soil formation, as p for podzolized soil horizons. None of these proposals has come into general use to date except the letters to indicate material translocated or accumulated (discussion of these letters is given in U. S. Department of Agriculture, 1951, pp. 181-182).

Glinka (1927) proposed an additional horizon - a G horizon for glei or waterlogged horizon. The G horizon was described by Glinka as formed by influence of groundwater, characterized by presence of ferrous iron and other reduced compounds and mottled with greenish, bluish, and reddish hues.

Revisions of the ABC notation and suggestions for additional horizons have been proposed by Norton and Smith (1928, 1929) and by Bushnell (1946). Norton and Smith proposed revision of the C horizon concept and additional D and E horizons for variations in leaching and oxidation of the underlying material. Bushnell's proposals involved special horizon notations for soils of poor natural drainage - H, U, and M, and two additional horizons for other soils - the X and Y, differentiated on the basis of consistence of the
Horizon notations of a special kind to indicate interpretations of soil-forming processes have recently been used in published profile descriptions by Gardner and Whiteside (1952) and by Folks (1954). Gardner and Whiteside used subscripts on horizon notations to indicate specific great soil group characteristics for soils in which two different kinds of horizons have developed, such as $B_{2GB}$ for a $B$ horizon with gray-brown podzolic characteristics, and $B_{2p}$ for a $B$ horizon in the same profile with podzol characteristics. Folks proposed using a compound symbol of $A_{2Bi}$ to indicate iron bands with associated interband layers in the deeper portions of the Thurman soil of Polk County and similar very sandy soils of Iowa.

Soil horizon notations and definitions now official for the Soil Survey in the U. S. Department of Agriculture are given in the Soil Survey Manual (U. S. Department of Agriculture, 1951). Since a number of Polk County soils are minimal in development, with low degree of horizon expression, a study of horizon criteria and development of quantitative horizon definitions seemed desirable to complement the qualitative definitions given in the Soil Survey Manual. Also some sort of principles need to be developed for horizon notations, because soil horizon designations are important in classification.
Also, the question arises whether Polk County soils with poor natural drainage have G or glei horizons. The G horizon is defined in the Soil Survey Manual as "a layer of intense reduction, characterized by the presence of ferrous iron and neutral gray colors that commonly change to brown upon exposure to the air," and as developed by a process which "involves saturation of the soil with water for long periods in the presence of organic matter."

Present practice of defining the A horizon as a master horizon consisting of the A1 with maximum organic accumulation and dark color, and the A2 with maximum eluviation and light color has not been followed in this study. The processes in the horizon ordinarily labelled A2 are quite distinct from those in the horizon ordinarily labelled A1. For this reason the light eluvial layer is labelled Ae in this study, the dark organic accumulation layer, Ah.

Study of data and descriptions of some soil horizons designated as Ah in this study are summarized in Tables 8 and 9.

Data of Tables 8 and 9 indicate that the characteristics which horizons designated Ah (or Ap horizons, which in this study are Ah horizons disturbed by cultivation) have in common are (1) all are upper or surface horizons; (2) dark color of 10YR hue and of numerical value (Munsell color system) of 2 to 4 and chroma of 1 or 2; (3) all have color contrast
Table 8. Some morphologic characteristics of Ah (surface) horizons of selected Polk County soil series (unless otherwise indicated, color comparisons are from morphological descriptions in Appendix)

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Natural drainage</th>
<th>Cultivated or virgin</th>
<th>forest vegetation</th>
<th>Munsell color</th>
<th>Color differences from B</th>
<th>C if no B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hue Value Chroma</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hue Value Chroma</td>
<td></td>
</tr>
<tr>
<td>Ames</td>
<td>Poor</td>
<td>V</td>
<td>F</td>
<td>10YR3/1</td>
<td>+2.5</td>
<td>-2</td>
</tr>
<tr>
<td>Clarion</td>
<td>Good</td>
<td>C</td>
<td>P</td>
<td>10YR2/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Colo</td>
<td>Poor</td>
<td>C</td>
<td>P</td>
<td>10YR2/1</td>
<td>+2.5</td>
<td>-1</td>
</tr>
<tr>
<td>Dakota</td>
<td>Good</td>
<td>C</td>
<td>P</td>
<td>10YR2/2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Dorchester</td>
<td>Intermed.</td>
<td>C</td>
<td>(?)</td>
<td>10YR3/1</td>
<td>(no B)</td>
<td>0</td>
</tr>
<tr>
<td>Fayette</td>
<td>Good</td>
<td>V</td>
<td>F</td>
<td>10YR4/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Ferrera</td>
<td>Good</td>
<td>C</td>
<td>P</td>
<td>10YR2/2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Hayden</td>
<td>Good</td>
<td>V</td>
<td>F</td>
<td>10YR3/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Huntsville</td>
<td>Intermed.</td>
<td>C</td>
<td>P</td>
<td>10YR3/1</td>
<td>(no B)</td>
<td>0</td>
</tr>
<tr>
<td>Kato</td>
<td>Intermed.</td>
<td>C</td>
<td>P</td>
<td>10YR3/1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Lester</td>
<td>Good</td>
<td>V</td>
<td>PF</td>
<td>10YR3/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Lindley</td>
<td>Good</td>
<td>V</td>
<td>F</td>
<td>10YR4/2</td>
<td>-2.5</td>
<td>-1</td>
</tr>
<tr>
<td>Marshan</td>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td>10YR2/1</td>
<td>+2.5</td>
</tr>
<tr>
<td>Nicollet</td>
<td>Intermed.</td>
<td>C</td>
<td>P</td>
<td>10YR3/1</td>
<td>0</td>
<td>C</td>
</tr>
<tr>
<td>Sharpburg</td>
<td>Good</td>
<td>C</td>
<td>P</td>
<td>10YR3/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Shelby</td>
<td>Good</td>
<td>C</td>
<td>P</td>
<td>10YR3/2</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Thurman</td>
<td>Good</td>
<td>V</td>
<td>P</td>
<td>10YR3/2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Wabash</td>
<td>Poor</td>
<td>C</td>
<td>P</td>
<td>10YR2/1?</td>
<td>+0.5</td>
<td>-3</td>
</tr>
<tr>
<td>Webster</td>
<td>Poor</td>
<td>C</td>
<td>P</td>
<td>10YR2/1</td>
<td>+5.0</td>
<td>-3</td>
</tr>
</tbody>
</table>

\(a\) Description from White (1953).
\(b\) Description from Prill (1955).
\(c\) Description from Folks (1954).
Table 9. Some chemical characteristics of Ah (surface) horizons of selected Polk County soils (unless otherwise indicated, data are from Table 4 and 6)

<table>
<thead>
<tr>
<th>Soil</th>
<th>Inches thick</th>
<th>Free Fe Ah Free Fe B</th>
<th>pH</th>
<th>pH units different from B (or C, if no B)</th>
<th>Organic C Ah</th>
<th>Organic C B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames</td>
<td>7</td>
<td>0.5</td>
<td>6.9</td>
<td>+1.2</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Clarion</td>
<td>9</td>
<td>0.8</td>
<td>6.7</td>
<td>+0.9</td>
<td>1.6</td>
<td>--</td>
</tr>
<tr>
<td>Colo</td>
<td>14</td>
<td>1.3</td>
<td>6.5</td>
<td>+0.1</td>
<td>2.1</td>
<td>--</td>
</tr>
<tr>
<td>Dakota</td>
<td>11</td>
<td>--</td>
<td>5.8</td>
<td>+0.2</td>
<td>2.0</td>
<td>--</td>
</tr>
<tr>
<td>Dorchester</td>
<td>7</td>
<td>--</td>
<td>7.9</td>
<td>+0.2</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fayette</td>
<td>4 1/2</td>
<td>--</td>
<td>5.5</td>
<td>+0.9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Farrar(^a)</td>
<td>12 1/2</td>
<td>0.6</td>
<td>5.8</td>
<td>-0.2</td>
<td>3.6</td>
<td>--</td>
</tr>
<tr>
<td>Hayden(^a)</td>
<td>3</td>
<td>0.5</td>
<td>6.2</td>
<td>+1.0</td>
<td>7.8</td>
<td>--</td>
</tr>
<tr>
<td>Huntsville</td>
<td>9</td>
<td>--</td>
<td>6.9</td>
<td>+0.1</td>
<td>1.2</td>
<td>--</td>
</tr>
<tr>
<td>Kato</td>
<td>15</td>
<td>1.3</td>
<td>6.3</td>
<td>+0.2</td>
<td>2.4</td>
<td>--</td>
</tr>
<tr>
<td>Lester(^a)</td>
<td>4</td>
<td>--</td>
<td>6.2</td>
<td>+0.7</td>
<td>6.0</td>
<td>--</td>
</tr>
<tr>
<td>Lindley(^b)</td>
<td>5</td>
<td>0.6</td>
<td>5.8</td>
<td>+0.9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Marshall</td>
<td>13</td>
<td>0.5</td>
<td>5.3</td>
<td>+0.3</td>
<td>1.6</td>
<td>--</td>
</tr>
<tr>
<td>Nicollet</td>
<td>13</td>
<td>1.1</td>
<td>6.2</td>
<td>-0.7</td>
<td>2.4</td>
<td>--</td>
</tr>
<tr>
<td>Sharpsburg</td>
<td>13</td>
<td>0.8</td>
<td>6.4</td>
<td>+0.8</td>
<td>2.3</td>
<td>--</td>
</tr>
<tr>
<td>Shelby</td>
<td>7</td>
<td>0.5</td>
<td>5.3</td>
<td>+0.3</td>
<td>1.6</td>
<td>--</td>
</tr>
<tr>
<td>Thurman(^c)</td>
<td>20</td>
<td>0.9</td>
<td>6.2</td>
<td>+0.2</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Wabash</td>
<td>14</td>
<td>1.7</td>
<td>5.7</td>
<td>-0.6</td>
<td>1.6</td>
<td>--</td>
</tr>
<tr>
<td>Webster</td>
<td>15</td>
<td>1.0</td>
<td>7.4</td>
<td>-0.4</td>
<td>3.1</td>
<td>--</td>
</tr>
</tbody>
</table>

\(^a\)Farrar, Hayden, and Lester data from White (1953).
\(^b\)Linley data from Prill (1955).
\(^c\)Thurman data from Folks (1954).

from B horizon, or next underlying horizon if no B, of at least one chroma unit, or if no chroma or value contrast then of less yellow hue than underlying horizons; (4) all are horizons of maximum organic matter accumulation, except
that in young Alluvial soils (as Huntsville) lower layers may have higher organic matter than the surface (buried former surface horizons?) but the surface horizon is immediately underlain by one of lower content of organic matter and less dark color; (5) all are highly base saturated, at least more than 75 percent, based on inferences from pH and base saturation data; (6) organic matter accumulation seems the dominant soil genetic process.

Study of the data of Tables 8 and 9 indicate additional statements can be made if the soils are stratified according to native vegetation and natural drainage status. In well-drained forest soils, the Ah horizons have the following characteristics in common: (1) less than 6 inches thick; (2) the highest pH value of the entire solum (A plus B horizons); (3) from scant evidence seem to have five times or more organic matter in the surface than in the B2 horizon; (4) on basis of a few data, may have C/N ratios wider than 12 in the uppermost part of the A horizon (data of White, 1953); (5) some indication that ratio of free Fe percentage in A to free Fe percentage in B is in neighborhood of 0.5.

For well-drained and somewhat poorly drained soils with B horizons developed under prairie vegetation, the Ah (or Ap) horizons have in common the following characteristics: (1) about 12 inches or more thick where relatively uneroded; (2) either have the lowest pH in the solum or are immediately
underlain by horizons with the lowest pH in the solum where cultivated and limed, except in the soils underlain by outwash gravel or developed from sandy parent material; (3) tend to have ratios of organic matter in the A to organic matter in the B of about 1.5 to 4.5; (4) on the basis of data for the Ferrer profile, and for Tama soils outside the county by White (1953), C/N ratios are probably less than 12 in these horizons; (5) these prairie soils with good natural drainage seem to have free Fe A/B ratios of the order of 0.5 to 1, the imperfectly drained soils may have free Fe A/B ratios of greater than 1 - on the basis of a few profiles. Microscopic study of thin sections of the Clarion and Nicollet soils indicate that the Ah horizons are undergoing the most alteration of primary minerals of any horizon in profile.

Surface or uppermost horizons of poorly drained soils of the grasslands seem to have the following characteristics in common (except where underlain by an eluvial horizon as in the Rolfe or Blockton soils) on the basis of limited data:
(1) generally thick horizons, 14 inches or more in thickness;
(2) the pH values are the lowest in the solum, except where limed; (3) ratio of organic matter in A to that in B ranging from 1.5 to about 3.0; (4) ratios of free Fe in the A to that in the B horizon greater than 1 but less than 2.

Some characteristics of horizons designated as Ae horizons are listed in Tables 10 and 11.
Table 10. Some morphologic characteristics of Ae horizons of Polk County soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Forest or prairie</th>
<th>Natural drainage</th>
<th>Horizon thickness</th>
<th>Horizon color</th>
<th>Color differences from</th>
<th>Color differences from</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ah Hue Value Chroma</td>
<td>B2 Hue Value Chroma</td>
</tr>
<tr>
<td>Ames</td>
<td>F</td>
<td>Poor</td>
<td>7</td>
<td>10YR5/2</td>
<td>0 +2 +1 +2.5 0 -2</td>
<td></td>
</tr>
<tr>
<td>Downs</td>
<td>P</td>
<td>Good</td>
<td>4</td>
<td>10YR4/2</td>
<td>0 +1 0 0 -1 -1</td>
<td></td>
</tr>
<tr>
<td>Fayette</td>
<td>F</td>
<td>Good</td>
<td>5</td>
<td>10YR5/2</td>
<td>0 +1 0 0 -2</td>
<td></td>
</tr>
<tr>
<td>Hayden a</td>
<td>F</td>
<td>Good</td>
<td>5</td>
<td>10YR5/3</td>
<td>0 +2 +1 0 +1 -1</td>
<td></td>
</tr>
<tr>
<td>Lester a</td>
<td>PF</td>
<td>Good</td>
<td>5</td>
<td>10YR4/2</td>
<td>0 +1 +1 0 0 -1</td>
<td></td>
</tr>
<tr>
<td>Lindley b</td>
<td>F</td>
<td>Good</td>
<td>4</td>
<td>10YR6/2</td>
<td>0 +1 0 -2.5 0 -2</td>
<td></td>
</tr>
<tr>
<td>Rolfe</td>
<td>P</td>
<td>Poor</td>
<td>7</td>
<td>10YR4/1</td>
<td>0 +2 0 +2.5 +1 -1</td>
<td></td>
</tr>
</tbody>
</table>

aFrom description by White (1953).

bFrom description by Prill (1955).
Table 11. Some chemical and physical characteristics of Ae horizons of Polk County soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>pH</th>
<th>pH difference from</th>
<th>Clay Ae Clay Ah</th>
<th>Clay Ae Clay B2</th>
<th>Free Fe Ae Free Fe B2</th>
<th>Organic matter Ae Organic matter Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames</td>
<td>6.3</td>
<td>-0.6</td>
<td>+0.6</td>
<td>1.02</td>
<td>0.62</td>
<td>0.52</td>
</tr>
<tr>
<td>Downs</td>
<td>6.4</td>
<td>-0.2</td>
<td>+0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fayette</td>
<td>5.5</td>
<td>0</td>
<td>+0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hayden&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.8</td>
<td>-0.3</td>
<td>+0.7</td>
<td>0.93</td>
<td>0.37</td>
<td>0.49</td>
</tr>
<tr>
<td>Lester&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.1</td>
<td>-0.1</td>
<td>+0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindley&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.0</td>
<td>-0.8</td>
<td>+0.2</td>
<td>0.96</td>
<td>0.48</td>
<td>0.44</td>
</tr>
</tbody>
</table>

<sup>a</sup>From data of White (1953).

<sup>b</sup>From data of Prill (1955).
Characteristics held in common by those genetic layers designated as Ae horizons of Polk County soils as deduced from Tables 10 and 11 are: (1) at least one unit of color value higher than overlying Ah horizons; (2) at least one unit of chroma lighter than underlying Bg horizons; (3) colors of 10YR hue of 4 to 5 in value and 1 to 3 in chroma; (4) slightly more acid than overlying Ah horizons; (5) slightly lower in clay than the overlying Ah horizon (deduced from scanty data and field estimates of texture) but underlain by B horizons with significantly more clay; (6) a few data indicate that they contain about the same amount of free iron as the overlying Ah, but that underlying B horizons may contain about twice as much free iron; (7) on the basis of a few data, the overlying Ah horizons contain much more organic matter, perhaps two to four times as much; (8) eluviation seems the dominant soil genetic process.

The Ae horizons of poorly drained soils are less yellow in hue than underlying Bg horizons and are thicker than the other Ae horizons; data at hand do not indicate other differences from Ae horizons of well-drained soils. The one grassland soil listed in Tables 10 and 11, the Rolfe soil, has an Ae horizon of darker color than those of the forested soils, but no other inferences seem justified. In general, Ae horizons seem to be more homogeneous in properties than other soil horizons.
Characteristics of horizons of some Polk County soil series designated as B2 horizons in field examination are summarized in Tables 12 and 13.

Inspection of the data of Tables 8 to 13 indicates that horizons designated as B2 in field study contrast in color to the overlying A horizons and underlying C horizons. The only uniform trend in color contrast is for higher chroma of the B2 as compared to the overlying A horizons. The B horizons contrast in color to underlying C but the nature of the contrast is variably one of hue, value, or chroma or some combination of these. Content of organic carbon is distinctly less in the B2 horizons as compared to A horizons in those profiles on which data are available. Clay accumulation and mobilization or accumulation of iron seem to be dominant genetic processes.

The horizons designated B have blocky structure as compared to the more granular A or surface horizons. However, many soils have blocky structure at depths far below that to which B horizons ordinarily extend, and many soils from relatively fresh alluvium show blocky structure. The morphological description of the Zook, Webash, Marshan, Webster, and Huntsville soils tend to support this. Furthermore, estimates of structure are rather subjective, and are not subject to precise laboratory measurement. Therefore, blocky structure does not seem acceptable as a unique characteristic or a
Table 12. Some morphologic characteristics of Bz horizons of selected Polk County soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Native vegetation</th>
<th>Natural drainage</th>
<th>Dominant color</th>
<th>Color difference from C</th>
<th>Clay films visible on structure aggregates b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hue</td>
<td>Value</td>
</tr>
<tr>
<td>Ames</td>
<td>F</td>
<td>P</td>
<td>2.5Y5/4</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Clarion</td>
<td>P</td>
<td>G</td>
<td>10YR3/3</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Colo</td>
<td>P</td>
<td>P</td>
<td>2.5Y2/1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Dakota</td>
<td>P</td>
<td>G</td>
<td>10YR4/3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fayette</td>
<td>F</td>
<td>G</td>
<td>10YR5/4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Farrar c</td>
<td>P</td>
<td>G</td>
<td>10YR4/4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hayden c</td>
<td>F</td>
<td>G</td>
<td>10YR4/4</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Kato</td>
<td>P</td>
<td>I</td>
<td>10YR4/2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lester c</td>
<td>FF</td>
<td>G</td>
<td>10YR4/3</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Lindley d</td>
<td>F</td>
<td>G</td>
<td>7.5YR5/6</td>
<td>2.5</td>
<td>0</td>
</tr>
</tbody>
</table>

bG = good natural drainage, I = intermediate natural drainage, P = poor natural drainage.

b++ indicates clay films visible with hand lens on both horizontal and vertical surfaces of aggregates, taken as evidence of clay translocation; + indicates doubtful presence of clay films, sometimes visible with hand lens and mostly on vertical faces but not visible in many profiles, with some pore linings of clay. (That these are oriented clay films have been confirmed in study of thin sections of B horizons of Tama, Clarion, Nicollet, and Webster soils.)

cFrom description by White (1953).

dFrom description by Prill (1955).
Table 12. (Continued)

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Native vegetation</th>
<th>Natural drainage</th>
<th>Dominant color</th>
<th>Color difference from C</th>
<th>Clay films visible on structure aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hue</td>
<td>Value</td>
</tr>
<tr>
<td>Marshan</td>
<td>P</td>
<td>P</td>
<td>2.5Y3/2</td>
<td>-2.5</td>
<td>-1</td>
</tr>
<tr>
<td>Nicollet</td>
<td>P</td>
<td>I</td>
<td>10YR3/2</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Sharpsburg</td>
<td>P</td>
<td>G</td>
<td>10YR4/3</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Tama</td>
<td>P</td>
<td>G</td>
<td>10YR5/4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thurman e</td>
<td>P</td>
<td>G</td>
<td>5Y3/1</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>Wabash</td>
<td>P</td>
<td>P</td>
<td>5Y4/2</td>
<td>0</td>
<td>-2</td>
</tr>
</tbody>
</table>

*From description by Folks (1954).*
Table 13. Some chemical and physical characteristics of B$_2$ horizons of selected Polk County soil series

<table>
<thead>
<tr>
<th>Soil series</th>
<th>pH</th>
<th>Clay B$_2$/Clay C</th>
<th>Free Fe B$_2$/Free Fe C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames</td>
<td>6.7</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Clarion</td>
<td>5.7</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Colo</td>
<td>6.4</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Farrar$^a$</td>
<td>6.1</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Hayden$^a$</td>
<td>5.1</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Kato</td>
<td>6.6</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Lindley$^b$</td>
<td>4.9</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Marshall</td>
<td>6.9</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Nicollet</td>
<td>6.9</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Sharpsburg</td>
<td>5.6</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Tama</td>
<td>5.7</td>
<td>1.3</td>
<td>--</td>
</tr>
<tr>
<td>Thurman</td>
<td>6.0</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Wabash</td>
<td>6.3</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Webster</td>
<td>7.8</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$^a$Data from White (1953).
$^b$Data from Prill (1955).

criterion of B horizons.

Clay ratios of B$_2$/C greater than one do not seem to reflect clay translocation due to soil genesis in many of the profiles listed in Table 13. Ratios greater than one seem due to stratification in parent material and dilution of clay by carbonates in the C horizons of Clarion, Farrar, Nicollet, and Webster soils. There is only slight evidence of clay translocation, such as a few clay films or pore fillings, often not visible with hand lens examination. This incipient
clay translocation is not believed large enough in amount to produce real clay differences among horizons within these soils. The high $B_2/C$ clay ratio of the Thurman represents a difference between about four percent total clay in the $B$ and slightly more than two percent total clay in the $C$, probably not significant at such low clay percentages accompanied by high sand percentages. The free iron $B_2/C$ ratios greater than one probably are not significant in the Colo, Marshan, and Wabash soils since these are reflections of a few hundredths of a percent difference at very low contents of free iron. Ames, Fayette, Hayden, Lester, Lindley, Shaparsburg, and Tama soils show significant clay accumulation in their $B$ horizons both by mechanical analyses and recognition of differences in clay percentage in the field accompanied with visual evidence of clay translocation in the form of pronounced clay films. Percentages of free iron at various depths in the profile in those soils without definite evidence of clay accumulation in the $B_2$ horizon as measured by particle size distribution analyses are plotted in Figure 20.

That soils such as Clarion and Farrar have horizons of minimal clay accumulation but containing some free Fe concentration can be inferred from Figure 20, and the description of Clarion thin sections in the previous section. Thus, these soils can be classed as having $B$ horizons as the term is currently defined, as discussed earlier in this section (U. S.}
Figure 20. Percentage of free Fe in some Polk County soil profiles lacking evidence of clay accumulation as measured by particle size distribution analyses.
Department of Agriculture, 1951). Some slight evidence of clay translocation can be seen in the field, but this does not seem a suitable field criterion since the ability to see the clay films and pore linings is dependent on moisture status of the sample, texture of the material, and the experience and training of the observer. The term proto B horizon is suggested for these soils, since they show signs of incipient silicate clay accumulation. The color contrast as judged in the field is the reliable criterion, consisting of a color contrast from the A horizons of at least one unit of value or chroma.

A somewhat different type of horizon is seen in the layers underlying A horizon of Nicollet and Kato soils which have somewhat poor natural drainage and which lack the slight accumulation of free Fe of the well-drained Clarion or Farrar soils but do have an apparent free Fe level above that of the poorly drained soils such as the Webster. Study of the Nicollet in thin section reveals some pore filling and aggregate coatings of apparently translocated clay, along with some stringers of clay which may have formed in place. These horizons would seem best classed with the minimal B horizons of the Clarion and Farrar soils. Recognition of clay films or pore fillings by field examination of these particular soils does not seem a useful criterion, since the degree of development is variable and the ability to recognize them
varies with moisture content and the qualifications of the observer.

Another type of horizon designated B in field studies is that of the Webster, Marshan, Wabash and similar soils with poor natural drainage and lacking pronounced evidence of clay translocation. These soils are consistently lower in free iron than well drained and somewhat poorly drained profiles also lacking definite evidence of clay translocation (such as the Clarion and Nicollet profiles), as illustrated in Figure 20. Evidence is for net loss of iron from these poorly drained profiles. Microscopic study of thin sections of the subsoil of a Webster profile indicates presence of thin clay films and pore fillings of clay, probably translocated. However, these signs of clay translocation cannot be consistently recognized in field study. A rather distinctive feature of these horizons is the presence of clay stringers throughout the groundmass, as discussed in the previous section. Since study of the "older" more developed Edina soil, also developed under poor drainage, reveals appreciable clay films as well as many groundmass stringers of clay, it is thought that Webster and related soils will develop more definite evidence of clay translocation with time. Their dominant characteristic is the gray color as observed in the field, low content of free iron, and presence of many groundmass stringers of clay which may have developed in place. Therefore, genetic
layers of clay concentration are here designated as gley B horizons with notation of Bg. They are recognized in field studies by their yellower hues than overlying A horizons and by colors of lower value and less mottling than the underlying C horizon. Note that application of this criteria tends to rule out consideration of the Colo soil series as having a gley B horizon. It must be considered as having a proto B, or as not having a B horizon.

**Higher categories**

**Theory and principles.** In a population as diverse in properties as soils, a multiscategorical system of classification is a necessity if classification into discrete classes is practiced. (A definition of category offered by Cline, 1949a, is "a series of classes, collectively, formed by differentiation within a population on the basis of a single set of criteria"). This was realized by Marbut (1927) in his development of the first comprehensive soil classification scheme. Marbut indicated the necessity for classes in the higher categories of a multiscategorical system to be differentiated on a small number of properties whereas classes of the lowest category should be distinguished by a maximum number of differentiating characteristics. Cline (1949a) pointed out that in a multiscategorical system the least
number of statements can be made about units of the highest category and the greatest number of statements about the lower category. Marbut specified that the classes of higher categorical levels should be based on features of soils with fully developed, mature (normal) profiles.

Definition of classes. Highest category of the present widely used mult$categorical classification (Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949) consists of orders of zonal, intrazonal, and azonal soils. Second highest category is composed of classes of suborders. Great soil groups comprise the third highest level of generalization in this classification outline.

Soil zonality was introduced as a criterion for classes of the highest categorical level in the revision of Marbut's soil classification by Baldwin, Kellogg, and Thorp (1938). The concept of soil zonality was first developed by Sibirtsev (1995).

Zonal soils were defined by Baldwin, Kellogg, and Thorp as comprising those soils with well-developed characteristics reflecting the influence of climate and vegetation as active factors of soil formation. Thorp and Smith (1949) stated that the term normal soil as employed by Marbut (1927, 1935) is a synonym for zonal soil.

Intrazonal soils were defined by Baldwin, Kellogg, and Thorp as well-developed soils having characteristics reflect-
ing the predominance of relief or parent material as a local
factor over the "normal" effect of climatic and vegetational
soil-forming factors.

Azonal soils were described by Baldwin, Kellogg, and
Thorp as those soils without well-developed characteristics
due to youth or to local factors of relief or parent mate-
rial preventing development of definite soil characteristics.
Thorp and Smith (1949) have described azonal soils as "those
in which profile development is at a minimum or near minimum".
They stated that soils "cease to be azonal at an arbitrary
stage of development when zonal or intrazonal characteristics
become unmistakably evident".

Soil suborders are based in part on soil characteristics
and are partly defined in genetic terms, as has been pointed
out by Thorp and Smith (1949). Included in definition accord-
ing to genesis are both genetic processes and climatic-ecologic
characteristics of the environment. For example, Polk County
soils of the zonal order are placed in the suborder of "light-
colored podzolized soils of the timbered regions" if formed
under forest following this classification. If formed under
prairie, they are in the suborder of "dark-colored soils of
the semi-arid, subhumid, and humid grasslands".

Baldwin, Kellogg, and Thorp (1938) considered a great
soil group as comprising a number of soil series showing the
same general sort of profile and having common internal soil
characteristics. The "same general sort of profile" is interpreted in the present study as similar kind and sequence of horizons resulting from similar profile processes. (By profile process is meant one which produces differentiation of soil into horizons, such as organic matter accumulation, silicate clay translocation and accumulation, and gleying or reduction and loss of iron.) The great soil groups as a concept in soil classification has persisted essentially unchanged since its inception by the early Russian workers.

Suggested revisions of classes. Soil orders and suborders in their current conception as described in the preceding section seem to possess a number of weaknesses and defects.

Soil zonality as a concept and criterion for soil classification at the highest categorical level, particularly the concept of intrazonal soils, can be shown to contain a number of theoretical and mechanical weaknesses. It is concluded from data developed in the present study that many soils associated together on a landscape but separated into zonal and intrazonal orders by current definition and practice are much more alike in processes of soil development than are most zonal soils. That is, so-called intrazonal soils show some zonal characteristics, making a mutually exclusive definition difficult. Thorp and Smith (1949) arrived at a similar conclusion. There is the additional observation that in
the landscape of the northern four-fifths of Polk County,
the intrazonal or "abnormal" soils occupy more than one-third
of the area. Studies of soils elsewhere in Iowa considered
intrazonal because of their formation under conditions of
poor aeration and prolonged water saturation (Ulrich, 1949,
1950; Cain, 1956) have indicated that such soils are passing
through a developmental course similar to that of associated
zonal soils formed from similar material. Additional evidence
for discounting the concept of soil zonality can be found in
the newer concepts of landscape evolution (Ruhe, 1956; Ruhe
and Scholtes, 1956) which tend to discount the concept of
intrazonal soils as ephemeral and transitory and to indicate
that more than one kind of regional or normal profile can be
present in a given region, depending on slope position and
landscape element a given soil occupies.

Similarities in kind of profile and of developmental
process in soils which are classed as zonal and intrazonal in
current concepts are shown in Figures 21 and 22. The "zonal"
Nicollet soil series is associated with the "intrazonal"
Webster on the Gary till plain under prairie vegetation; the
"zonal" Kato is associated with the "intrazonal" Marshan on
the Late Wisconsin outwash terraces under prairie vegetation;
and the "zonal" Hayden is associated with the "intrazonal"
Ames on the Gary till plain under forest vegetation. Data
plotted for the Hayden series are those previously presented
Figure 21. Comparison of some properties of zonal Kato and Nicollet profiles with intra-zonal Karshan and Webster profiles
Figure 22. Comparison of some properties of Hayden and Ames profiles
by White (1953). Inspection of the curves of Figures 21 and 22 and of morphological descriptions of these soils indicates that the pairs of soils associated together on a landscape have about the same kind and sequence of horizons. Profile properties and soil-forming processes are essentially similar between the soils of each of the pair. There are differences between the soils of the pairs. Greatest differences shown in the figures are in content of free iron and of organic carbon. Greatest difference in morphology is in color of the B horizons. However, these differences do not seem sufficiently profound to warrant discrimination of the pairs of soils at the highest levels of generalization in classification — where criteria must be broad and fundamental as was indicated in the section on theory and principles.

Wide extent of Webster soil series, considered intrazonal by current concepts, on the landscape in a township representative of the soil pattern in the northern four-fifths of Polk County is shown in Table 14.

Relatively wide extent of the Webster soil series on the landscape could be taken as evidence that it should not be considered intrazonal, implying abnormality.

Several weaknesses can be found in the currently-defined classes of the second highest categorial level, the suborders. Perhaps the major one is that criteria are based in large part on broad and ill-defined soil processes and assumed
Table 14. Percentage of soil series of the uplands area of Elkhart Township, Polk County, Iowa.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarion, &quot;zonal&quot;</td>
<td>21.6</td>
</tr>
<tr>
<td>Nicollet, &quot;zonal&quot;</td>
<td>40.8</td>
</tr>
<tr>
<td>Webster, &quot;intrazonal&quot;</td>
<td>36.2</td>
</tr>
<tr>
<td>Others</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Compiled from measurements made by the office of the Polk County Assessor from detailed soil maps.

genesis rather than specific soil characteristics. Genetic bias is strong. For example, soils can not be placed in sub-orders of the zonal order until it is decided whether their genesis has been predominantly under forest or prairie vegetation. This is an important problem in the prairie-forest "tension zones" of Polk County and other parts of Iowa where evidence suggests that many former prairie areas have only recently been invaded by trees (McComb and Loomis, 1944). Thorp and Smith (1949) have also pointed out the strong genetic bias in the soil suborders.

Basic soundness of the concept of the great soil group is indicated in its persistence since its inception in the late nineteenth century by the early Russian workers in soil classification. Thorp and Smith (1949) commented that the great soil group has proved the most useful of the higher categories, probably due to the more numerous specific state-
ments that can be made concerning the various great soil groups than classes of higher categories. If concepts and criteria for higher categories than the great soil group are revised, as seems desirable, some modification of individual great soil groups may be necessary in view of accumulation at this level of differentiating characteristics from the higher categories.

In consequence of the weaknesses and defects in the current concepts of classes of the two highest categorical levels, revision or abandonment of these concepts seems indicated. It seems desirable that soil zonality be abandoned as a basis for soil taxonomy and that classification at the highest categorical levels be revised into terms of fundamental differences in soils themselves.

If the principle is accepted that the purposes of soil classification are not only to organize soil knowledge but also to lead to acquisition of more knowledge and to understanding of the laws governing soil development, then a fresh approach to soil classification is indicated.

The approach which seems best suited to meet these objectives is that of classification by series, as described by Mill (1868). This approach is called classification by array to avoid confusion with the soil groups of soil series. Following is a quotation from Mill (p. 285) which describes this approach:
The requisites of a classification intended to facilitate the study of a particular phenomenon are, first, to bring into one class all kinds of things which exhibit that phenomenon, in whatever variety of forms and degrees; and secondly, to arrange these kinds in a series according to the degree in which they exhibit most of it, and terminating with those which exhibit least.

On the basis of this logic, it can be reasoned that "soil" as a natural phenomenon exhibits as a primary characteristic the possession of horizons, which characteristic serves to bring all soils into one class and differentiate them from "not soil". The next step is to array soils according to the degree to which they exhibit horizons. In Polk County, the following array of soils can be made on the basis of their horizons:

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ah</td>
<td>Ah</td>
<td>Ah</td>
<td>Ah</td>
<td>Ah</td>
<td></td>
</tr>
<tr>
<td>C(or D)</td>
<td>B</td>
<td>Bg</td>
<td>Ae</td>
<td>Ae</td>
<td></td>
</tr>
<tr>
<td>C(or D)</td>
<td>C(or D)</td>
<td>B</td>
<td>Bg</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C(or D)</td>
<td>C(or D)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From this array, it might be concluded that the highest level of classification could best be defined in terms of two classes: those with B(or Bg) and those without B horizons.

However, such a broad classification with only two classes does not seem desirable upon consideration of the large number of broad soil differences within the whole population of soils. In the previous discussions of soil genesis and horizon designations, it was indicated that all B horizons of Polk County soils have as a common characteristic accumulation of silicate clay (ranging from incipient in the
proto B to pronounced accumulation). But B horizons of many soils elsewhere possess as primary characteristics accumulations of translocated iron or aluminum with accessory organic matter or concentrations of iron and/or aluminum by extreme weathering, without significant silicate clay accumulation in either case (Byers and other, 1938; Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949).

An alternative approach for classification at the highest categorical level is to consider soils without B horizons as the zero class of an array of soils with B horizons and to array soils with B horizons according to the broad kind of B horizon they possess. (Soils with concentrations of iron and aluminum due to extreme weathering could be considered the end member of this array.) This approach seems the more desirable for soil classification at the highest categorical level. The two classes of this suggested category present in Polk County are soils without B horizons and those with B horizons of silicate clay accumulation.

Classification at the next lower level of generalization can then be based on presence or absence of secondary horizons - the Ae and the Bg. Classes at this level correspond to the previous array of Polk County soils by horizons present. These classes can be shown to correspond with the great soil groups of Polk County with the exception that the class of soils without B horizons contains a number of presently-
defined great soil groups. However, many of the individual classes at this proposed second level of generalization will include a number of great soil groups when soils other than those of Polk County are considered. Therefore retention of this second level of generalization as described above with great soil groups as classes of the third highest level of generalization seems desirable for purposes of this discussion, though modifications will doubtless be necessary for classification of the many kinds of soils not present in Polk County.

Placement of soil series in classes. Polk County soil series can be placed in either of two classes in the highest categorical level as defined on basis of classification by array as proposed in the previous section. These two classes are soils without B horizons and soils in which accumulation of silicate clay in the B horizon seems the most important soil genetic process. Due to the small number of soil series in the first class and the very large number in the second class, a listing of class placement at this categorical level is not shown.

It was suggested in the previous section that there is a 1:1 correspondence between classes of the second categorical level developed in the approach by array and great soil groups believed to occur in Polk County, with the exception of great soil groups comprised of soils without B horizons. The
classes suggested for the second categorical level as developed by the array approach and the great soil groups probably occurring within the county are listed in Table 15. The classes of second categorical level are listed according to their horizon sequence.

Table 15. Proposed classes of second categorical level and corresponding great soil groups

<table>
<thead>
<tr>
<th>Class:</th>
<th>Great soil group:</th>
<th>Ah/C (or D)</th>
<th>Ah/B/C</th>
<th>Ah/Bg/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class:</td>
<td>Ah/Be/C</td>
<td>Alluvial</td>
<td>Brunizem</td>
<td>Wiesenboden (or</td>
</tr>
<tr>
<td>Great soil group:</td>
<td>Lithosol</td>
<td></td>
<td></td>
<td>Humic Glei)</td>
</tr>
<tr>
<td></td>
<td>Regosol</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class:</th>
<th>Great soil group:</th>
<th>Ah/Ae/B/C</th>
<th>Ah/Ae/Bg/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class:</td>
<td>Gray-brown Podzolic</td>
<td></td>
<td>Planosol</td>
</tr>
</tbody>
</table>

This list of great soil groups of Polk County was developed by comparison of the data, morphological descriptions, and assumed genesis of soils of the county with that of great soil groups presently recognized in Iowa (Smith, Allaway, and Riecken, 1950; Simonson, Riecken, and Smith, 1952) and with the general descriptions of presently recognized great soil groups (Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949).

Distribution of associations of great soil groups in Polk County is shown in Figure 23. These associations are great soil groups associated together on the landscape. The associations have been stratified to indicate the nature of
Figure 23. Associations of great soil groups of Polk County, Iowa, stratified according to nature of parent material

Bl: Brunizems formed mostly from loess

Bs: Brunizems formed from sandy material, chiefly aeolian deposits or wind-modified glacial drift

BWA: Brunizems, Wiesenboden, and Alluvial soils formed from glacial outwash and alluvium

BWT: Brunizems and Wiesenboden formed from Cary till (or translocated sediments from Cary till)

Gl: Gray-Brown Podzolics formed mostly from loess

Gt: Gray-Brown Podzolics formed mostly from Cary till
the parent material.

A possible approach to placement of soil series in the appropriate great soil group, as a class at the third highest categorical level, is that of soil modality as proposed by Cline (1949a). In this approach the test is similarity of a soil in question to a modal individual of one class as compared to similarity to a modal individual of another class. The modal individual is defined by Cline in terms of a maximum in the frequency distribution according to value of a selected property or a number of properties of a class of soils. The modal individual is the central nucleus, typifying the modal properties of the class, as described by Cline.

Application of this approach to placement of Polk County soil series into great soil groups necessitates selection of a soil series as the modal individual for each of the great soil groups believed to occur in the county. For example, within Polk County the Clarion soil series would seem most logically designated as modal for the Brunizem great soil group. It is by far the most extensive of soils Brunizemic in nature and its properties would be highest in a frequency distribution analysis of properties of soils considered Brunizems. However, the Tama soil series has been selected as "modal" for Brunizems in studies of soils of this great soil group over their range of occurrence (Smith, Allaway, and Riecken, 1950). Yet Tama soils of Polk County are not
typical of Tama soils in general, as can be seen in comparison of data obtained in this study with Tama data presented by Smith, Allaway, and Riecken (1950). (This is probably due in part to the occurrence of Tama soils in Polk County at the western side of the general locale of Tama soils and may also be due in part to the slope position of the profile sampled, as is discussed later.)

As far as can be determined, no published material contains descriptions or specifications of properties of modal individuals of the great soil groups, other than Brunizems, which occur in the county in order that tests for placement can be made. Many Polk County soil series, particularly those formed from Late Wisconsin glacial drift, are minimal in development and exhibit low degree of horizon development such that their comparison with a modal soil series would be difficult, even if a modal series were defined and available for comparison. In summary, use of the test of similarity to a modal soil series does not seem a feasible means of placing Polk County soil series in great soil groups.

An alternative approach to class placement is the "conceptualist" standpoint advocated by Robinson (1941). A soil class is based on an abstraction formed from one's own impressions plus the described impressions of others of a general similarity of soils and the class is defined in terms of the most convenient criteria for the objective, according
to Robinson. (This is essentially the approach of Smith, Allaway, and Riecken, 1950, in defining the common characteristics of the Brunizem great soil group.) This approach suggests that placement of a soil series in a great soil group class should be based on conclusions drawn from study of the soil to determine if it possesses similar kind and arrangement of soil horizons, developed from a similar summation of processes in the profile, as other soils with similar fundamental profile features and summation of processes. This approach will be followed in the following discussion of great soil groups.

Brunizem soils. Brunizem soils were originally included with Prairie soils (Simonson, Riecken, and Smith, 1952). The Prairie soils were first recognized as a distinct great soil group by Marbut (1927). Coffey (1911) established "dark-colored prairie soils" as a broad soil unit, but his group was much wider in scope than the great soil group established by Marbut. Brunizems have recently been described by Smith, Allaway, and Riecken (1950) as having characteristics summarized as follows:

1. Dark-colored surface horizons 6 inches or more in thickness with moist Munsell color values of about 10YR3/1, 3/2 or 2/2 and content of organic carbon from 0.5 to 6 percent which decreases with depth.
2. Brown, yellowish brown or grayish brown subsoil
colors, frequently with mottles or incipient gleying.
3. Percentage of base saturation greater than 50 per-
cent.
4. Diffuse horizon boundaries with broad transitional
horizons.

Graphic comparison of the Sharpsburg soil series, believed
to be well within the range of the Brunizem concept, with the
widely differing Thurman soil series, placement of which in
the Brunizem group seems questionalbe is shown in Figure 24
(data for the Thurman series from Folks, 1954). The Sharps­
burg soil series has formed from loess under prairie vegeta-
tion and shows strong horizon differentiation. Thurman soil
series has formed from loamy sands, probably aeolian, under
prairie in that portion of the county mantled by Late Wis-
consin glacial drift. Though these soils have some gross
differences in terms of absolute soil properties, especially
particle size distribution and accessory properties, soil
developmental processes in the profile seem to have taken a
similar course in each. Base saturation, pH, organic carbon
distribution in the upper parts of the profiles, nature of
silicate clay accumulation, and morphological nature of
horizons indicate that these soils have the same kind and
sequence of horizons and that profile developmental processes
have been similar in each.

The following Polk County soil series are classed as
Figure 24. Comparison of some properties of Sharpsburg and Thurman profiles
Brunizems in view of their morphology and available data:

<table>
<thead>
<tr>
<th>Burchard</th>
<th>Gilbert</th>
<th>Olmitz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarion</td>
<td>Gravity</td>
<td>Saylor</td>
</tr>
<tr>
<td>Clearfield</td>
<td>Judson</td>
<td>Sharpsburg</td>
</tr>
<tr>
<td>Cooper</td>
<td>Kato</td>
<td>Shelby</td>
</tr>
<tr>
<td>Dakota</td>
<td>Lagonda</td>
<td>Tama</td>
</tr>
<tr>
<td>Dickinson</td>
<td>Lakeville</td>
<td>Terril</td>
</tr>
<tr>
<td>Farrar</td>
<td>Muscatine</td>
<td>Thurman</td>
</tr>
<tr>
<td>Flagler</td>
<td>Nicollet</td>
<td>Waukegan</td>
</tr>
</tbody>
</table>

Characteristics of Brunizem soils of Polk County are summarized as follows:

1. Ah or surface horizons are of Munsell colors 10YR3/1, 3/2, and 2/2 when moist and range from loamy sand to silty clay loam.

2. They lack Ae horizons.

3. B horizons of incipient to pronounced silicate clay accumulation due to soil genetic processes; colors are of some shade of brown in 10Yr hue with chroma no lower than 2 and value no higher than 5; loamy sand to silty clay.

4. Organic carbon diminishes rather gradually with increasing depth in profile.

5. Relationship between pH and depth is of similar pattern to that of organic carbon and depth is less uniform. The pH ordinarily increases with increasing depth in the profile, though there are exceptions where soils are underlain by leached outwash gravel, as in the Waukegan profile.
6. Clarion and Tama B horizons contain dominantly 2:1-layer lattice clay minerals. Other Brunizemic soils of the county have similar clay mineralogy, by inference.

**Gray-Brown Podzolic soils.** The Gray-Brown Podzolic great soil group was assigned its present name and general concept by Marbut (1935). The "light-colored timbered soils" earlier established as a broad group by Coffey (1911) had a much wider range and scope, as did the Brown Forest soils earlier discussed by Marbut (1927). Gray-Brown Podzolic profile characteristics were summarized by Baldwin, Kellogg, and Thorp (1938) as:

- Thin leaf litter over mild humus over dark-colored surface soil 2 to 4 inches thick over grayish brown leached horizon over brown heavy B horizon. Less acid than Podzols.

Polk County is near the westernmost edge of the area of occurrence of Gray-Brown Podzolic soils in the central United States. In Iowa, the continuous large areas of Gray-Brown Podzolic soils are east of Polk County, as can be seen in the distribution of the Gray-Brown Podzolic Fayette, Clinton, and Weller soil series in Figure 2. Distribution of Gray-Brown Podzolic soils in Polk County is confined to more sloping areas along streams (Figure 23) since this is the locale of native forest vegetation (Figure 4) under which they have developed.
Data for Polk County soils classed as Gray-Brown Podzolic have been reported by White (1953) and by Prill (1955). White studied the Hayden soil series formed under forest vegetation from Cary till and the Lester soil formed under prairie-forest transition vegetation from similar parent material as the Hayden. White classed both with the Gray-Brown Podzolic group. Prill studied the Lindley soil series, formed under forest vegetation from Kansan till. No studies have been made in Polk County of soils formed from coarse-textured material under forest vegetation such as the Chelsea and Lamont soil series. However Folks (1954) studied a profile of the Chelsea soil series from Linn County, Iowa, and classified it with the Gray-Brown Podzolic soils. All these soils possess Ae horizons, thin Ah horizons, and increased translocation of silicate clay and to a certain extent greater acidity than soils formed from comparable material under prairie vegetation. Their kind and sequence of horizons is similar regardless of their parent material or absolute differences in properties.

However, not all upland soils formed under forest vegetation have historically been classed with Gray-Brown Podzolic soils. Level or nearly level, poorly aerated forested soils have been classed in the intrazonal order and the Planosol great soil group. Comparison of some of the properties of the Hayden soil (Gray-Brown Podzolic) and the associated Ames soil series, formed from similar parent material but
under conditions of poor aeration with frequent water saturation, is shown in Figure 22. Data plotted for the Hayden series are those previously presented by White (1953). (It should be pointed out that the upper portion of the Hayden profile has been somewhat modified by some admixture of aeolian sand.) It can be seen that these two profiles possess a number of common features. However, somewhat different processes are indicated for the Ames soil, such as the lower content of free iron which reflects the gleying process active in this soil. Though not obvious from the plotted data, field observations indicate greater translocation of silicate clay with accompanying greater accumulation in the Ames soil. Therefore, placing of the Ames soils in the suggested class of Ah/Ae/Bg/C soils at the second highest categorical level and placing them in the Plenosol great soil group rather than Gray-Brown Podzolic group at the third highest categorical level seems justified.

The following Polk County soil series are placed in the Gray-Brown Podzolic great soil group on basis of their morphology and available data:

<table>
<thead>
<tr>
<th>Atterberry</th>
<th>Gara</th>
<th>Lester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chelsea</td>
<td>Gosport</td>
<td>Lindley</td>
</tr>
<tr>
<td>Chula(?)</td>
<td>Hayden</td>
<td>Runnells</td>
</tr>
<tr>
<td>Crocker</td>
<td>Ledoga</td>
<td>Stronghurst</td>
</tr>
<tr>
<td>Downs</td>
<td>Lamont</td>
<td></td>
</tr>
<tr>
<td>Fayette</td>
<td>LeSueur</td>
<td></td>
</tr>
</tbody>
</table>

Characteristics of Gray-Brown Podzolic soils of Polk County are:
1. Thin Ah horizons, in no case thicker than about 8 inches, of colors of Munsell 10YR hue no lower than 3 in value, ordinarily many times higher in organic matter than underlying horizon; textural range from loamy sand to silt loam.

2. Presence of Ae horizon.

3. Presence of B horizon of silicate clay accumulation accompanied by accumulation of free Fe; textural range from loamy sand to silty clay; colors of 10YR to 7.5 YR hue with dominant color no lower in chroma than 2.

4. Relationship between pH and depth in profile such that if pH is plotted on the abscissa and depth on the ordinate, the resulting curve is strongly convex toward the ordinate.

**Wiesenboden soils.** Wiesenboden soils were not given status as a great soil group until development of the classification outline in the 1938 Yearbook of Agriculture (Baldwin, Kellogg, and Thorp, 1938). Marbut (1935) considered these wet and poorly aerated soils as abnormal and imperfectly developed, consequently did not classify them at all in higher categories of his classification outline.

Revision in range and concept of the Wiesenboden great soil group since its establishment in 1938 has been reported by Thorp and Smith (1949). Humic-Glei was tentatively sug-
gested as a name for this soil group.\textsuperscript{1} Thorp and Smith (p. 119) offered the following tentative definition for this group:

An intrazonal group of poorly to very poorly drained hydromorphic soils with dark-colored organic-mineral horizons of moderate thickness underlain by mineral glei horizons . . . . Humic-Glei soils occur naturally under either swamp-forest or herbaceous marsh vegetation mostly in humid and subhumid climates of greatly varying thermal efficiency. A large proportion of Humic-Glei soils range from medium acid to mildly alkaline in reaction. Few are strongly acid.

Application of this characterization using the Soil Survey Manual definition of a mineral glei horizon (U. S. Department of Agriculture, 1951, p. 180) would result in no Polk County soils being placed in the Wiesenboden (Humic-Glei) great soil group. No Polk County soils possess the "neutral gray colors" required by this Manual definition. The Bg horizons of the soils with poor natural drainage apparently have undergone reducing conditions and loss of iron but do not seem to contain appreciable ferrous iron, as is required in the Soil Survey Manual definition of gley horizons.

Consequently, presence of a gley B (Bg notation) as defined in the section on horizon designations is considered a

\textsuperscript{1}In the present discussion, Wiesenboden is retained as a group name for these soils since it is felt that the term Humic-Glei implies that "gleying" is unique to these soils though many Brunizem and Gray-Brown Podzolic soils exhibit slight gleying as seen in mottles and grayish brown colors and as shown by free Fe determinations in the laboratory.
necessary attribute of Wiesenboden soils.

Study of content of free iron in a number of Polk County profiles indicates that the wet, poorly aerated Wiesenboden soils are consistently lower in content of free iron than associated soils of good to intermediate natural drainage formed from essentially similar parent material under similar natural vegetation, as seen in Figure 20. It is assumed that this is due to loss of iron from the profile due to poor aeration with consequent reduction and mobilization of iron. This is a relative criterion (as are most great soil group criteria), since the well-drained Brunizemic Thurman soil is lower in content of free iron than representative Wiesenboden soils and the poorly aerated Ames soil formed under forest is higher in content of free iron than the Webster soil of comparable aeration and parent material formed under prairie, as seen in Figure 25.

Colo soil series was considered as having poor natural drainage and Wiesenboden characteristics during the field survey of the county, but subsequent study of profile samples revealed this soil contained higher percentages of free iron than comparable soils classed as Wiesenboden. Percentage of free iron in the Colo profile as compared to the Kato, Nicollet, Wabash and Webster profiles is shown in Figure 26. The Wabash and Webster profiles are believed to have formed under conditions of poor aeration and prolonged water satura-
Figure 25. Percentage of free Fe in Ames, Nicollet, Thurman, and Webster profiles
Figure 26. Percentage of rare Fe in Colo, Kato, Nicollet, Webster, and Wabash profiles
PERCENT FREE Fe

0.25 0.50 0.75 1.0

DEPTH IN INCHES

DATUM POINT

WEBSTER P466
WABASH P499
NICOLLET P472
KATO P407
COLO P481
tion; the Kato and Nicollet profiles under conditions of intermediate aeration and infrequent water saturation. All have formed under prairie vegetation. Parent material is essentially comparable, though the Kato and Nicollet profiles are somewhat lower in clay. From the figure it can be seen that the Colo profile falls within the range of the soils with intermediate aeration. Inspection of the morphological description of the Colo profile (in Appendix) indicates that it does not have the pronounced yellow hues and strong color contrast between Ah and Bg horizons shown by the Webster and Wabash profiles.

Three different conclusions might be drawn from these data and descriptions. One is that the Colo soil series does not have poor natural drainage and should not be classed with the Wiessenboden great soil group. A second is that since the Colo has formed from alluvial material, the profile is not "old" enough for appreciable iron translocation to have taken place. A third is that some sort of process may be operative in the Colo in which the iron has moved into concretions and was measured in this form in the free iron determination. No evidence of silicate clay translocation and accumulation was found in the Colo profile by either particle size distribution analysis or by field study with hand lens. Accordingly, a combination of the first two alternatives of the above three seems the most plausible. Therefore it seems
that the Colo soil series, and the associated Zook and Zearling soil series, can not be classed with either the Wiesenboden or Brunizem great soil groups, consequently must be classed with the Alluvial great soil group. However, if classed with Alluvial soils, this group becomes quite broad. One facet of the question is how much weight should be given in classification to processes of organic matter accumulation and gleying, as reflected in profile properties.

Another problem involving range and concept of Wiesenboden great soil group is whether the Harptser soil series should be included in this group. This soil is highly calcareous throughout, is associated with Webster and Glencoe soils, and ordinarily occupies rims around former ponds on the Cary till plain. The soil has the yellow hues and color contrast requisite for a Bg horizon and seems to have formed under conditions of prolonged water saturation and poor aeration. No data are available on content of free iron or clay distribution. It would not be expected that silicate clay minerals would be translocated and accumulated in the calcareous Harpster profile, since presumably the clay would remain flocculated and primary minerals would be preserved. There are at least three alternatives for classification of this soil. One is to relax somewhat the criterion of silicate clay accumulation for a Bg horizon in the case of the Harpster and thus class it in the Wiesenboden group. Another
is to consider the Harpster as having no B horizon, thus
classing it with the Alluvial or Regosol great soil group.
A third alternative is classification of Harpster in the
Solonchak great soil group. Solonchak soils are defined as
ordinarily saline soils of arid and semi-arid regions, contain­
ing amounts of highly soluble salts (more soluble than
calcium carbonate, as in the Harpster profile) in sufficient
quantity to inhibit plant growth. (Solonchak soils are de­
scribed by Baldwin, Kellogg, and Thorp, 1938). The alterna­
tive of classing Harpster with the Wiesenboden great soil
group seems the more reasonable of the three.

The following Polk County soil series are classed in
the Wiesenboden great soil group:

- Clarinda
- Glencoe
- Harpster
- Marshan
- Okoboji
- Wabash
- Webster

Properties of the Wiesenbodens of Polk County are sum­
marized:

1. Ah horizons 14 inches or more in thickness of no
higher value than 2 and chroma of 1 or less in hues
of 10YR or yellower, of lowest pH value in the pro­
file unless limed, and containing 1 1/2 to 3 times
more organic carbon than underlying Bg horizons.

2. Presence of Bg horizons.

3. Lower content of free Fe than soils with inter­
mediate and good natural drainage formed from
similar parent material under prairie vegetation.

**Planosols**. Planosols were first designated as a great soil group in the 1938 Yearbook classification outline (Baldwin, Kellogg, and Thorp, 1938). The following provisional definition of the Planosol group was offered by Thorp and Smith (1949, p. 120) in their summary of revisions of the 1938 classification outline:

Intrazonal soils having one or more horizons abruptly separated from and sharply contrasting to an adjacent horizon because of cementation, compaction, or high clay content. They are found under forest or grass vegetation in mesothermal to tropical per-humid to semiarid climates, usually but not always with a fluctuating water table.

Three kinds of "pan" layers in Planosols were recognized by Winters and Simonson (1951): claypan, fragipan, and hardpan. The claypan designation seems applicable to those Polk County soil series which seem to have properties of Planosols.

Figure 27 illustrates the high content of clay in the B horizon as compared to the A horizon in a profile of the Ames series. In Figure 22, in a previous section, properties of an Ames profile were compared with those of the associated well-drained Hayden profile, illustrating the lower content of free iron and greater silicate clay translocation in the Ames.

The Ames profile is representative of the three Planosol soil series in Polk County. The Rolfe soil series has similar profile properties and has also formed from Late Wisconsin
Figure 27. Clay distribution with depth in Ames profile
drift but has formed under prairie vegetation. The Blockton soil has formed from older alluvium under mixed prairie-forest vegetation.

Summary of the properties of Planosols in Polk County:
1. Thick, dark Ah horizons of Munsell colors 10YR3/1-2/1 (moist); loam or silt loam.
2. Presence of Ae horizon.
3. Bg horizons of silty clay or clay contrasting sharply in content of clay to the overlying A horizons.
4. Formed under either forest or prairie native vegetation.

Alluvial soils. Alluvial soils were not given great soil group status until 1938 (Baldwin, Kellogg, and Thorp, 1938), since Marbut did not include them in his great soil groups because they lacked profile development (Marbut, 1935). Baldwin, Kellogg, and Thorp characterized Alluvial soils as having little profile development with some accumulation of organic matter in stratified alluvial deposits.

The following Polk County soil series are classed with the Alluvial great soil group:
- Chaseburg
- Colo(?)
- Dorchester
- Huntsville
- Nodaway
- Sarpy
- Sawmill
- Zearing
- Zook(?)

A summary of the characteristics of Alluvial soil series
in Polk County:

1. Thin Ah horizons, 6 inches or less in thickness; sand to silty clay; slightly acid to calcareous.
2. Lack of B horizons.
3. Parent material of recently deposited stream alluvium or slopewash.
4. Range in natural drainage from poor to good.

**Lithosols and Regosols.** Lithosols were established as a great soil group in the 1938 Yearbook of Agriculture classification (Baldwin, Kellogg, and Thorp, 1938) from which Regosols were subdivided as a distinct great soil group in the revisions summarized by Thorp and Smith (1949). As revised, Lithosols were described as incomplete soils without clearly expressed morphology consisting of a freshly weathered mass of hard rock fragments and hard rock; Regosols as soils consisting of deep unconsolidated rock (soft mineral deposits) in which few or no soil characteristics have developed (Thorp and Smith, 1949).

The Bauer soil series is the only Polk County soil classed in the Lithosol group. This thin soil, lacking a B horizon, has formed from the Des Moines shale.

Polk County soil series classed with the Regosol great soil group are Buckner, Ida, and Storden. Storden and Ida are thin soils lacking B horizons formed from calcareous glacial till; the Buckner soil is formed from coarse sand.
Intermediate and lower categories

Theory and principles

Soil families and great soil sub-groups. Soil family groups as an intermediate level of generalization in soil classification were first established by Marbut (1927) and revised somewhat in a later classification (Marbut, 1935). Soil family groups were described by Baldwin, Kellogg, and Thorp (1938) as soil groups intermediate between the soil series and great soil group categorical levels and composed of soil series with the same general sort of profile. This concept of the soil family was accepted by Riecken and Smith (1949). Possible need for an additional category between family and great soil group categories was suggested by Thorp and Smith (1949).

Smith, Allaway, and Riecken (1950) stated that not all of the fundamental soil features can be used in this intermediate level of generalization else an excessively large number of soil groups would result. In their suggestion of an additional intermediate category, Thorp and Smith (1949) stated that minimal, medial, and maximal developmental stages within great soil groups can be interpreted from differences in profile characteristics and suggested that these seem suitable criteria for intermediate generalization. Lack of suitable criteria for soil family grouping was indicated by Riecken and Smith (1949).
Criteria for a categorical level immediately below the great soil group in level of generalization seem best developed as logical derivations from the criteria for great soil groups, employing in part the approach of classification by array. It was previously stated that the great soil groups are defined on basis of similarity in kind and sequence of horizons and of profile processes responsible for these horizons and their relative arrangement. It seems logical to base the next lower generalization level on a conceptual or representative type-group of soils within the great soil group and groups of soils representing departures therefrom due to blending or intergrading of profile processes producing modifications in nature of horizons and their arrangement, utilizing the concept of the intergrade (Cline, 1949b). For example, within the Brunizem great soil group, a group of soils can be set aside as a conceptual or type-group which display fully the kind and sequence of horizons representative of Brunizems, essentially unmodified by profile processes responsible for development of Wiesenboden or Planosol or Gray-Brown Podzolic kinds-of-profile and well advanced beyond the stage of lack of horizons of the Alluvial, Lithosol, and Regosol groups. Those Brunizemic soils exhibiting some modification in kind and sequence of horizons, reflecting a diffusion of different profile processes, should be placed in separate groups from the conceptual group in this approach.
Placement of Polk County soils in such groups, called great soil sub-groups, is given in the next section, together with criteria for their placement. It should be emphasized that this categorical level is proposed to be based on relative or profile differences. Since a wide gap can be seen to exist between the great soil sub-groups and the soil series, need for another intermediate level of generalization is indicated. This categorical level, below that of the great soil sub-group, is here called the soil family category.

Selection of criteria for differentiation into classes at the family categorical level is based on the following reasoning:

1. All fundamental profile features, the relative profile properties reflecting developmental processes, have been adequately used at higher levels, therefore the next lower grouping must be based on absolute horizon properties.

2. There is need for a grouping according to textural ranges of the profile, particularly B horizons. This will allow some expression of the minimal-maximal concept of Thorp and Smith (1949), though there will be some confounding due to parent material differences. That is, a coarse or fine texture of a soil may be more nearly a reflection of texture of parent material rather than a reflection of minimal
3. Application of the principle of accumulating differentia postulated by Cline (1949a) suggests that criteria which express or reflect texture of the horizons, and physical character, thickness, mineralogy, level of exchange capacity, and degree of leaching of the soil material should be family criteria. That is, by this principle all criteria for differentiation of a soil series must be accumulated from differentiating and accessory characteristics of higher categories. Study of the ten criteria for a soil series proposed by Morett (1921, 1922) indicates that all are reflected in the criteria for classes of categories above the family level except those listed above. Therefore these should be employed directly or indirectly at the family categorical level in order that differentiating characteristics for the soil series, the next lower generalization level, can be accumulated.

Criteria proposed for soil family classes on basis of the above reasoning are texture and thickness of individual horizons and the soil material, physical characteristics (including texture, permeability), mineralogy, level of exchange capacity and degree of leaching (reaction level) of the whole soil - but with broader class intervals than em-
ployed in soil series separations. Texture and thickness of horizons and texture (and related physical characteristics) of the whole soil are suggested as the main criteria for soil families in Polk County, since the remaining characteristics listed are essentially homogeneous within a given textural range. Examples of soil families developed on this basis are presented in a following section.

**Soil series.** The soil series as a taxonomic concept has been traced in the background section from its original definition as a group of soils of differing textures formed from material of similar geologic origin and broadly similar in natural drainage and color to the status given it by Marbut as a basic, narrowly-defined soil unit. Marbut (1921, 1922) listed the following features as differentiating for a soil series:

1. Number of horizons in the soil profile.
2. Color of the various horizons, with special emphasis on the surface one or two.
3. Texture of the horizons.
4. Structure of the horizons.
5. Relative arrangement of the horizons.
7. Thickness of the horizons.
8. Geology of the soil material.
9. Thickness of the true soil.
10. Character of the soil material.

Whiteside (1954) has suggested additional criteria for the soil body or whole soil of shape, temperature, moisture, degree of development, age, biology, and possibly aeration relationships. He proposed revision of the indefinite phrase "geology of the soil material" into more definite terms of mineralogical and chemical composition, texture, and structure or fabric of the parent rock. Whiteside has also proposed addition of consistence and mineralogical composition of soil horizons. Some objection might be raised that temperature and moisture are genetic factors and hence are not appropriate classification criteria, as has been stated by Cline (1949a).

Ableiter (1949), the authors of the Soil Survey Manual (1951), and Whiteside (1954) have emphasized the recent shift to conception of a basic soil unit (soil series or soil type) as a three-dimensional natural geographic body. Definition of the soil series given in the Soil Survey Manual (p. 280) is:

... a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, except for texture of the surface soil; and developed from a particular type of parent material.

The soil series was described by Riecken and Smith (1949) as "a unit of soil classification which recognizes the maximum number of fundamental features of the soil". Riecken and Smith stated that the series had evolved in concept to that
of a landscape unit with a narrow range of soil properties, most of which are significant to agriculture.

Increase in the number of soil series from two to 35 in the past 50 years of soil investigation in central Iowa has been described in the background section. This increase has been in response to demand for soil units about which detailed predictive statements as to crop yield and soil behavior can be made and in response to need for expressing concepts and knowledge of soil genesis. The increase has been facilitated by improved mapping techniques, such as use of airphotos, and by increased soil knowledge. However, this large increase indicates the serious need for evaluation of the concept and differentiating characteristics of this basic unit. The usefulness of the soil series may be impaired by sheer large numbers if the present trend of narrowing of class intervals and increasing numbers continues.

Further evaluation of the concept of a soil series as a natural landscape unit seems indicated, as a consequence of acceptance of soil units as three-dimensional bodies. Acceptance of this concept and its application means that a soil series would be defined not only in terms of its profile and horizon properties but also in terms of its slope position, the landform it occupies, and the soils with which it is associated on the landscape. For example, definition of the Clarion series in these terms would mean specification of its
position on convex, non-accumulative slopes of the Cary till plain. Furthermore, its intergradation on the landscape to Nicollet soils as frequency of and length of water saturation increases and convexity of slope decreases, to Storden soils as slope convexity and rate of geologic erosion increases, and to Lester soils as effect of forest vegetation increases would need to be specified.

Some disadvantages and weaknesses of definition of soil series as landscape units are that their generalization into family units would be difficult, and the number of soil series would be increased since many present soil series seem to contain a number of distinct genetic types of landscape in view of the newer theories of landscape evolution. Recognition of three-dimensional and shape aspects of soil units seems best recognized at a lower level of generalization than the soil series category.

Some possibility for modification of series criteria in order that number of soil series can be held to a reasonable, workable number yet fulfill their purpose as predictive units can be seen in the substitution by Whiteside (1954) of mineralogy, chemical composition and texture of parent rock for the term "geology of soil material" proposed by Marbut (1921, 1922) as a criterion for soil series. Application of this criterion has meant that similar soils from loess sheets of different sources have been differentiated into different
series. Also, soils essentially similar in properties formed from loess and from glacial till have been distinguished in different soil series. Clay mineralogy studies reported in a previous section indicate no qualitative differences in clay mineralogy of Tama soil formed from loess and Clarion soil formed from till. Quantitative differences are not large and seem mostly a reflection of slightly greater silicate clay accumulation in the Tama B horizon. Inspection of data for the Tama and Clarion soil series in Tables 2 and 4-7 indicates no significant differences in morphology other than somewhat greater clay accumulation in the Tama B horizon. Reasoning from these data, soils in Iowa with comparable silicate clay accumulation could possibly be placed in the same soil series, though formed from loess sheets of different sources or from either loess or till with relaxation of the "similar parent material" requirement for a soil series. Full exploration of this possibility is beyond the scope of this work.

Acceptance of the Merbut criteria for soil series as modified by Whiteside (1954) seems desirable, with the exception of shape of the soil body and the parameters of temperature and moisture. Yet these must be weighted for use, since the importance of one of the criteria depends upon its interaction with others. Class intervals must be assigned. Simonson (1952) has pointed out that these processes are done
within a frame of reference of the genetic theories and knowledge of soil behavior and morphology held in the minds of the people making the classification. A desirable working principle in series differentiation problems would seem to be that the choice criterion for relevant properties and class intervals should be known agricultural or soil behavior significance. A series distinction can be made on basis of agricultural significance if this distinction does not actually knowingly decrease the number of statements that can be made in regard to some other use of the soil unit, as soil engineering. In the present state of imperfect knowledge, it must be admitted that soil classification as practiced at the series categorical level probably is not "natural" classification but diagnostic (Searle, 1948).

Examples of some series differentiation problems are discussed in a later section on placement of soils in classes.

**Soil type.** The term soil type was first used in the American soil survey (Whitney, 1908) for soils "alike in all respects" within a soil series as then defined. As a consequence of the early concept of a soil series as soils formed from material of similar geologic origin, many soil series consisted of types ranging from sand to clay. That is, a soil series as then defined could consist of a sand type which was sandy throughout the profile. Karbut and others working in soil classification later narrowed the range of
series and redefined the type. By the time of appearance of Marbut's classification scheme (1927), types were recognized within soil series on the basis of textural differences in the surface horizon only, for the most part. At present, soil series are ordinarily defined rather narrowly in most characteristics such that a series has only one or at most two or three types (Riecken and Smith, 1949). Thus, the former great distinction between soil type and the soil series has essentially vanished, as has also been pointed out by Riecken and Smith (1949).

Only five of the 63 series recognized in the recent Polk County survey have more than one type. Of these, four have only two types and one has three types. Decrease in number of types with respect to the numbers of soil series in 50 years of soil investigations in Polk and Story counties is shown in Figure 1.

Soil type as a category in soil classification seems to have outlived its usefulness. Many distinctions defined as phases of soil series are more meaningful and important than the soil type. It would seem desirable to eliminate the type as now defined as a taxonomic concept. Distinctions formerly indicated by the soil type could well be indicated as phases of soil series.

Soil phase. Soil phase as a concept in soil classification and mapping in the United States seems to have
developed and evolved gradually. The first formal definition of soil phase which could be found in published material is that of Shaw and others (1928). They defined the soil phase as "a subdivision of the soil type covering departures from typical soil characteristics, insufficient to justify the establishment of a new type." It was stated in further explanation of this definition that phase variations could include color, texture, structure, topography, drainage, or any other feature of deviation from the typical.

Soil phase was defined by Baldwin, Kellogg, and Thorp (1938) as a subdivision of a soil type based on soil or landscape characteristics important for land use but which are not differentiating characteristics of the soil profile.

Riecken and Smith (1949) described soil phase as a subdivision of the soil type, with properties within the range of the particular type of which it is a subdivision. They stated that phases are separated within a type according to differences in characteristics significant for land use by man but which have little or no significance in soil genesis. Slope variations, degree of accelerated erosion, stoniness, and relative thickness of alluvial deposits have customarily been used as bases for phase separations, though not too consistently, according to these authors.

Definition of the soil phase has recently been broadened by the U. S. Department of Agriculture soil survey staff.
(U. S. Department of Agriculture, 1951, p. 289), to comprise a subdivision of any class in the taxonomic soil classification system, though not itself a category in that system. Basis for subdivision is stated to be "any characteristic or combination of characteristics potentially significant to man's use or management of soils."

Use of soil phase in the early stages of soil survey and classification in Iowa seems to have been as variations in soil profile characteristics not deemed sufficient in magnitude to establish a new type, such as mucky and shallow phases (based on inspection of soil survey reports of Iowa counties published by Bureau of Soils, U. S. Department of Agriculture). First published use of the soil phase in Iowa to subdivide a soil type according to ranges of slope gradients seems to have been in the Emmet County soil survey report (Gray and Reich, 1923), in which a "rolling phase" of Clarion loam is described. First published subdivisions of Iowa soil types into both slope phases and phases according to degree of eroded soil seems to have been in the Story County soil survey report (Meldrum, Perfect, and Mogen, 1941).

Soil phases were employed in the recent Polk County soil survey (McCracken, McClelland, and others, 1956) to indicate four distinct conditions:

✓ 1. Ranges in slope gradient.

3. Differences in physiographic position.

4. Differences in nature of and depth to underlying substrata.

Slope gradient phases as established in the recent Polk County soil survey were defined in terms of class intervals of slope range believed significant for use and management of the soil, as is general practice in soil surveys in the United States at present. Class intervals of slope percentage were made to coincide with assumed desirable changes in management practices. For example, it is assumed that Tama silt loam of 5 to 8 percent slope gradient could safely be terraced for minimization of erosion losses and conservation of summer rainfall but that terracing is not a feasible practice on Tama silt loam of 9 to 13 percent slope gradient.

Phases of eroded soil were defined in the recent Polk County survey in terms of the assumed degree to which accelerated erosion has taken place in a given area, as is general practice in soil surveys elsewhere. Inferences as to degree of accelerated erosion were ordinarily based on Ap or Ah horizon (or "topsoil") remaining, such that these phases are actually surface horizon thickness phases.

Terrace phases of soil types were established in cases of loess or aeolian sand deposition on terrace landforms where soils developed from these materials were judged similar in properties to upland soils developed from similar
materials and in cases of soils on terraces not appreciably differing from established upland soils.

List of terrace phases of Polk County soils:

<table>
<thead>
<tr>
<th>Soil</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atterberry silt loam, terrace phase</td>
<td>Loess</td>
</tr>
<tr>
<td>Rolfe loam, terrace phase</td>
<td>Stratified Late Wisconsin glacial drift</td>
</tr>
<tr>
<td>Sharpshurg silt loam, terrace phase</td>
<td>Loess</td>
</tr>
<tr>
<td>Stronghurst silt loam, terrace phase</td>
<td>Loess</td>
</tr>
<tr>
<td>Thurman loamy fine sand, terrace phase</td>
<td>Aeolian sand</td>
</tr>
</tbody>
</table>

Depth phases of certain Polk County soil types were established where unconformining substrata were present at varying depths below surface and which had not appreciably affected properties of the A and B horizons. Such phases were established within two soil types of the county.

In summary, it can be seen that two kinds of variations in soil properties are involved in the present usage of soil phases. One type of phase distinction concerns those soil features related to its shape or occurrence on the landscape in three dimensions, such as slope gradient and physiographic position. A second type of phase distinction concerns variations within the soil profile itself not considered of sufficient magnitude or expedient for use as criteria for soil series distinctions. These are profile or point distinctions as contrasted to the spatial or three-dimensional distinctions. Profile or point distinctions include substratum phases and
"topsoil thickness" phases. Though the latter are defined as phases of eroded soil and are considered to express degree of accelerated erosion, in actual practice they are profile distinctions.

It is therefore proposed that those phases which are differentiated on basis of profile properties supplant the present type category in the taxonomic classification. It is proposed that "topsoil thickness" and substratum variations be among the phase criteria. Certain characteristics now employed as series criteria could be shifted to phase criteria, such as slight parent material differences, thereby reducing numbers of series.

It is further proposed that those present phase distinctions which are three-dimensional and spatial in nature be defined as classes called utiles. These classes would not be considered part of the taxonomic scheme, but could be used as subdivisions for any category of classification.

Placement of soil series in classes

Great soil sub-groups. Placement of Polk County soil series in great soil sub-groups on the basis of principles developed in the previous section, using data of Tables 2-6, data obtained in previous studies of certain soils of the county (White, 1953; Folks, 1954; Prill, 1955), and morphological descriptions (in Appendix) is indicated in the following lists. (Minor great soil sub-groups and minor
soil series are not shown.)

1. Type-group Brunizem: Burchard, Clarion, Dakota, Dickinson, Farrar, Sharpsburg, Shelby, Tama, Waukegan.

Horizon sequence for group: Ah/B/C
Degree of horizon expression: medium

Summary of profile processes

Organic matter accumulation in profile: medium
Silicate clay accumulation: medium to low
Degree of cation leaching: low
Relative eluviation and illuviation: low to none
Gleying: none

1A. Brunizem - Alluvial intergrade: Ankeny, Flagler, Saylor, Terril.

 Modifications in profile processes of type-group
Organic matter accumulation in profile: low
Silicate clay accumulation: incipient

Criteria for differences from type-group
Less dark Ah color value > 2. Color contrast of B from A and C, a few clay films visible in Terril, others may contain weak "iron bands".

1B. Brunizem-Wissenboden intergrade: Clearfield, Cooper, Gilbert, Gravity, Kato, Lagonda, Muscatine,
Nicollet.

Modifications in profile processes of type-group

Gleying: incipient

Criteria for differences from type-groups

Mottles in B and base color of B of value < 4, chroma < 3 and chroma of A < 2; lower content of free Fe in comparable material.

Organic matter accumulation in profile: medium

Higher organic C content, Ah thicker than 12".

to high

Because a definite Ae horizon and accessory characteristics must be developed before it is possible to recognize forest influence consistently and because prairie-forest transition areas are narrow, making recognition of more than one intergrade group unfeasible, a Brunizem-Grey-Brown Podzolic intergrade group is not recognized.


Horizon sequence for group: Ah/Ae/B/C

Degree of horizon expression: strong

Summary of profile processes

Organic matter accumulation in profile: low

Silicate clay accumulation: medium

Degree of cation leaching: medium to high
Relative eluviation and illuviation: medium

Gleying: none

2A. Gray-Brown Podzolic - Brunizem intergrade: Crocker, Downs, Gara, Ladoga, Lester, Runnells.

Modifications in profile processes of type-group
Organic matter accumulation in profile: medium
Relative eluviation and illuviation: low to medium
Degree of cation leaching: low to medium

Criteria for difference from type-group
Thicker Ah, > 6", higher organic C in lower A and upper B.
Thin Ae, less pronounced clay translocation than forested soil.
Higher base saturation and pH than comparable fully forested soil.


Modifications in profile processes of type-group
Gleying: incipient
Organic matter accumulation in profile: medium to low

Criteria for difference from type-group
Mottles in B and base color of value < 4, and chroma < 3 in B; Ah of chroma < 2.
Thicker Ah, > 6".
3. Type-group Wiesenboden: Glencoe, Marshan, Okoboji, Wabash, Webster.

Horizon sequence for group: Ah/Bg/C

Degree of horizon expression: low

Summary of profile processes

Organic matter accumulation in profile: high
Silicate clay accumulation: low
Degree of cation leaching: low
Relative eluviation and illuviation: low
Gleying: strong

3A. A group of Wiesenboden - Alluvial intergrades comprised of Colo, Glencoe, Okoboji, Wabash, and Zook soil series is an alternative classification.

4. Type-group Alluvial: Dorchester, Sarpy, Sawmill.

Horizon sequence for group: Ah/C

Degree of horizon expression: very low to none

Summary of profile processes

Organic matter accumulation in profile: very low to low
Silicate clay accumulation: none
Degree of cation leaching: none to very low
Relative eluviation and illuviation: none
Gleying: none to incipient

4A. Alluvial - Brunizem intergrade: Huntsville.
Modifications in profile processes of type-group

Criteria for difference from type-group

Darker, thicker Ah with higher percent of organic C.

Incipient B horizon as seen in color contrast to Ah and C.

4B. Alluvial - Wiesenboden intergrade: Colo, Zeering, Zook.

Modifications in profile processes of type-group

Organic matter accumulation in profile: low to medium

Silicate clay accumulation: incipient

Criteria for difference from type-group

Dark Ah > 12".

Subsoil colors of chrome < 2, some tendency to hues yellower than 10YR, low free Fe but not as low as Wiesenboden from comparable material.

Few thin clay films visible.

Soil families. Some examples of soil family groups formed by application of principles developed in the previous section are listed in the following:
A. Families of type-group Brunizem listed by soil series:

1. Burchard, Clarion, Dakota, Waukegan

   Criteria for group
   20 to 27 percent clay in B, medium texture of A and B

2. Dickinson, Farrar

   Less than 20 percent clay and greater than 50 percent sand in most of B, moderately coarse texture of A and most of B

3. Sharpsburg, Tama, Shelby(?)

   30 to 40 percent clay in B, medium to moderately fine texture of A

B. Families of type-group Gray-Brown Podzolic:

1. Fayette, Hayden, Lindley

   Criteria for group
   30 to 40 percent clay in B, medium texture of A

2. Lemont

   Less than 27 percent clay and greater than 50 percent sand in B; moderately fine texture of A, medium texture of B.
Soil series differentiation problems. Some examples of problems in classification of Polk County soils into soil series are presented in the following discussion.

The continuum problem. The Early Wisconsin loess mantling the Kansan till landscape in the southern fifth of Polk County may have originated from two sources: a Missouri River Valley source, and the Tazewell glacial drift area (based on discussion of loess sources and age by Ruhe and Scholtes, 1956). It seems likely that the loess in southwestern Polk County may have originated largely from the Missouri Valley source; that in southeastern Polk County may have dominantly originated from the Tazewell till plain.

A soil association map for Iowa, Figure 2, shows Sharpsburg and associated soils in southwestern Polk County, Temple and associated soils in southeastern Polk County, with a gradational boundary between.

On the basis of field observations during the Polk survey and laboratory study of profile samples it seemed desirable to specify that Sharpsburg soils should be recognized west of the Des Moines River in southwestern Polk County and Temple soils east of the Des Moines in southeastern Polk County, with the exception of some few areas in a small strip of a few square miles immediately west of the Des Moines River where local loess seems to have influenced soil development. Profile data for each of these soils are shown in Figures 28 and
Study of the plots in Figures 28 and 29, inspection of the data for Sharpsburg and Tama soils in Tables 2-6, and study of their morphological descriptions (in Appendix) tends to indicate that these two soils fall within the commonly accepted permissible range of a soil series. One could conclude that their separation is not justified, since the degree of clay accumulation is nearly similar, chemical properties are of the same order of magnitude, morphology is similar, and parent material of each is apparently similar in properties. If the entire extent of these soils were in Polk County, and if these data were representative of the entire population of these soils, distinction of two soil series would not be justified.

The Tama profile sampled may have undergone some truncation or modification since the clay maximum is nearer the surface than seems typical for these soils. However, as observed in the field, this soil did not seem to have undergone severe sheet erosion. This Tama profile is somewhat lower in organic carbon than that of Tama profiles previously studied, though this does not affect the color of the Ah horizon. This profile sample was taken less than three miles from the end moraine of the Late Wisconsin glaciation, which may be a clue to its somewhat unusual properties. An alternative explanation for the occurrence of the clay maximum nearer
Figure 28. Clay, sand, and organic carbon distribution with depth in Sharpsburg and Tama profiles
Figure 29. Percent base saturation and pH with depth in Sharpsburg and Tama profiles
PERCENT BASE SATURATION

- DATUM POINT
  - TAMA P482
  - SHARPSBURG P408

pH

- DATUM POINT
  - TAMA P482
  - SHARPSBURG P408
the surface than would be expected in this Tama profile is its slope position. This profile sample was taken on a slope of five percent gradient at the margin of a rather narrow ridgetop divide. The Sherpsburg profile sample was taken on a broad ridgetop which is a divide between two minor drainageways leading into the Raccoon River. Perhaps the position of the Tama profile on the upper flank of a ridgetop divide may have influenced the nature of its silicate clay accumulation.

The Sherpsburg soils of southwestern Polk County are in the easternmost portion of the band of Sherpsburg soils extending across southwest Iowa, and are a portion of the continuum of soil properties developed from loess deposits in that area, as reported by Hutton (1947, 1950). Sherpsburg soils range from 35 to 40 percent content of clay less than 2 microns in diameter in their B horizons (Riecken and Smith, 1949). Soils designated as Sherpsburg in Polk County seem to be towards the upper end of the range in properties of this soil.

Tama soils of southeastern Polk County are in the far northwestern corner of the band of Tama soils in east central Iowa which are part of a continuum of soils formed from the loess from the Tazewell till plain source to the north (Ruhe and Scholtes, 1956). The soils assigned to the Tama series in Polk County are at the extreme upper end of the range of
properties of Tama soils in general and approach very closely the properties of the Otley series. Including these soils with the Sharpsburg in Polk County would merely postpone the decision on separation of these two soil areas and create problems in another county.

The boundary on the landscape between these two soils is transitional and gradational in nature. Demarcation between the two soil areas must of necessity be rather arbitrary in field mapping. Local environmental factors or parent material factors tend to determine which soil is formed on a given site in this transitional area, but the nature and effect of these local factors and their use in field mapping has not yet been worked out. In defining Tama and Sharpsburg soils in general, it must be borne in mind that they include ranges such as shown in the Polk County data.

Poly lithogenous soil problem. A number of Polk County soils have developed under influence of two different types of material, such as wind-modified or wind-deposited sandy soil material of variable thickness over loam glacial till, or soil material of medium texture over coarse-textured sandy and gravelly outwash. The term poly lithogenous is here proposed to describe these soils. This term is a modification of the term polygenetic proposed by Bryan and Albritton (1943) to describe soils developed under more than one climatic regime. Since the term has become loosely used to
describe also those soils developed under influence of more than one parent material, redefinition is thought desirable. The term polyclimogenetic is suggested to convey the meaning intended by Bryan and Albritton.

One type of problem in classification of polylithogenetic soils is the establishment and definition of ranges of soil series in areas in which a rather thin mantle of windblown or wind-modified fine sandy loam or sandy clay loam overlies well-oxidized soil material of medium texture formed from loam glacial till. Without the sandy material, the soil is readily classed with the Clarion series. If the sandy material were consistently only a few inches thick, the soil might be classed as a type (similar to Clarion loam except differing in surface texture) of the Clarion. But with thicknesses varying from about 6 to 24 or more inches, as in some areas of Polk County, the problem is whether such soils should be (a) classed as a type of Clarion, (b) classed as a phase of Clarion, or (c) established as a new series. Graphic comparison of some properties of a Clarion profile and a profile of a soil formed from similar loam till in the lower part but formed from coarser material, apparently windblown or wind-modified in the upper portion is shown in Figure 30. This latter soil has provisionally been named the Farrar series, since alternative (c) above has been tentatively accepted. Data for the Farrar profile have been previously
Figure 30. Distribution of clay, silt, and sand with depth in Clarion and Farrar profiles; organic carbon, pH, and cation exchange capacity with depth in Clarion and Farrar profiles.
presented by White (1953).

Because the presence of the fine sandy loam seems to have appreciably influenced properties of the solum in ways other than simple dilution of the clay and silt by sand in the upper part, there seems to be justification for establishment of a separate series within the present framework of series and phase definitions. The lower content of organic carbon throughout, the lower exchange capacity of the upper solum, as well as estimated lower available moisture-holding capacity, all seem to set apart the unit with the wind-modified sand influence - here tentatively designated the Farrar series. Also, Daniels (1955) has demonstrated the influence of higher content of sand in the Clarion profiles as compared to that of Marshall profiles in lowering the supply of available potassium. Presumably, a similar relationship should hold in this case, since the upper part of the Farrar soil is much higher in content of sand.

Another classification problem in poly lithogenetic soils is that of unconformable sandy and gravelly substrata underlying soils of comparable texture of solum at varying depths below the surface. This type of situation is common on the Late Wisconsin outwash terraces of Polk County. Natural drainage ranges from poor to good in this "two-storied" material, so that it seems desirable to establish three natural drainage classes or conditions, following
present classification practice for soils of the Cary till plain. The solums (A and B horizons) of these soils on the terraces seem similar to those of soils on the Cary till plain, if soils of comparable natural drainage are compared. Soils containing unconformable substrata and with good natural drainage are of loam to silty clay loam solum texture, and generally those with poor natural drainage are of clay loam to silty clay loam solum texture. The classification problem is selection of one of a number of alternatives for classification of these soils at the soil series level of abstraction. That is, these soils with coarse-textured substrata could be either (a) classed in the same soil series as the comparable soil of the Cary till plain whereby the soils with the gravelly substrata could be recognized as two or more rather arbitrary "depth" phases, based on depth to coarse material (practice is to attempt to establish depth ranges which have relevance for crop growth, or (b) classed in distinct soil series according to natural drainage, with two or more rather arbitrary depth phases within the soil series, or (c) established as a number of distinct soil series for each natural drainage class, basing the series distinctions primarily on various ranges of depth to the unconforming coarse-textured substrates. In Figures 31 and 32 comparisons are made of some properties of two soils of the terraces with good natural drainage and different depths to unconforming coarse
Figure 31. Distribution of clay, silt, and sand with depth in Clarion, Dakota(?), and Waukegan(?) soil profiles
Figure 32. Percent organic carbon and pH with depth in Clarion, Dakota(?), and Waukegan(?) profiles; percent free Fe with depth in Clarion and Waukegan(?) profiles.
substrate (the tentative Waukegan and Dakota series) and Clarion soil with calcareous loam till parent material. The two terrace soil profile samples were selected to represent the two depth ranges (24 to 30 inches to sand and gravel, and greater than 36 inches to sand and gravel) mapped during the recent soil survey.

Inspection of the data for these soils, Tables 2-6, and of the plots in Figures 31 and 32 seems to indicate the feasibility of continuing the distinguishing of Clarion, with its calcareous loam till substrate, as a soil series distinct from the soils of the terraces with similar solums but with unconforming substrates, if the present procedure and practice of series classification is continued. Content of sand rises sharply and content of clay drops with increasing depth below B horizons of the terrace soils. Since a number of properties co-vary with the particle size distribution, it seems reasonable to assume significant change in physical and chemical properties below the B horizons in these terrace soils. Failure of pH to increase with increasing depth in the profile coupled with increase in content of free iron with increasing depth in the Waukegan profile (P470) may be a reflection of reworked sand and gravel dominant in this Late Wisconsin glacial outwash, leached and iron-stained from a previous weathering cycle. Coulteras (1951) has reported data for similar well-drained soils formed from similar poly-
lithogenetic parent material in Polk County, as well as a few other counties, which indicate a drop or no significant increase in pH and percentage of base saturation in the gravelly substrates as compared to overlying solums of loam texture. The increase of pH below the B horizon in the Dakota (P405) profile may indicate some admixture of limestone fragments in the underlying outwash, though the material is not calcareous. Some few deposits of outwash in Polk County were found to be locally calcareous but these were minor in extent and no attempt was made to define and map separate soil series on this basis. To the extent that the outwash underlying the Dakota profile is of different chemical composition from that underlying the Waukegan profile selected for study, a simple depth-to-gravel relationship between these profiles is somewhat confounded.

Strict application of the ten criteria for a soil series would tend to indicate the desirability of separating depth phases of the terrace soils as distinct series. This alternative would also make nomenclature less cumbersome, as there would not be the need to refer to depth phases. It could also be argued that the relative position of the coarse substrate seems to have produced no fundamental differences in the solums (A and B horizons) of these soils, and that establishment of distinct soil series for a number of depth ranges would increase beyond practical limits the number of soil
series, for a similar situation would be encountered in each drainage class. If only two series were established for each natural drainage class, a total of six series would be required if three drainage classes are established for this one condition of material of medium texture over dominantly non-calcareous coarse substrates. Establishment of phases of soil series for variation in depth to substrate seems the more desirable solution. In the problem previously discussed, the A and B horizons were affected by the overlying coarse material. It could be argued that the criteria for series differentiation apply only to solum characteristics, and the requirement that soil series be formed from similar parent material (U. S. Department of Agriculture, 1941) is met, since the solums seem to have developed from similar material. Combination of the tentative Dakota and Waukegan soil series therefore seems desirable.

**Hydrologic sequence - slope position problem.** On the Cary till plain in the northern four-fifths of Polk County, soils can be seen to vary in properties and in degree of wetness as an essentially continuous function of their slope position. Their properties also seem functionally related to the degree and duration of time they were water-saturated in their natural condition. The soils form a sort of continuum on the landscape. The problem in differentiation at the soil series level of generalization is how to
break this continuum into segments which are meaningful
taxonomic and cartographic units. In the survey and classification process in the county, this type of landscape was
differentiated into three major classes. These are soils
with poor natural drainage, soils with somewhat poor to
moderately good natural drainage, and soils with good to
thus related are considered to form a "catena" (Bushnell,
1942, 1945). Soil series names assigned to these are Webster, Nicollet, and Clarion, in order as described above.
They were recognized in field mapping by differences in color
and texture, predominantly. A representative profile of each
was sampled for laboratory study. The plots of Figure 33 are
a graphic comparison of some of their properties.

These plots and the data for these soils in Tables 2-6
indicate a similarity between Clarion and Nicollet soils, as
contrasted to Webster, in physical properties and in cation
exchange capacity. However, the Nicollet profile occupies
an intermediate position in those characteristics related
to degree of wetness, as content of free iron and of organic
matter. It can be concluded that the separation of Clarion,
Nicollet, and Webster soil series as cartographic and tax-
onomic units on the basis of morphology visible in field
examination such as color and texture of the various hori-
Figure 33. Comparison of some properties of Clarion, Nicollet, and Webster soil profiles
zones, is well supported by laboratory data. The free iron data support the field observations of color differences.

Data for the Webster series, plotted in Figure 33, tend to indicate that this soil differs in parent material from the Clarion and Nicollet soils. Higher content of clay in the Webster solum, lack of evidence for significant clay translocation within the profile when studied in thin section, and a rather sharp drop in content of clay at 30 inches indicates this upper material is unconforming. Increase in content of sand below 30 inches tends to confirm this hypothesis. Texture below 36 inches is very similar to that of the till in the C horizon of the Clarion soil. It is further hypothesized that the parent material for the Webster solum is eolian in nature, having accumulated over time as depositions in the depressional and concave areas topographically below the knolls on which Clarion and Nicollet soils have developed.

Clarion, Nicollet, and Webster soils of Minnesota were studied by Arneman and McMiller (1955), who concluded that the distinguishing characteristics of these soils are mainly morphological rather than chemical or mineralogical. These authors stated that the color of the A horizon of these soils is directly related to the natural drainage condition.

Yield differences among Clarion, Nicollet, and Webster soils were reported by Shrader (1953) after a study of long-
term yields from various rotations on the Agronomy Experimental Farm at Ames. In this study, corn yields on Clarion soils were lower than on Nicollet soils on all rotations and treatments, and relative corn yields of Nicollet and Webster soils followed no consistent trend and were of the same order of magnitude. Oat yields tended to be lower on Clarion and higher on Webster than on Nicollet soils. In general, differences in crop yields were found to be related to or correlated with soil differences in this study.

Selection and weighing of criteria for differentiation of soil series within a sequence of catena such as the Clarion-Nicollet-Webster relationship has been based on agricultural significance. Establishment of three soil series (four, if the very poorly drained inextensive Glencoe soil is included) seems optimum for making statements and predictions of present agriculture. If agriculture in this area were either more or less extensive, or if crops were grown of either more or less sensitivity to moisture and drainage conditions, a greater number or fewer number of soils series would have been established.

Series differentiation in young soils from alluvium. Definition of taxonomic units as soil series and the mapping of each as a distinct cartographic unit is ordinarily difficult in the case of parent material of relatively young alluvium of somewhat variable texture (particle size distribution)
which has not undergone appreciable differentiation by soil
development. The texture of the alluvial material, upon
which soil series differentiation is largely based in soils
formed from this material if natural drainage is similar,
ordinarily is variable both laterally and vertically. This
pattern of variability makes for problems in definition and
mapping of units, particularly if the sedimentation factors
responsible for the variability are obscure. A problem in
the Polk County soil classification is the definition and
ranges of soil series formed from moderately fine to fine-
textured alluvium with poor natural drainage. Little soil
development has taken place in this material. Graphic com-
parisons of some of the properties of profiles selected for
study of tentative units formed from these materials are
shown in Figures 34, 35, and 36. Reaction does not differ
appreciably among these soils except that the upper solum of
Wabash is slightly lower in pH.

Particle size distribution comparisons among these soils,
as shown in Figure 34 and tabulated in Table 4, indicate the
profile sampled to represent the tentative Zook series is
somewhat higher in content of clay throughout. The Wabash
profile sampled is consistently lower in content of sand,
probably a reflection of the dominance of loess-derived soils
in the upland landscape adjoining the Wabash sampling site as
compared to the dominance of Cary till-derived soils of the
Figure 34. Distribution of clay, silt, and sand with depth in Colo, Wabash, and Zook soil profiles
Figure 35. Hydraulic conductivity and percent organic carbon with depth in Colo, Wabash, and Zook soil profiles; percent free Fe with depth in Colo and Wabash soil profiles
HYDRAULIC CONDUCTIVITY
inches /hour

COLO (?) P481
WABASH P499
ZOOK (?) P484
DATUM POINT

PERCENT ORGANIC CARBON

COLO (?)
WABASH
ZOOK (?)

PERCENT FREE Fe
Figure 36. Capillary porosity, aeration porosity, and soil solids with depth in Colo, Wabash, and Zook soil profiles.
upland landscape adjoining the sampling sites of the Colo and Zook soils.

Comparison of physical parameters of these profiles indicates the Wabash profile is lower in aeration porosity (determined at 40 centimeters of water tension) and in hydraulic conductivity in the lower portion. The Zook profile is slightly lower in aeration porosity in the upper portion of the profile than the other two profile samples. If hydraulic conductivity classes were to be established on a log scale of less than 1, 1 to 10 and greater than 10 inches per hour (as seems reasonable), then the Colo profile would be placed in a higher class distinct from the Wabash and Zook profiles. These latter profiles might be placed in the same class, or Wabash in a lower class because of the hydraulic conductivity values of less than one inch per hour in the lower portion of the profile.

Higher content of organic carbon in the Ah horizon of the Zook profile is in accord with the field observations that the tentative Zook soils have poorer natural drainage (are water-saturated to a greater degree) than the Colo and Wabash soils.

Higher content of free iron in the Colo profile places it within the range of prairie soils with intermediate rather than poor natural drainage, as has previously been discussed.

In this classification problem, perhaps more than in the
problems previously discussed, selection and weighting of criteria for taxonomic units at the soil series level has been largely based on agricultural considerations. It is desirable to separate those soils in which the poor natural drainage can be rather readily alleviated from those in which artificial drainage is difficult due to impermeability and other accessory features related to the clayey textures and high water tables.

Since the soils tentatively designated Colo and Zook are associated together on the floodplains of Skunk River and Indian Creek in Polk County and data from a selected profile of each were rather inconclusive as to validity of their discrimination, further textural studies were made. A number of profiles of each were randomly sampled, though detailed profile samples were not taken. One sample of the Ah horizon, one or two from the B horizon, and one or two from the C horizon were collected. Seven profile samples from areas mapped as Colo soil series and four profile samples from areas mapped as Zook soil series were randomly collected. Means and standard deviations of content of clay (believed to be the critical parameter) are listed in Table 16.

These data tend to indicate the lower solum or subsoil of the areas mapped as Zook soil are slightly higher in content of clay than similar layers of the areas mapped as Colo soil. Admittedly sample size is quite small. From these
Table 16. Mean clay content and standard deviation of some randomly collected samples of the tentative Colo and Zook soil series of Polk County

<table>
<thead>
<tr>
<th>Soil</th>
<th>Number profiles sampled</th>
<th>Horizon</th>
<th>Mean clay content</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colo(?)</td>
<td>7</td>
<td>Ah</td>
<td>39.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Colo(?)</td>
<td>7</td>
<td>Bg or BC (16-25&quot;)</td>
<td>38.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Zook(?)</td>
<td>4</td>
<td>Ah</td>
<td>46.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Zook(?)</td>
<td>4</td>
<td>Bg or BC</td>
<td>45.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Most of the samples for this part of the study of the Colo-Zook problem were collected by G. H. Simonson. Particle size distribution analyses of these special samples were by J. M. Soileau, J. A. Phillips, and I. Polhemus.

Data, it may be inferred that the chances are about two of three that an area mapped as Zook soil in Polk County will be of clay texture and higher in content of clay than areas mapped as Colo soil. Data of Table 16 indicate, however, some overlapping of the surface textures of these soils as mapped. The mean clay content of the subsoil of the special Colo samples is a few percent less than the detailed profile sample collected by "purposive selection" (Figure 34).

That Zook soil should be and in actual practice can be discriminated as a soil series distinct from Colo soils seems a reasonable conclusion, on the basis of present concepts and definitions of soil series. Higher content of clay, lower
hydraulic conductivity and aeration porosity, and possibly poorer natural drainage of the Zook soil are arguments for this conclusion. If soil series concepts and definitions are broadened somewhat and features responsible for potential differences in agricultural productivity are made phase separations within a series, then these soils could be confined in one series. However, discrimination of the Wabash and the tentative Zook soil series seems questionable and in part depends upon the weighting given properties other than content of clay.

Summary of categorical soil classification

Abandonment of the concept of soil zonality as a criterion for soil classification at the highest categorical level, presently called the soil order, is proposed. Revision of criteria for the second highest categorical level is also proposed. An approach of classification by array is suggested for the higher categorical levels. Following this approach, soils are placed in classes at the highest categorical level according to kind of B horizon, or lack of a B horizon, as a reflection of the dominant soil-developmental processes. Only two classes of this category are present in Polk County - those soils without B horizons and those in which accumulation of silicate clay seems the dominant soil-developmental process.
Classification at the second highest categorical level in the suggested approach is based on array according to presence or absence of subsidiary soil horizons. Retention of great soil groups essentially as defined in current literature on soil classification in the United States is proposed for the third highest categorical level. These groups are based on similarity in general kind and sequence of horizons, as a reflection of the summation of profile processes operating within the soils.

Subdivision of the great soil groups into subgroups based on modifications of kinds of horizons as a reflection of modification or blending of profile processes is proposed in the present approach. Type-groups as subgroups representative of the concept of the great soil group and subgroups with properties indicating an intergrading to other great soil groups are proposed as component classes of the fourth categorical level. Soil families are proposed to consist of soil series broadly similar in texture of A and B horizons and associated characteristics in the Polk County soil classification. Elsewhere, additional characteristics such as mineralogical composition, level of exchange capacity, and soil thickness will doubtless need to be considered as soil family criteria.

Large increases in numbers of soil series in recent years as a function of narrowing of criteria in response to need for
basic soil units about which precise predictive statements can be made and as a result of increased soil knowledge indicates need for sound principles of series differentiation. A proposal is made to broaden slightly the criterion for similar parent material to that of similarity in mineralogy and chemical composition. Criteria for soil series developed by Marbut (1921, 1932) as modified by Whiteside (1954) in general seem adequate, but relative weighting of these criteria and appropriate class intervals is a continuing problem. Agricultural relevance is suggested as a choice criterion where establishment of additional classes does not decrease the total number of statements which can be made concerning soil units. Examples are given of the rationale employed in disposition of several Polk County series classification problems. Soil series classification can not be a truly "natural" classification in view of lack of knowledge and demands placed upon it.

Abandonment of the present concept of the soil type, or texture of the A horizon, as a taxonomic category is suggested, since it is nearly an empty category due to narrowing of the soil series concept.

Placement of the type category with those portions of the present phase concept which are soil profile and horizon properties is suggested. Phases become the lowest category of the taxonomic soil classification in this approach. Possibility of relegation of some present series criteria to
the phase category would further aid in restricting soil series numbers.

Those aspects of the present phase concept which are concerned with soil shape, or its three-dimensional properties, such as slope gradient and physiographic position are proposed as bases for a new non-taxonomic subsidiary classification. Suggested name for these classes is utiles, since they are important in man's use of the soil.
The most suitable area in Polk County for a trial application of the quantitative analyses of soils by the sequence concept (Jenny, 1941, 1946) would seem to be the Cary till plain. This surface has had relatively limited opportunity to be exposed to vegetational and climatic changes and to changes associated with landscape evolution, since it seems to be of the order of 12,000-13,500 years old (Ruhe and Scholtes, 1956). However, even this young landscape may have been exposed to vegetational and climatic changes (Ruhe and Scholtes, 1956). A greater part of this till plain is occupied by soils which seem upon preliminary study to differ mainly in the relief or slope-position they occupy and the degree of wetness, or lack of it, associated with their slope position. Three extensive soils illustrating this relationship are Clarion, Nicollet, and Webster. Graphic illustration of some of their properties is shown in Figure 33. Their relationship would seem from casual inspection to be an illustration of the toposequence as defined by Jenny (1946) and denoted by equation (5) as discussed in the earlier section on
approaches to soil classification.

Since it can be seen from study of characteristics of these soils that they apparently differ according to both slope position and water table effects, the toposquence may be resolved into two functions, treating both slope, \( i \), and water table, \( w \), as independent variables:

\[
S = f(i, w)_{cl, o, p, t, ...} \tag{7}
\]

The functions of \( i \) are named clinofunctions by Jenny; the functions of \( w \), hydrofunctions.

If we consider the definite integral for the slope factor as relatively small, that is, \( \int_0^\infty \frac{dS}{di} \approx 0 \), which may not be a reasonable consideration, then the differences in soil properties according to water table effects can be isolated and quantitatively studied, provided that the other fundamental soil-forming factors are essentially constant.

Inspection of the graphic comparison of properties of profiles Clarion, Nicollet, and Webster soils, Figure 33, and of data describing them, Tables 2 and 4-6, indicates variation in a number of properties which could be postulated as due to differences in water table effects. These are percentage of organic carbon, of free iron, and possibly of clay.

An evaluation of the Jenny functions in relation to the observed differences in free iron, for example, between the \( B_2 \) horizons of Clarion and Webster can be attempted by study of the following expression:
where $Fe^t = \text{free iron in the B horizons of Clarion and Webster soils, and } 1 \text{ in integral notations} = \text{Clarion and Webster, respectively, and the remaining notations have the meaning ascribed in equation (1). The general nature of the conditioning factors has been described in the section on soil-forming factors of Folk County.}

If it can be assumed that definite integrals of all factors except water table, $w$, are small or negligible, then the difference $Fe^t_{\text{Clarion}} - Fe^t_{\text{Webster}}$ can be attributed to water table differences in these two soils. With assignment of some sort of parameter expressing water table effects, the free iron content could be predicted for similar conditions elsewhere. A similar analysis could be applied to the differences in organic carbon and other property differences.

Study of the factors involved in the definite integrals other than for water table indicates that it is not reasonable to consider all of them small or negligible, particularly parent material, vegetation, and climatic factors. Further,
it is difficult or impossible to develop or assign parameters for the soil-forming factors.

As regards parent material, the Webster profile sampled for this study contains 39 to 40 percent clay in the horizons called Bg, and about 25 percent clay in the horizon designated C2; the Clarion profile sampled for this study contains about 27 percent clay in the B horizon, and about 25 percent clay in the horizon designated C2 (Table 4). Study of the Webster soil in thin sections and in the field revealed only slight evidence of clay translocation within the profile and consequent accumulation in the B horizon. The Clarion and Webster profiles have about the same percentages of sand and clay in their C2 horizons, both within the ranges of composition of Late Wisconsin till as reported by Riecken, Allaway, and Smith (1947). Therefore, the possibility of the clay differences between the Clarion and Webster being genetic (due to soil-forming processes) seems eliminated.

The texture of the Webster surface and B horizon must be due to presence of unconforming material over underlying glacial drift. Since Webster soils occupy depressional areas topographically below the Clarion and Micollet soils, it is likely that they have received continual accretions of soil material from upslope. As many Webster areas were intermittent ponds before drained and cultivated by man, it seems reasonable to expect that deposition in these ponds
was of material relatively high in clay and silt. It seems necessary to conclude that parent material has not been constant, or similar, during formation of Clarion and Webster soils. How much greater than zero the term $\frac{\partial \text{Fe}^1}{\partial \text{p}}$ is cannot be stated, but it should not be ignored. The term $\frac{\partial \text{organic C}}{\partial \text{p}}$ is certainly much greater than zero if the greater part of the Webster parent material is accretionary from slopes above. Slope position is important if the Webster had an accretionary development; therefore the expression $\frac{\partial \text{Fe}^1}{\partial \text{i}}$ probably cannot be ignored, due to the relatively low content of free iron in the Clarion surface soil which is source material for the accretion of material downslope in the Webster position.

As regards vegetation and climate, the wet Webster soils apparently had a different vegetative pattern at the time of settlement of Iowa than did the moist Nicollet and well-drained Clarion sites (Weaver, 1954). It is not known how much these vegetational differences would affect relative content of organic carbon and the free iron status; their effect on the former may have been of some significance. If the Webster soil material has been accumulating over time, and the areas have been ponded (as seems to have been the case), then the organism factor is not constant or negligible, because Clarion and Webster areas have not had equal opportunity to develop similar vegetation. Climatic fluctuations
since deposition of the Gary till and during time of formation of the Clarion, Nicollet, and Webster soils (Ruhe and Scholtes, 1956) may have affected these soils differently, though no estimate can be made of this effect.

In summary, it does not seem possible to develop a precise and quantitative evaluation of the toposequential function for Clarion, Nicollet, and Webster soils, especially for the Clarion-Webster and Nicollet-Webster relationships. Such a function might be evaluated for the Clarion and Nicollet soils since they seem to have a greater constancy of factors than between Webster and these two soils. Qualitative relationships and differences among these soils can be distinguished and are useful in their study.

Biosequences of certain Iowa soils developed from loess and till have been studied by White (1953), including Hayden, Lester, and Farrar (described as Clarion fine sandy loam by White) profiles from Polk County. He found distinct chemical differences among Brunizem, Brunizem-Gray-Brown Podzolic transition, and Gray-Brown Podzolic soils which were associated with distinct morphological differences. However, in any of these sequences, quantitative evaluation in the functional manner proposed by Jenny does not seem possible because of lack of constancy of some of the factors. The Hayden, Lester, and Farrar soils contain varying amounts of apparently aeolian sand. The "parent material" (State of
soil system at time zero of soil formation, according to Jen-
ny, 1941) for the development of Gray-Brown Podzolic soils
following encroachment of trees on the prairie, a Brunizem
soil profile, is quite different from the parent material of
calcareous loess from which development of the Brunizem was
initiated. The high probability of climatic fluctuations in
the past also make it difficult or impossible to define
"parent material".

It is concluded that quantitative evaluation of the five
functions postulated by Jenny (1946) cannot be achieved in
Polk County, but that the functional approach is useful when
qualitative use is made of approximate single-factor func-
tions to bring out soil relationships and to predict soil
properties, given certain conditioning factors. Probably the
greatest practical use of the functional approach is in soil
correlation studies. For example, if a newly recognized soil
series is proposed for establishment in an area, study of
records and reports from other areas where similar soil-
forming factors prevail should reveal whether the proposed
soil unit has previously been recognized and defined in an-
other area. Conversely, when a newly recognized soil is
established as a taxonomic unit, specification of its con-
ditioning factors and of its place in the sequence of which
it is a member help to define the soil. Also, if one member
of a given sequence is found in a study of a given area, it
can be expected that additional members may be found with changes in the single-factor function of which the newly recognized soil is a member.

Arrangement of important Folk County soils into sequences is shown in Table 17.

Soil deductive systems and soil surfaces

Since soil classification stems from and is based on theories of soil genesis and morphology, it seems imperative that hypotheses on soil genesis be developed and stated in a manner subject to testing. Much of the body of soil genetic theory as expressed in recent literature is in terms of broad and vague soil-forming processes, such as calcification, podzolization, and the like (Byers and others, 1938). These "processes" have been given different meanings by various authors and are ill-defined. It was concluded in the previous section on application of the sequence concept to Folk County that a functional, factorial approach to soil genesis studies must be qualitative and approximate in nature, that it is difficult to put numerical values on the soil forming factors, and thus the approach is not well suited to deducing soil genesis.

In general, the logic and theoretical background of soil classification has been based on a general discussion of
Table 17. Soil sequences of Polk County

<table>
<thead>
<tr>
<th>Natural drainage</th>
<th>Prairie</th>
<th>Prairie-forest transition</th>
<th>Forested</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPO-BIOSEQUENCES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Biosequences in rows, toposequences in columns)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. From Cary till:

- Good
  - Good
  - Nicollet
  - Poor
  - Webster\(^a\)

2. From loess, probable Tazewell till plain source:

- Good
  - Tama
  - Muscatine
  - Poor
  - None recognized

\(^a\)Solum probably developed from translocated sediments overlying glacial till.

1. From loess, probable Missouri River flood plain source:

- Good
  - Sharpsburg
  - None recognized

2. From Kansan till, and translocated sediments from Kansan till to some extent:

- Good
  - Shelby
  - Gara
  - Lindley
Table 17. (Continued)

<table>
<thead>
<tr>
<th>Natural drainage</th>
<th>Prairie</th>
<th>Prairie-forest transition</th>
<th>Forested</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. From aeolian sand and wind-modified Cary glacial drift:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good (coarse texture)</td>
<td>Good, Dickinson (moderately coarse texture)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good, Thurman</td>
<td>Good, Lamont</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOPOSEQUENCES ONLY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From silt loam or loam over Late Wisconsin outwash sand and gravel, prairie vegetation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural drainage</td>
<td>36-60&quot; over coarse substrate</td>
<td>24-30&quot; over coarse substrate</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>Waukegan</td>
<td>Dakota</td>
<td></td>
</tr>
<tr>
<td>Somewhat poor</td>
<td>Kato</td>
<td>Gilbert</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>Marshan</td>
<td>Marshan</td>
<td></td>
</tr>
</tbody>
</table>

classification by Mill (1868). The logic of Mill does not, however, provide a deductive system for developing and testing soil genetic hypotheses for use as a basis of classification.

It is suggested that a more systematic approach to development and testing of soil genetic hypotheses be adopted as a logical framework for development of taxonomic soil classes. Lack of such a systematic, logical approach has led to unsatisfactory soil classification in the past. For
example, Marbut inductively established the criterion of presence or absence of a calcium carbonate zone in the soil profile as basis for his two classes of the highest category, Pedalfers and Pedocals, apparently without sufficiently testing it as an empirical hypothesis. Later study has shown that this criterion must be abandoned.

A scientific deductive system and a logic for classes has been developed by Braithwaite (1953) which seems adaptable to soil genesis and classification. This system involves correlation of principles of deduction with a set of symbolic manipulations called a "calculus" by Braithwaite.

Basis of the system as developed by Braithwaite involves three fundamental formulae:

\[ a \leftrightarrow (\lambda \mu) \quad (9) \]
\[ b \leftrightarrow (\mu \nu) \quad (10) \]
\[ y \leftrightarrow (\nu \lambda) \quad (11) \]

from which are derived, within a prescribed set of "rules":

\[ (a \beta) \leftrightarrow (y (a \beta)) \quad (12) \]
\[ (\beta y) \leftrightarrow (a (\beta y)) \quad (13) \]
\[ (y a) \leftrightarrow (\beta (y a)) \quad (14) \]

where \( \leftrightarrow \) indicates class identity. These formulae represent a deductive chain in which from the initial formulae, (9)-(11), given meanings as follows:

(9) any class which is (or has the property of) A also is (or has the property of) both L and M, and vice
versa,

(10) any class which is (or has the property of) B is (or has the property of) both M and N, and vice versa,

(11) any class which is (or has the property of) C is (or has the property of) both L and N, and vice versa,

can be deduced the following meanings for formulae (12)-(14):

(12) any class which is (or has the property of) both A and B is (or has property of) also C,

(13) any class which is (or has the property of) both B and C is (or has property of) also A,

(14) any class which is (or has the property of) both C and A is (or has property of) also B.

These formulae can be interpreted and applied in the following manner, according to the "three-factor" theory of Braithwaite. Assume there are three observable properties - A, B, C - about which it has been found by experiment or observation that these two empirical generalizations apply:

(g1) any class which has properties A and B has also the property C,

(g2) any class which has properties B and C has also the property A.

According to Braithwaite, one can then try explaining the generalizations by a scientific theory by postulating
three theoretical factors or properties $L, M, N$ such that the presence of each of the observable properties $- A, B, C -$ is associated with the joint occurrence of two out of three of the theoretical factors. That is, the following three hypotheses are proposed, which follow from the initial formulae:

(h1) any class with the property $A$ has also theoretical properties (or is associated with the theoretical factors) $L$ and $M$, and vice versa,

(h2) any class with the property $B$ has also theoretical properties (or is associated with the theoretical factors) $M$ and $N$, and vice versa,

(h3) any class with the property $C$ has also theoretical properties (or is associated with the theoretical factors) $N$ and $L$, and vice versa.

From these hypotheses, if found to be acceptable, results a third empirical generalization:

(g3) any class with properties $C$ and $A$ have also property $B$.

If this generalization is acceptable, after testing by observation or experiment, it supports the theory.

Feasibility of application of this deductive system with its basis of symbolic manipulation to soil classification and genesis studies can be questioned. Objection can be raised that soil relationships can be seen and the bases for soil classes developed without such a system. However, the
system seems useful in formalizing and systematizing the approach, suggesting and testing hypotheses, and predicting relationships and generalizations that might be overlooked. Furthermore, many of the terms and concepts in soil classification and genesis have indirect meanings or are relative terms—that is, are used and defined relative to some other soil term or concept or property. The empirical generalizations and hypotheses of this deductive system, based on formulae, serve to define or give meanings to these terms and concepts.

Application of this type of deductive system to study of soil relationships and soil classification is illustrated with two examples in the following discussion.

Study of soils by three-dimensional plots of selected parameters seems a convenient way of illustrating soil relationships and differences. This method is somewhat complementary to the functional, factorial approach of Jenny (1942, 1946) for it illustrates in spatial fashion some of the soil relationships Jenny seeks to bring out by arranging soils in sequences. Selection of parameters for plotting involves making of generalizations concerning properties of the particular soils under study and making hypotheses concerning their genesis. For these purposes the deductive system previously described is well suited. Illustrations of this method are given in Figures 37 and 38.
Figure 37. Soil surface illustrating relationships among great soil groups of Iowa as developed by a deductive system; each dot represents the plot of a particular soil profile.
Decreasing Organic Matter Distribution Throughout Profile (Percent Organic Carbon $A/B$)
Figure 38. Soil surfaces illustrating relationships among Clarion, Nicollet, and Webster soil series as developed by a deductive system; uppermost surface represents Clarion soils, surface in intermediate position represents Nicollet soils, and lower surface represents Webster soils; dots are plots of particular profiles.
Increasing Slope, Aeration, and Decreasing Accretion of Material (Percent Organic Carbon in Ah)
Relationship between primarily Brunizems and Gray-Brown Podzolic great soil groups are shown in Figure 37. Wiesen­boden soils have been included to show their similarity to Brunizems, but not all their important characteristics have been considered. Planosols are also included.

Selection of parameters for plotting of the great soil group relationships was by application of the deductive sys­tem previously described. Data for these great soil groups were obtained from profile studies both within Polk County and elsewhere in Iowa. This great soil group study was restricted to soils formed from loess or glacial till parent material in Iowa. That is, these are the limits of the system. Two empirical generalizations were made:

(gl) all soils with ratios of organic carbon in Ah horizon to organic carbon in the B1 horizon of greater than 4 and with ratios of minimum content of clay in the A horizon to maximum content in B horizon less than 0.75 have also relatively low base saturation throughout the solum (except for Ah), with the minimum in B horizon less than 80 percent.

(g2) all soils with a ratio of minimum clay in A to maximum clay in B of less than 0.75 and of relatively low base saturation throughout the solum have also ratios of organic carbon in Ah to
organic carbon in the B greater than 4.

Three hypotheses were then postulated concerning these properties about which generalizations were made:

(h1) all soils with ratios of organic carbon in Ah to organic carbon in B1 greater than 4 have formed under forest native vegetation and have relatively extensive leaching throughout the profile.

(h2) all soils with ratios of minimum clay in the A to maximum clay in B of less than 0.75 have relatively extensive leaching throughout their profiles and have undergone significant silicate clay translocation.

(h3) all soils with relatively low base saturation throughout the solum (except for Ah horizon) and with the minimum of base saturation in the B less than 80 percent have formed under forest natural vegetation and have undergone significant silicate clay translocation.

Since these hypotheses seem reasonably acceptable, a third generalization follows:

(g3) all soils with ratios of organic carbon in Ah to organic carbon in the B1 greater than 4 and relatively low base saturation throughout the solum also have ratios of minimum clay in the A to maximum clay in the B of less than 0.75.
Since relative silicate clay translocation is assumed to be dependent, at least in part, on effect of forest native vegetation with its decreased organic matter distribution throughout the profile and on relative extent of leaching, it is plotted on the z-axis in the three-dimensional plot of Figure 37. This relationship is measured by the ratio of minimum clay in A to maximum clay in B. Plotting of points based on profile data followed by "contouring" of those points to form a surface results in the three-dimensional diagram of great soil group relationships of Figure 37.

Gray-Brown Podzolic soils form a rather distinct portion of the surface, though their intergradation to Flano-sols can be seen. Close relationship between Brunizem and Wiesenboden soils is seen in their close association on this surface.

Relationships among Clarion, Nicollet and Webster soils as shown in Figure 38 were developed by application of the deductive system as previously described. Profile data used for plotting Figure 38 were those obtained in the present study; data of nine profiles from Minnesota as reported by Khan (1949), Arneman and McMiler (1955), and Arneman (1956); two Clarion profiles from Iowa as reported by Riecken, Allaway, and Smith (1947); and data for one Webster profile from Iowa presented by Simonson, Riecken, and Smith (1952). Limits of the system studied are soils formed from Late Wisconsin
till under prairie vegetation in Iowa and Minnesota. Study of these data indicated the following two generalizations could be made to distinguish Clarion from Nicollet and Webster:

(g1) soils lowest in organic matter and in content of clay in A and B horizons have also brown B horizon colors.

(g2) soils lowest in content of clay and with brown B horizon colors are also lowest in content of organic matter.

Three hypotheses were then postulated concerning these generalizations:

(h1) soils lowest in organic matter have formed under conditions of good natural drainage on convex upland slopes.

(h2) soils lowest in clay content have developed on convex upland slopes and have formed from loam till parent material.

(h3) soils with brown B horizon color have formed under conditions of good natural drainage, and have formed from loam till parent material.

Since these hypotheses seem acceptable and coincide with hypotheses for origin of Clarion soils, properties or parameters contained in the generalizations seem to define Clarion as compared to Nicollet and Webster.
A similar approach is used to attempt to define Webster soils as contrasted to Clarion and Nicollet soils:

1) Soils highest in content of organic matter and of clay have gray B horizon color.

2) Soils highest in content of clay and with gray B horizon color have highest content of organic matter.

Three hypotheses were made concerning these generalizations:

1) Soils highest in content of organic matter have formed under conditions of poor natural drainage with prolonged water saturation in concave depressional areas, often water-filled.

2) Soils highest in content of clay have formed in concave depressional areas (often water-filled) from accretionary parent material.

3) Soils with gray B horizons have formed under conditions of poor natural drainage with prolonged water saturation and have formed from accretionary parent material.

These hypotheses seem reasonably acceptable and seem to coincide with those proposed for genesis of Webster soils. Therefore, the parameters in the generalizations seem to define Webster as contrasted to Clarion and Nicollet.

Therefore, data on content of organic matter, clay, and on B horizon color have been plotted in Figure 38 to illus-
treat relationships among these three soil series. Since content of organic matter seems functionally dependent to some degree on slope position (as expressed in content of clay) and degree of water-saturation (as expressed in B horizon color), this parameter has been plotted on the z-axis.

Clustering of the plots for the three soils can be seen in Figure 38 to form three distinct fragmental surfaces. This tends to support the validity of these series distinctions. Tendency of the plots for each soil series to cluster is also a reflection of the fact that the profiles from which the data were obtained were purposively selected to be as representative or typical of the series as possible.

Modal Profile and Modal Soil Concept

This concept was introduced by Cline (1949) as a basis for definition of soil classes, or taxonomic units. A summary of the concept is given in an earlier section.

Validity of the modal profile concept is questioned on the basis of doubt if there is a truly modal soil or profile, in the statistical sense, in many soil classes as presently defined. A given soil individual may be "modal" with respect to one characteristic or property but also may be amodal with respect to another characteristic or property which is differ-
entitling for the unit.

Properties of Clarion, Nicollet, and Webster profiles of three Minnesota counties for which data are reported by Khan (1949), Arneman and McMiller (1955), and Arneman (1956); of Polk County reported in the present study; and of other Iowa counties as reported by Riecken, Allaway, and Smith (1947), and Simonson, Riecken, and Smith (1952) are summarized in Tables 18, 19, and 20. Means of certain parameters have been computed in each table for the four to six profiles for which data are available. Insufficient data are available to compile a frequency distribution of these properties. However, the means can be taken as an approximation to the modal value of the soil properties, since there seems no reason to suspect appreciable skewing or kurtosis if frequency distribution curves could be plotted. It can be seen in Tables 18, 19, and 20 that no one profile of Clarion, Nicollet, or Webster is consistently nearest the mean for the series in many of the selected parameters. If it is accepted that nearness to the mean indicates modality, then it must be concluded that not one of these profiles is truly modal. No Nicollet or Clarion profile seems to approach modality. The Webster profile labeled W1 in the table seems nearly modal in many respects, but its content of organic carbon in the surface is lowest for the group, and overlaps the Nicollet range.
Table 18. Summary of some properties of Clarion soil profiles

<table>
<thead>
<tr>
<th></th>
<th>C1a</th>
<th>C2a</th>
<th>C3a</th>
<th>C4b</th>
<th>C5c</th>
<th>C6d</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>percentage, Ah (A1)</td>
<td>2.90</td>
<td>2.91</td>
<td>2.97</td>
<td>1.96</td>
<td>3.00</td>
<td>1.89</td>
<td>2.61</td>
</tr>
<tr>
<td>Clay percentage,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ah (A1)</td>
<td>32.7</td>
<td>32.6</td>
<td>27.4</td>
<td>25.0</td>
<td>24.8</td>
<td>21.8</td>
<td>27.4</td>
</tr>
<tr>
<td>Clay percentage,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>30.9</td>
<td>30.0</td>
<td>24.1</td>
<td>27.8</td>
<td>25.8</td>
<td>20.7</td>
<td>26.6</td>
</tr>
<tr>
<td>Percent base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>saturation, Ah (A1)</td>
<td>68</td>
<td>72</td>
<td>65</td>
<td>83</td>
<td>84</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>Percent base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>saturation, B2</td>
<td>75</td>
<td>88</td>
<td>78</td>
<td>86</td>
<td>88</td>
<td>94</td>
<td>85</td>
</tr>
<tr>
<td>Exchange capacity,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ah (meq./100 g.)</td>
<td>28.5</td>
<td>22.8</td>
<td>30.3</td>
<td>22.8</td>
<td>26.7</td>
<td>19.1</td>
<td>26.2</td>
</tr>
</tbody>
</table>

*aCompiled from data of Khan (1949), Arneman and McMillan (1955), and Arneman (1958) for profiles from Nicollet, Brown, and McLeod Counties, Minnesota, respectively.*

*bPolk County, Iowa, profile P471.*

*cData for profile P97 from Dickinson County, Iowa, as reported by Riecken, Allaway, and Smith (1947).*

*dData for profile P49 from Story County, Iowa, as reported by Riecken, Allaway, and Smith (1947).*
Table 18. (Continued)

<table>
<thead>
<tr>
<th>Property</th>
<th>Cl</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange capacity, ( B_2 )</td>
<td>29.3</td>
<td>25.2</td>
<td>21.0</td>
<td>19.4</td>
<td>21.6</td>
<td>15.2</td>
<td>22.0</td>
</tr>
<tr>
<td>Color of ( Ah )</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
<td>10YR2/2</td>
</tr>
</tbody>
</table>

Summary of profiles nearest mean for selected properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Profile nearest mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon, ( Ah ) (( A_1 ))</td>
<td>Cl, C2</td>
</tr>
<tr>
<td>Clay percentage, ( A )</td>
<td>C3</td>
</tr>
<tr>
<td>Clay percentage, ( B_2 )</td>
<td>C5</td>
</tr>
<tr>
<td>Percent base saturation, ( A )</td>
<td>C6</td>
</tr>
<tr>
<td>Percent base saturation, ( B_2 )</td>
<td>C4</td>
</tr>
<tr>
<td>Exchange capacity, ( A )</td>
<td>C5</td>
</tr>
<tr>
<td>Exchange capacity, ( B_2 )</td>
<td>C5</td>
</tr>
<tr>
<td>Color of ( A )</td>
<td>(all similar)</td>
</tr>
<tr>
<td>Color of ( B_2 )</td>
<td>C2, C3, C5, C6</td>
</tr>
</tbody>
</table>
Table 19. Summary of some properties of Nicollet soil profiles

<table>
<thead>
<tr>
<th>Property</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon percentage, Ah (A1)</td>
<td>3.70</td>
<td>3.43</td>
<td>3.57</td>
<td>2.56</td>
<td>3.27</td>
</tr>
<tr>
<td>Clay percentage, Ah (A1)</td>
<td>32.4</td>
<td>31.8</td>
<td>30.3</td>
<td>24.4</td>
<td>29.7</td>
</tr>
<tr>
<td>Clay percentage, B2</td>
<td>32.1</td>
<td>32.1</td>
<td>27.0</td>
<td>25.7</td>
<td>29.2</td>
</tr>
<tr>
<td>Percent base saturation, Ah (A1)</td>
<td>70.0</td>
<td>68.1</td>
<td>67.9</td>
<td>80.6</td>
<td>71.7</td>
</tr>
<tr>
<td>Percent base saturation, B2</td>
<td>81.7</td>
<td>80.4</td>
<td>77.6</td>
<td>97.2</td>
<td>84.2</td>
</tr>
<tr>
<td>Exchange capacity, Ah (meq./100 g.)</td>
<td>34.3</td>
<td>34.9</td>
<td>35.8</td>
<td>21.6</td>
<td>31.7</td>
</tr>
<tr>
<td>Exchange capacity, B2</td>
<td>27.8</td>
<td>27.4</td>
<td>23.6</td>
<td>17.2</td>
<td>24.0</td>
</tr>
<tr>
<td>Color of Ah (A1)</td>
<td>2.5Y2/0</td>
<td>10YR2/2</td>
<td>2.5Y2/0</td>
<td>10YR3/1</td>
<td>10YR2.5/1.5</td>
</tr>
<tr>
<td>Color of B2</td>
<td>2.5Y4/2</td>
<td>10YR4/4</td>
<td>2.5Y5/4</td>
<td>10YR3/2</td>
<td>10YR3.5/3</td>
</tr>
</tbody>
</table>

Summary of profiles nearest mean for selected properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Profile nearest mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon Ah (A1)</td>
<td>N3</td>
</tr>
<tr>
<td>Clay percentage, A</td>
<td>N3</td>
</tr>
<tr>
<td>Clay percentage, B</td>
<td>N3</td>
</tr>
<tr>
<td>Percent base saturation, A</td>
<td>N1</td>
</tr>
<tr>
<td>Percent base saturation, B</td>
<td>N1</td>
</tr>
<tr>
<td>Exchange capacity, A</td>
<td>N1</td>
</tr>
<tr>
<td>Exchange capacity, B</td>
<td>N3</td>
</tr>
<tr>
<td>Color of A</td>
<td>(indeterminate)</td>
</tr>
<tr>
<td>Color of B</td>
<td>(indeterminate)</td>
</tr>
</tbody>
</table>

*aCompiled from data of Khan (1949), Arneman and McMiller (1955), and Arneman (1956) for three profiles from Nicollet, Brown, and McLeod Counties, Minnesota, respectively.

bPolk County, Iowa, profile P472.
<table>
<thead>
<tr>
<th></th>
<th>W1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>W2&lt;sup&gt;a&lt;/sup&gt;</th>
<th>W3&lt;sup&gt;a&lt;/sup&gt;</th>
<th>W4&lt;sup&gt;b&lt;/sup&gt;</th>
<th>W5&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon, Ah (A&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>3.19</td>
<td>3.30</td>
<td>3.71</td>
<td>3.50</td>
<td>4.13</td>
<td>3.54</td>
</tr>
<tr>
<td>Clay percentage, Ah (A&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>37.7</td>
<td>35.3</td>
<td>31.8</td>
<td>39.6</td>
<td>34.2</td>
<td>35.7</td>
</tr>
<tr>
<td>Clay percentage, Bgg</td>
<td>38.0</td>
<td>35.4</td>
<td>30.0</td>
<td>39.7</td>
<td>34.0</td>
<td>35.4</td>
</tr>
<tr>
<td>Percent base saturation, A&lt;sub&gt;1&lt;/sub&gt;</td>
<td>83.4</td>
<td>72.6</td>
<td>78.9</td>
<td>100.0</td>
<td>93.0</td>
<td>85.6</td>
</tr>
<tr>
<td>Percent base saturation, Bgg</td>
<td>100.0</td>
<td>68.8</td>
<td>100.0</td>
<td>100.0</td>
<td>87.0</td>
<td>95.2</td>
</tr>
<tr>
<td>Exchange capacity, Ah (meq./100 g.)</td>
<td>38.2</td>
<td>41.2</td>
<td>37.4</td>
<td>40.9</td>
<td>43.1</td>
<td>40.2</td>
</tr>
<tr>
<td>Exchange capacity, Bgg</td>
<td>27.6</td>
<td>31.6</td>
<td>20.5</td>
<td>30.4</td>
<td>30.6</td>
<td>28.1</td>
</tr>
<tr>
<td>Color of Ah (A&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>5Y2/1</td>
<td>5Y2/2</td>
<td>5Y2/1</td>
<td>10YR2/1</td>
<td>10YR2/1?</td>
<td>5Y2/1-2.5Y2/1</td>
</tr>
<tr>
<td>Color of Bgg</td>
<td>5Y5/2</td>
<td>5Y4/2</td>
<td>5Y5/3</td>
<td>5Y5/2</td>
<td>5Y5/2?</td>
<td>5Y5/2</td>
</tr>
</tbody>
</table>

<sup>a</sup>Compiled from data of Khan (1949), Arnesen and McMiller (1955), and Arnesen (1956) for Nicollet, Brown, and McLeod counties, Minnesota, respectively.

<sup>b</sup>Polk County, Iowa, profile P466.

<sup>c</sup>Data of Humboldt County, Iowa, profile reported by Simonson, Riecken, and Smith (1952).
Table 20. (Continued)

<table>
<thead>
<tr>
<th>Property</th>
<th>Profile nearest mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon, Ah(A1)</td>
<td>W4</td>
</tr>
<tr>
<td>Clay percentage, A</td>
<td>W2</td>
</tr>
<tr>
<td>Clay percentage, Bgg</td>
<td>W2</td>
</tr>
<tr>
<td>Percent base saturation, A</td>
<td>W1</td>
</tr>
<tr>
<td>Percent base saturation, B</td>
<td>W1, W3, W4</td>
</tr>
<tr>
<td>Exchange capacity, A</td>
<td>W4</td>
</tr>
<tr>
<td>Exchange capacity, B</td>
<td>W1</td>
</tr>
<tr>
<td>Color of A</td>
<td>W1, W3</td>
</tr>
<tr>
<td>Color of B</td>
<td>W1, W4</td>
</tr>
</tbody>
</table>
This study of properties of several Clarion, Nicollet, and Webster profiles tends to indicate that the hypothesis of a truly modal soil profile as an actual definitive concept of a soil class may be invalid. Modal soil may then be an abstraction, constructed in the mind for better illustration of the properties of a soil class.

In the discussion of the placement of Polk County soils in the present taxonomic classification, it was pointed out that it was necessary to refer to the whole known universe of Brunisols for great soil-group classification, or of Tama and Sharpsburg soils for series classification. That is, the modal soil of the county in the class under consideration could not be used as modal when the whole population is considered. Whiteside (1954) has pointed out that the modal individual would vary with the relative areas of different portions of the range of soil properties and thus is an unacceptable concept.

Modal soil as a concept seems an attempt to define a model for taxonomic classes. Use of a model as a sort of picture or symbol of a class of objects seems desirable, but the suitability of the modal soil concept as a definition for taxonomic classes seems questionable. Disadvantages and dangers in the use of modal soil as a classification basis are that the properties of the selected modal soil of a class are likely to be taken as properties of the class as a
whole, that attention and study is centered on the modal soil at the expense of other members of the class, and that some of the logically necessary aspects of selection of a modal soil for the class are erroneously made part of soil classification and genesis theory without confirmation. These dangers and disadvantages tend to be true for all models, but are especially true for the model soil concept.

Dangers and disadvantages of the erroneous tendency for specific properties of the selected model soil to be taken as properties of the class in general can be seen in the selection of Tama soil series as "modal" for the Brunizem great soil group. There is some tendency to ascribe to Brunizems as a group those properties of Tama which are responsible for its high productivity under average management - but which are not representative of the sandy Thurman soils or clayey Lagonda soils (described in an earlier section) and which are also Brunizems.

A consequence of the centering of attention and study on the modal soil of a class is the neglect of the amodal members of the class. It is postulated that many soil classes when mapped as cartographic units are comprised largely of amodal soils, differing to some degree from the soil selected as modal. Yet inferences are commonly made to the class as a whole on basis of study of the modal soil. Too, study of the amodal soils which are intergrading to other
classes may well reveal more information of importance to soil genesis and classification than study of the selected modal soil.

Acceptance of the modal soil concept implies acceptance of the propositions that soil-forming factors interact to produce soil differences and similarities which can be used to distinguish discrete classes of soils defined by maxima of frequency distributions of properties used as differentiating characteristics. In this concept it is considered as logically necessary, not a proposition contingent on testing, that distinguishing characteristics be maxima of frequency distributions of certain properties.

That natural groups or classes are best framed and determined by common characteristics and are not determined by reference to a "type" is postulated by Mill (1868) in his discussion of logic of classification. From context it seems that "modal individual" or "modal soil" is equivalent to type as used by Mill. A quotation illustrating his view (Mill, 1868, p. 276):

We do not compose the species Ranunculus acris, of all plants which bear a satisfactory degree of resemblance to a model-buttercup, but of those which possess certain characters selected as marks by which we might recognize the possibility of a common parentage; and the enumeration of those characters is the definition of the species.

His view on the role of the type (modal individual) is contained in the following quotation (p. 279):
And hence our conception of the class, the image in our minds which is representative of it, is that of a specimen complete in all characters; most naturally a specimen which, by possessing them all in the greatest degree in which they are ever found, is the best fitted to exhibit clearly, and in a marked manner, what they are. It is by a mental reference to this standard, not instead of, but in illustration of, the definition of the class, that we usually and advantageously determine whether any individual or species belongs to the class or not.

It is concluded that the most desirable approach to definition of classes in a soil taxonomic scheme is by common characteristics, those characteristics being selected which carry the greatest number of accessory characteristics. These characteristics are probably best deduced and a rationale for the classes best established by use of the deductive system previously described. Role of the "modal soil" or "central tendency" would seem to be that of a sort of model as a mental aid for determining membership in a class and as a mechanical aid in describing the class, but not as the basis for definition of the class.

Rejection of the modal soil concept on theoretical grounds and rejection of the functional, factorial, approach, largely on basis of mechanical difficulties in its application, results in a dilemma. It seems necessary to admit that soils constitute a continuum as conceived in the functional, factorial approach. But it also seems necessary to break this continuum into discrete rather arbitrary classes in order to meet the objectives of soil classification, which tends to
lead to the modal soil concept as a means of establishing the classes. It is a problem to avoid the dangers of the modal soil concept while using it as a mental tool to help frame the desired classes.

Normal Soil Concept

Frame of reference in Marbut's soil classification (Marbut, 1927, 1935) was the "normal soil on normal relief" or "regional profile" concept. This concept has been continued to some extent in the revisions of Marbut's classification (Baldwin, Kellogg, and Thorp, 1938; Thorp and Smith, 1949). It seems that normal soil as a frame of reference has introduced an undesirable bias in soil classification. The concept is based on relationships between soils and concept of landscape evolution which have been greatly modified by recent geomorphic investigations relating soil development to landscape development (Ruhe, 1956; Ruhe and Scholtes, 1956). Normal soil concept also overemphasizes morphology and soil development in certain soils at the expense of "abnormal" soils, many of which undergo developmental processes similar to associated normal soils.

Marbut was strongly influenced by the classic concepts of landscape evolution since he studied under the leading exponent and developer of these concepts, W. M. Davis (see
Moomaw in Life and Work of C. F. Marbut). In the classical concept, interstream divides are reduced and there is a lowering of valley slopes as landscape development proceeds (Davis, 1902). Newer concepts of landscape evolution in relation to soil development postulate relatively stable upland in the interstream areas and development of pediments by retreat of valley slopes (Ruhe, 1956; Ruhe and Scholtes, 1956). Poorly drained, "abnormal" soils apparently can persist on the uplands. Consequently, specification of a "normal soil on normal relief" as a frame of reference for soil classification does not seem feasible.
SUMMARY AND CONCLUSIONS

A study and appraisal of soil classification was made which was delimited to Polk County, Iowa. The present widely used approach to soil classification, the multicategorical taxonomic scheme, was used as a basis for this study. Evolution and development of this approach to soil classification since its inception by Russian soil scientists in the late nineteenth century is traced.

Greatly increased numbers of soil series and map units in the past 50 years of soil classification and mapping in the Polk County area with attendant shifts in concept and nomenclature are shown. Lack of any appreciable discussion of the rationale and underlying logic for these changes is indicated as one of a number of reasons for undertaking the present study. Other factors involved in undertaking this study were the inherent defects and indicated need for revision of the multicategorical taxonomic approach and the need for evaluation of alternative or complementary approaches to soil classification.

It is concluded from this study that the multicategorical approach is acceptable, but that there is need for revision of criteria for classes at many of the categorical levels. The concept of soil modality as a specific test for placement of soils in classes is rejected, though this concept
seems useful as a mental tool or model. An alternative conceptual or type-group approach is suggested whereby classes are defined in terms of common characteristics.

A functional, factorial approach to soil taxonomy and genesis studies was evaluated. It is concluded that this approach contains such a large number of mechanical difficulties in its application that it cannot be considered an alternative to the multiclasserical approach. However, it seems extremely useful as a complementary subsidiary approach when employed in qualitative fashion in soil studies.

It is concluded that in the present imperfect state of knowledge about soils and significance of their properties that soil classification cannot at present be a truly natural taxonomic system but must be diagnostic in nature, particularly at lower levels of generalization such as the soil series category. It is suggested that agricultural relevance serve as a choice criterion for selection and weighting of differentiating characteristics except where utility of the class for other uses would be decreased.

Physical and chemical data for a number of Polk County soil profiles were obtained and are presented in tabular form. These data and morphological descriptions presented in the Appendix have been drawn upon for classification studies.

General soil genetic trends in Polk County on the basis of soil profile data obtained in this study and previous
studies of Polk County soil profiles (White, 1953; Folks, 1954; Prill, 1955) are summarized as follows:

1. Formation of a horizon of accumulation of silicate clay, or B horizon. This soil developmental process is accelerated when trees encroach prairie areas.

2. Soils formed from Late Wisconsin deposits under prairie vegetation (chiefly Clarion, Micollet, and Webster soil series) do not possess horizons of clay accumulation as measured by particle size distribution analyses but do exhibit thin and discontinuous silicate clay films lining some pores in horizons below the A or surface horizons, but above the parent material, when studied in thin section with a petrographic microscope. Evidence for iron mobilization and concentration can also be obtained in thin section study. It is concluded that thin section study of soils is a highly useful tool in soil genesis and classification studies.

3. Slight accumulation of free iron in well-aerated soil profiles, including those soils without horizons of clay accumulation as measured by particle size distribution analyses; mobilization and apparent loss of free iron in poorly aerated soil profiles, all of which were found to be lower in content of free iron than well-aerated profiles formed from
similar parent material.

4. Organic matter accumulations in surface horizons of all upland soils; content of organic matter decreasing gradually with depth in soils formed under prairie vegetation but decreasing sharply with depth in profiles of forested soils.

5. Some degree of cation leaching, as inferred from data on pH and percentage saturation of the exchange complex, except in profiles of poorly aerated soils formed under prairie in which little or no leaching has taken place.

6. Clay mineralogy is dominantly of 2:1-layer lattice type, mostly montmorillonoid with subsidiary illite and small amounts of kaolinite, as inferred from clay mineralogy studies of Clarion and Tama soils.

Soil horizons, or genetic layers, have been quantitatively defined in terms of properties of Polk County soils. Some modifications of current soil horizon nomenclature and designations are proposed.

Specific suggestions for revision of higher categories of the multiclassification soil classification:

1. Abandonment of concept of soil zonality as a criterion for classes at highest level of generalization and substitution of classification by array (based on "classification by series" as developed
by Mill (1868) according to degree of display of the most important soil properties. This serves to remove the bias of the "normal soil" concept and places classification on basis of fundamental soil properties as reflections of dominant soil-forming processes. It is postulated that most fundamental property is possession or absence of a B horizon. It is therefore proposed that soils be stratified into classes at the highest categorical level according to major kind of B horizon or lack of B. Two such classes occur in Polk County - those soils in which silicate clay accumulation in B is dominant process and those lacking B horizons.

2. Abandonment of genetic-ecologic basis of definition of classes at second highest level is advocated with replacement by array of soils according to presence or absence of secondary soil horizons, such as Ae and Bg as defined in this study.

3. Essentially no modification of current concepts of great soil groups is suggested except redefinition of Wiesenboden group to indicate presence of clay B as defined in this study.

Principles and criteria for classes at intermediate levels of generalization are presented. Classification of Polk County soil series into great soil sub-groups and soil
families on basis of these principles and criteria are given.

A number of problems of soil series differentiation in Polk County are discussed and possible solutions suggested:

1. In case of soils formed from loessial deposits where soil properties are a continuous function of variation in properties of loess, a rather arbitrary separation of soil series is necessary as in discrimination of Tama and Sharpsburg soil series in southern Polk County. Properties of these soils and rationale of their discrimination are given.

2. Polylithogenetic soils (defined in this study as soil formed from more than one parent material) seem best discriminated on basis of degree of influence of the second parent material on the A and B horizons. Comparisons of properties of Clarion soil series formed from Cary glacial till and Ferrer soil series formed from similar till overlain with wind-deposited sandy loam and comparison of soils of outwash terraces with varying depth to underlying coarse-textured substrates are given.

3. Significant differences in profile properties were found among three soil profiles of Cary till plain formed under prairie vegetation but differing in slope position and assumed degree of wetness. These profiles were classed with the Clarion, Nicollet,
and Webster soil series. Correlation of free iron content of the profile with assumed and observed degree of wetness was found. Content of free iron increased in order of Webster, Nicollet, and Clarion, which is order of assumed increasing seration and decreasing degree of water saturation in their natural state prior to artificial drainage. It is concluded that parent material of the Webster soil is largely accretionary by translocation of soil material from adjoining slopes.

4. Soils of low degree of development formed from alluvial deposits of lateral and vertical variability seem best characterized by some sort of systematic or random sampling in order to obtain estimates of parameters important in agricultural use, such as particle size distribution. Properties of three profiles purposively selected to represent the tentative Colo, Wabash, and Zook soils are presented, together with results of studies of a small number of randomly collected profiles of Colo and Zook soils.

Reorganization of current soil type and phase concepts is proposed. Those profile or point properties now used as phase criteria are proposed to supplant or to be given equal status with the current criterion of surface soil texture for the soil type category, the lowest level of generalization.
Those shape characteristics of soil, or properties associated with the three-dimensional nature of soil, now used as phase criteria are suggested as a basis for subsidiary classification composed of classes called utiles, which could be used to subdivide any taxonomic category.

Relationships among great soil groups of Iowa and among Clarion, Nicollet, and Webster soil series are shown by means of three-dimensional plots. Properties are selected for plotting by application of a deductive system.

Problem areas in soil classification requiring much further consideration and study are:

1. Weighting of criteria for classes at all levels of generalization.
2. The range, concept, and definition of the soil series - the basic mapping and taxonomic unit.
3. Whether soil classification should attempt to approximate natural classification or be a diagnostic (intermediate between natural and artificial or technical) classification.
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APPENDIX
TAXONOMIC SOIL DESCRIPTIONS

Descriptions of the soil series of Polk County are included in this section. Those soils from which detailed soil profile samples were taken are indicated with a soil profile sample number preceded by the letter P, this being the official profile sample number of the Iowa soil survey. Profile descriptions of the soil series from which samples were taken are those taken at the sample site. A number of other soil series are described from which samples were not taken and which carry no P-number. In these instances the series description is a brief composite intended to represent typical concept of the soil series as recognized in the county. Farrar, Hayden, and Lester profiles from Polk County have been described by White (1953), Thurman soil by Folks (1954), and Lindley soil by Prill (1955). Terminology and nomenclature of the descriptions are essentially as defined in the Soil Survey Manual (U. S. Department of Agriculture, 1951) with the exception of certain horizon notations. Horizon notations deviating from those in the Soil Survey Manual are defined in the section on horizon designations. Soil series names which are tentative are marked with an asterisk. Where a profile is composed of two parent materials, the upper is indicated by 1 in front of the horizon designation and the lower is indicated by 2 in a similar manner.
The pH values given for the various horizons were determined by glass electrode according to the procedure described in the section on methods.

Ames Loam (P500)

Location: SW 1/4 SE 1/4 SW 1/4, Sec. 12, T. 80 N., R. 24 W., Crocker Township, Polk County, Iowa. This site is 30 feet north of State Highway 60, 20 feet east of fence on east side of gravel road.

Vegetation: Trees (mostly oak and elm) and grass used as pasture; original native vegetation presumed to be trees (near prairie-forest border).

Parent material: Late Wisconsin (Gary) glacial till.

Slope and aspect: Less than 1 percent gradient to east, incised drainageway (small creek) is several hundred feet to east.

Collected by Ralph McCracken October 2, 1953.

Ah 0-7" Very dark gray (10YR 3/1); loam; friable; weakly to moderately developed fine and medium granular structure; pH 6.9.

Ae 7-14" Grayish brown (10YR 5/2) and light brownish gray (10YR 6/2), the latter more dominant in lower part of this horizon; loam; friable; moderately developed fine platy structure in upper part and weak fine platy in lower part; contains a few fine dark concretions apparently ferromanganese; pH 6.3.

B11 14-19" Dark grayish brown (2.5Y 4/2) and light olive brown (2.5Y 5/4) with thick nearly continuous coatings of grayish brown (10YR 5/2); clay loam; firm; moderately developed medium and fine subangular blocky structure; a few fine dark concretions; pH 5.3.

B12 19-23" Dark grayish brown (2.5Y 4/2) and light olive brown (2.5Y 5/4) with thin discontinuous coatings of grayish brown (10YR 5/2); clay loam; firm;
moderately developed medium subangular blocky structure; a few thin discontinuous clay films; a few fine dark concretions; pH 5.2.

B21 23-26" Light olive brown (2.5Y 5/4), some aggregates coated with very dark gray (10YR 3/1); common fine mottles of strong brown (7.5YR 5/6); silty clay; very firm; strongly to moderately developed medium subangular blocky structure; some thick but discontinuous clay films; very few fine dark concretions; pH 4.6.

B22 26-31" Light olive brown (2.5Y 5/4), with common very fine mottles of reddish yellow (7.5YR 6/6), some aggregates coated with very dark gray (10YR 3/1); silty clay; very firm; strongly to moderately developed medium subangular blocky structure; common but discontinuous clay films; very few fine dark concretions; pH 5.8.

B3 31-37" Light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/4) with some medium mottles of reddish yellow (7.5YR 6/6) and some dark stains, apparently ferro-manganese; clay loam; firm; weak coarse angular blocky structure; pH 7.2.

C1 37-42" Light brownish gray (2.5Y 6/2) and olive yellow (2.5Y 6/6) with common coarse mottles of reddish yellow (7.5YR 6/6); clay loam to loam; firm; massive structure; a few fine dark concretions; pH 7.2.

C2 42-60" Light brownish gray (2.5Y 6/2) and olive yellow (2.5Y 6/6) with dark coatings, apparently ferro-manganese; loam; firm; massive structure; some pebbles effervesce when HCl applied; pH 7.7.

Ankeny Sandy Loam

Parent material: Sandy loam slopewash and colluvium in Cary till plain portion of the county.

Native vegetation: Prairie.

Profile summary:

Ah 0-10" Very dark grayish brown, weakly granular, sandy
loam.

B 10-30" Dark brown and dark grayish brown, very weakly blocky, sandy loam.

C 30-42" Brown and yellowish brown, loose, sandy loam to loamy sand.

Atterberry Silt Loam

Parent material: Loess.

Native vegetation: Forest.

Profile summary:

Ah 0-3" Very dark gray, granular, silt loam.

Ae 8-12" Very dark gray coated with grayish brown and gray, weakly granular, silt loam.

B 12-30" Dark grayish brown with yellowish brown mottles, weakly blocky, silty clay loam.

C 30-48" Grayish brown and brownish gray, massive, silt loam.

Bauer Silt Loam

Parent material: Des Moines shale.

Native vegetation: Prairie.

Profile summary:

Ah 0-12" Dark grayish brown to dark brown, friable, silt loam.

C 12-24" Yellowish brown, silty clay loam with many shale fragments.
Blockton Silt Loam

Parent material: Alluvium on floodplains in loess-mantled portion of county.

Native vegetation: Prairie-forest.

Profile summary:
Ah 0-12" Black, granular, silt loam.
Ae 12-18" Black coated with gray, weakly granular, silt loam.
Bg 18-32" Gray, weakly blocky, silty clay.
Cg 32-42" Dark gray, massive, silty clay

Buckner Loamy Sand

Parent material: Coarse aeolian or wind-modified sand.

Native vegetation: Prairie.

Profile summary:
Ah 0-9" Dark grayish brown, weakly granular, loamy coarse sand.
BG 9-30" Dark brown, loose, loamy coarse sand.
C 30-50" Dark grayish brown, loose, loamy coarse sand.

Burchard Loam

Parent material: Kansan till, or translocated material derived from Kansan till.

Native vegetation: Prairie.

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1This unit may be within the range of the Shelby series, which is now being redefined.
Profile summary:

Ah 0-10" Very dark grayish brown-dark brown; granular, loam.

B 10-36" Dark brown-yellowish brown, weakly blocky, loam-clay loam.

C 36-48"+ Yellowish brown, massive, loam.

Chaseburg Silt Loam

Parent material: Recent slopewash in forested, loess-derived soil areas.

Native vegetation: Forest.

Profile summary:

Ah 0-9" Grayish brown, weakly granular, silt loam.

BC 9-27" Grayish brown with mottles; very weakly blocky, silt loam.

C 27-36"+ Grayish brown-brownish gray, massive, silt loam.

Chelsea Loamy Sand

Parent material: Aeolian sands.

Native vegetation: Forest.

Profile summary:

Ah 0-2" Very dark brown, loose, loamy sand.

Ae 2-8" Dark gray, loose, loamy sand.

B 8-33" Yellowish brown, very weakly blocky, loamy sand.

C 33-48"+ Yellowish brown-grayish brown, loose, loamy sand, may contain iron-stained bands.
Chula Silt Loam

Parent material: Slopewash in loess-mantled portion of county.
Native vegetation: Forest.
Profile summary:
Ah 0-8" Dark grayish brown, granular, silt loam.
Ae 8-15" Grayish brown, weakly granular, silt loam.
B 15-36" Grayish brown-brown, weakly blocky, silty clay loam.
C 36-48"+ Very dark grayish brown-gray, massive, silt loam.

Clarinda Silt Loam

Parent material: Paleosol formed in Kansan till.
Native vegetation: Prairie.
Profile summary:
Ah 0-12" Very dark gray, granular, silt loam-silty clay loam.
Bg 12-36" Olive gray, weakly blocky, silty clay.
C 36-48" Olive gray, very weakly blocky, silty clay.

Clarion Loam (P471)

Location: Site is located in SW 1/4 SE 1/4 SW 1/4, Sec. 12, T. 80 N., R. 24 W., Crocker Township, Polk County, Iowa. Site is about 1450 east of Highway 69, in fresh roadcut on north side of road (taken just after road widening so that site was formerly in cultivated field).
Vegetation: Cultivated field in corn-oats-meadow rotation, native vegetation assumed to be prairie grasses, dominantly big bluestem.
Parent material: Glacial till of Cery (Late Wisconsin) age.

Slope and aspect: Gradient of 4 percent to north, on undulating till plain.

Collected by Ralph McCracken September 30, 1953.

Ap 0-9" Very dark brown (10YR 2/2); loam; friable; moderately developed medium granular structure; pH 6.7.

B1 9-13" Dark brown (10YR 3/3) with continuous but thin coatings of very dark brown (10YR 2/2); loam; friable to slightly firm; weakly developed fine and medium subangular blocky structure; pH 6.0.

B21 13-17" Dark brown (10YR 3/3) with thin nearly continuous coatings of very dark brown (10YR 2/2) which become thinner and less continuous in lower part of horizon; loam; friable to slightly firm; weakly developed fine and medium subangular blocky structure; pH 5.6.

B22 17-22" Dark brown (10YR 3/3) with some thin discontinuous coatings of very dark brown (10YR 2/2) and very dark grayish brown (10YR 3/2); loam; slightly firm; weakly developed fine and medium subangular blocky structure; pH 5.7.

B23 22-27" Dark brown (10YR 3/3) and brown (10YR 4/3); loam; slightly firm; weakly developed medium subangular blocky structure; pH 5.8.

B3 27-30" Yellowish brown (10YR 5/4) with common fine mottles of reddish yellow (7.5YR 6/6); loam; slightly firm; very weakly developed coarse subangular blocky structure. A slight concentration of gravel and pebbles form a thin 'stone line' at 30 inches depth; pH 5.2.

C1 30-36" Yellowish brown (10YR 5/4) with some coatings and seams of dark brown (10YR 3/3); loam; friable; massive structure; a few very fine soft concretions, apparently ferro-manganese; pH 6.5.

C2 36-54" Light yellowish brown (10YR 6/4) with common fine mottles of reddish yellow (7.5YR 6/6); loam; friable; massive structure; numerous concretions of calcium carbonate 2-10 mm. in diameter; pH 7.6.
Clearfield Silt Loam

Parent material: Loess.

Native vegetation: Prairie.

Profile summary:

Ah 0-12" Very dark gray, weakly granular, silt loam.

B 12-36" Very dark grayish brown-mottled, weakly blocky, silty clay loam.

C 36-48"+ Grayish brown-brownish gray, massive, silty clay loam.

Cooper* Silt Loam (P493)

Location: Site located in SW 1/4 NW 1/4 SW 1/4 Section 29, T. 78 N., R. 25 W., Bloomfield Township, Polk County, Iowa. This site is 1/2 mile south of the village of Commerce, south of Raccoon River, 200 feet east of north-south gravel road.

Vegetation: Cultivated field used for corn and soybean production. Native vegetation assumed to be prairie grasses.

Parent material: River alluvium over "slack water" deposits.

Slope and aspect: Gradient of 1 percent on undulating Raccoon River terrace.

Collected by Ralph McCracken October 2, 1953.

Ap 0-10" Very dark gray (10YR 3/1); silt loam; friable; weakly developed medium granular structure; upper 3 inches seems to be of recent deposition; pH 5.7.

AB 10-16" Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1); silt loam; friable; weakly developed medium subangular blocky structure which breaks to granular structure; pH 5.7.

Bl 16-22" Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1); silty clay loam; slightly firm; moderately developed fine and medium subangular blocky structure; pH 5.8; some
indications that this may be buried A_1 horizon of a buried soil.

2B21 22-28" Very dark grayish brown (10YR 3/2) with some thin coatings of very dark gray (10YR 3/1); silty clay loam; firm; moderately developed medium subangular blocky structure; pH 5.9.

2B22 28-35" Very dark gray (10YR 3/2) and dark gray (10YR 4/2); silty clay; firm; strongly developed medium and coarse subangular blocky structure; pH 5.8.

2B3 35-46" Dark grayish brown (10YR 4/2); silty clay or silty clay loam; firm; moderately developed coarse and medium subangular blocky structure; a few fine soft dark concretions, apparently ferro-manganese and some fine mottles; pH 5.6.

2C 46-57" Dark grayish brown (2.5Y 4/2) and light brownish gray (2.5Y 6/2); silty clay loam; weakly developed coarse subangular blocky structure; pH 5.8.

Colo# Silty Clay Loam (P481)

Location: Site is located in SW 1/4 SW 1/4 SE 1/4 Section 11, T. 81 N., R. 23 W., Elkhart Township, Polk County, Iowa. Samples taken from pit about 100 feet north of fence along east-west road, and about 250 feet northeast of southwest corner of field.

Vegetation: Native vegetation presumably moisture-loving prairie grasses; now used intensively for corn, soybeans, and small grain.

Parent material: Alluvium of Skunk River bottomlands, presumably post-Mankato in age.

Slope and aspect: Nearly level.

Physiography: Floodplain of Skunk River.

Collected by Ralph McCracken and L. E. Tyler July 15, 1953.

Ap 0-8" Black (10YR 2/1); silty clay loam; firm; moderately developed medium granular structure; pH 6.8.
AB 8-14" Black (10YR 2/1); silty clay loam; firm; moderately developed fine and medium granular structure; pH 6.4.

Bg1? 14-21" Black (10YR 2/1); silty clay loam; firm; very weakly developed medium subangular blocky structure; broad and diffuse transition to next lower horizon; pH 6.3.

Bg2? 21-28" Black (10YR 2/1) with some coatings of very dark gray (2.5Y 3/1); silty clay loam; firm; very weakly developed medium subangular blocky structure; gradual and diffuse lower horizon boundary; pH 6.4.

Bg3? 28-35" Very dark gray (10YR 3/1) and black (2.5Y 2/1); silty clay loam or silty clay; firm; very weakly developed medium subangular blocky structure; a few fine yellowish-brown mottles; pH 6.4.

Cg11 35-45" Very dark gray (2.5Y 3/1) with numerous fine yellowish-brown mottles; silty clay loam or silty clay; firm; weakly developed prismatic macrostructure; pH 6.6.

Cg12 45-56" Dark grayish brown (2.5Y 4/2) and olive gray (5Y 4/2), with numerous fine yellowish-brown mottles; silty clay loam or silty clay; firm; weakly developed prismatic macrostructure; pH 6.6.

Crocker\textsuperscript{a} Loamy Sand (P490)

Location: Site is located in NE 1/4 SW 1/4 NW 1/4, Section 7, T. 80 N., R. 24 W., Crocker Township, Polk County, Iowa. Samples taken from pit about 1/4 mile west of Highway 60, 100 feet from edge of steep slope above Big Creek.

Vegetation: Native vegetation assumed to be scattered trees and prairie, in prairie-forest border. Present vegetation bluegrass pasture with scattered trees.

Parent material: Aeolian sands over glacial till of Cary age.

Slope and aspect: Gradient of 3 percent to west.

Physiography: Undulating Late Wisconsin till plain, at edge of small stream valley.
Collected by Ralph McCracken September 28, 1953.

1Ah 0-10" Very dark grayish brown (10YR 3/2); loamy sand; loose; very weakly developed medium granular structure.

1Ae 10-12" Dark grayish brown (10YR 4/2) with coatings of grayish brown (10YR 5/2); fine sandy loam; very friable; very weakly developed medium granular structure.

2B1 12-17" Brown (10YR 4/3) with coatings of dark grayish brown (10YR 4/2); loam, with some gravel; slightly firm; weakly developed medium subangular blocky structure.

2B2 17-27" Brown (10YR 4/3) and yellowish brown (10YR 5/4); clay loam with some gravel; firm; moderately developed medium subangular blocky structure; some thin discontinuous clay films.

2B3 27-34" Yellowish brown (10YR 5/4) with some coatings of brown (10YR 4/3) and some spots of strong brown (7.5YR 5/6); clay loam or loam with some gravel; slightly firm; weakly developed coarse subangular blocky structure.

2C1 34-45" Yellowish brown (10YR 5/4) and light yellowish brown (10YR 6/4); loam; friable; massive structure.

Dakota* Loam (P405)"\(^1\)

Location: Site is located in SE 1/4 NE 1/4 NE 1/4 Section 13, T. 80 N., R. 25 W., Madison Township, Polk County, Iowa. Samples taken from pit located 50 feet north of east-west gravel road, about 300 feet west of point at which this road bends.

Vegetation: Native vegetation assumed to be prairie grasses; present use is for corn-oats-meadow rotation.

Parent material: Loamy overburden over Late Wisconsin outwash terrace gravel.

\(^1\)An alternative classification is as a phase of the Waukegan series.
Slope and aspect: Gradient about 1/2 percent westward.

Physiography: Nearly level Late Wisconsin high terrace along Des Moines River.

Collected by Ralph McCracken and Dean Einspahr November 30, 1951.

Ap 0-8" Very dark brown (10YR 2/2); loam; friable; weakly developed medium granular structure; pH 5.8.

AB 8-11" Very dark brown (10YR 2/2) and very dark grayish brown (10YR 3/2); loam; slightly firm; weakly developed medium granular structure; pH 5.9.

B1 11-16" Brown (10YR 4/3); loam; slightly firm; weakly developed coarse granular structure; pH 5.8.

B2 16-22" Brown (10YR 4/3); loam; weakly developed sub-angular blocky structure which readily breaks to coarse granular structure; pH 5.6.

D1 22-25" Brown (10YR 4/3) and dark brown (10YR 3/3); very gravelly sandy loam; loose; pH 5.6.

D2 25-36" Brown (7.5YR 4/4); gravelly loamy sand; loose; pH 6.9.

Dickinson Fine Sandy Loam (P498)

Location: Site is located in NW 1/4 NW 1/4 NW 1/4 Section 10, T. 81 N., R. 25 W., Union Township, Polk County, Iowa. Samples taken from a pit about 100 feet east of north-south road and 150 feet south of east-west road, at edge of abandoned school yard.

Vegetation: Native vegetation presumably prairie grasses; present vegetation bluegrass, apparently never cultivated.

Parent material: Wind-modified and stratified Gery glacial drift.

Slope and aspect: Gradient of 5 percent to west.

Physiography: Undulating Late Wisconsin till plain.

Collected by Ralph McCracken September 23, 1953.
Ah 0-11" Very dark grayish brown (10YR 3/2); fine sandy loam; very friable; weakly developed medium granular structure; diffuse lower horizon boundary.

B1 11-17" Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1); fine sandy loam; very friable, very weakly developed medium subangular blocky structure which readily breaks to granular structure.

B21 17-22" Dark brown (10YR 3/3) with some coatings of very dark grayish brown (10YR 3/2); fine sandy loam; very weakly developed medium subangular blocky structure.

B22 22-28" Dark brown (10YR 3/3) with a few coatings of very dark grayish brown (10YR 3/2); fine sandy loam; very friable; weakly developed medium subangular blocky structure.

B23 28-34" Dark brown (10YR 3/3); fine sandy loam; very friable; very weakly developed coarse subangular blocky structure.

B3 34-41" Brown (10YR 4/3) with a few fine mottles of yellowish brown (7.5YR 5/6); fine sandy loam with much gravel concentrated at about 40 inches depth; very friable; very weak coarse subangular blocky structure.

C11 41-51" Yellowish brown (10YR 5/3) with some spots of brown (10YR 4/3); sandy loam or fine sandy loam; very friable; single grain structure.

C12 51-60" Yellowish brown (10YR 5/6) with some mottles and stains apparently of Fe segregations; sandy loam or fine sandy loam; very friable; single grain structure.

Dorchester Silt Loam (P479)

Location: Site is located in SW 1/4 SE 1/4 Section 33, T. 81 N., R. 25 W., Madison Township, Polk County, Iowa. Samples taken from a pit about 100 feet north of a point on east-west gravel road which is about 250 feet east of bridge over Des Moines River.
Vegetation: Native vegetation probably forest and shrubs; present use is for intensive corn-soybean production.

Parent material: Alluvium, recently deposited.

Slope: About 1 percent gradient.

Physiography: Des Moines River floodplain.

Collected by Ralph McCracken in October, 1953.

Ap 0-7" Very dark gray (10YR 3/1); silt loam; friable; very weakly developed fine and medium granular structure; calcareous.

C11 7-20" Dark grayish brown (10YR 4/2) with some coatings of very dark gray (10YR 3/1); silt loam; very friable; massive structure; calcareous.

C12 20-60" Dark grayish brown (10YR 4/2) and grayish brown (10YR 5/2) with coarse mottles of pale brown (10YR 6/3); stratified silt loam and fine sandy loam; very friable; massive structure; calcareous.

Downs Silt Loam (P483)

Location: Site located in NW 1/4 SW 1/4 SW 1/4, Section 2, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit about 300 feet east of a point on north-south gravel road about 3/8 mile north of road junction.

Vegetation: Native vegetation presumed to be mixed forest and prairie grass in prairie-forest border. Present vegetation is bluegrass with numerous oak, ash, and hickory trees. Pastured but believed never to have been cultivated.

Parent material: Loess, presumably of Early Wisconsin age.

Slope and aspect: Slope gradient about 3 percent to southeast.

Physiography: Loess-mantled uplands, loess believed to be underlain by Kansan glacial till at 100 or more inches.

Collected by Ralph McCracken August 25, 1953.

Ah 0-5" Very dark grayish brown (10YR 3/2) with some coatings of very dark brown (10YR 2/2); silt loam;
friable; moderately developed medium granular structure; pH 6.6.

Ae 5-9” Dark grayish brown (10YR 4/2) with thin nearly continuous coatings of grayish brown (10YR 5/2); silt loam; friable; moderately developed medium granular structure; pH 6.4.

B1 9-12” Very dark grayish brown (10YR 3/2) with common small spots and coatings of grayish brown (10YR 5/2); silt loam; friable; weakly developed fine and medium subangular blocky structure; pH 6.5.

B21 12-15” Brown (10YR 5/3) with coatings of very dark grayish brown (10YR 3/2) on aggregate faces; silty clay loam; slightly firm; moderately developed medium subangular blocky structure; a few thin clay films; pH 6.5.

B22 15-20” Yellowish brown (10YR 5/4) with thin coatings of brown (10YR 5/3); silty clay loam; firm; moderately developed medium subangular blocky structure; a few fine soft dark concretions, presumably ferro-manganese; thin discontinuous clay films on aggregates; pH 6.6.

B23 20-25” Yellowish brown (10YR 5/4) with thin coatings of brown (10YR 4/3) and a few spots of reddish yellow (7.5YR 6/6); silty clay loam; firm; moderately developed medium and coarse subangular blocky structure; a few thin discontinuous clay films; pH 6.5.

B3 25-29” Brown (10YR 5/3) with common mottles of pale brown (10YR 6/3) and small spots of reddish yellow (7.5YR 6/6), presumably Fe segregations; silty clay loam; firm; weakly developed medium and coarse subangular blocky structure; a few thin clay films; a few fine soft dark concretions.

C11 29-36” Yellowish brown (10YR 5/4) and light yellowish brown (10YR 6/4) with common mottles of pale brown (10YR 6/3), thin coatings of dark brown (10YR 5/3) along cleavage planes which may be high in manganese (effervesces with hydrogen peroxide); silt loam; friable; massive structure; a few iron "pipestems" extend through this horizon; pH 6.6.
C12 36-60" Light brownish gray (10YR 6/2) and dark grayish brown (10YR 4/2) with mottles of reddish yellow; silt loam; friable; massive structure; common iron "pipestem"; pH 7.7.

Fayette Silt Loam (F485)

Location: Site is located in SW 1/4 NW 1/4 NE 1/4, Section 25, T. 78 N., R. 25 W., Camp Township, Polk County, Iowa. Samples taken from a pit about 200 feet east of a point of north-south gravel road about 900 feet south of the northwest corner of Section 25.

Vegetation: Native vegetation of forest, dominantly white oak and hickory. Forest has been cut-over, but area apparently has never been cleared and cultivated.

Parent material: Loess of Early Wisconsin age, presumably 100 or more inches thick over Kansan till.

Slope and aspect: Gradient of about 3 percent on gently convex east-west trending ridge.

Physiography: Convex, narrow (about 200 feet wide) ridgetop in loess-mantled terrain.

Samples taken by Ralph McCracken September, 1953.

Ah 0-4 1/2" Dark grayish brown (10YR 4/2); silt loam; friable; moderate medium granular structure; pH 5.5.

Ae 4 1/2-9 1/2" Grayish brown (10YR 5/2) with thin but nearly continuous coatings of light brownish gray (10YR 6/2); silt loam; friable; moderately developed fine and medium platy structure; pH 5.4.

B1 9 1/2-15" Yellowish brown (10YR 5/4) with thin discontinuous aggregate coatings of light brownish gray (10YR 6/2); silt loam or silty clay loam; slightly firm; weakly developed fine and medium subangular blocky structure; a few fine soft dark concretions, apparently ferro-manganese; pH 5.6.

B21 15-19" Yellowish brown (10YR 5/4) and brown (10YR 5/3); silty clay loam; firm; moderately developed medium subangular blocky structure, some thin discon-
tinuous clay films on aggregates; common soft fine dark concretions; pH 5.2.

B22 19-25" Yellowish brown (10YR 5/4) with thick coatings of brown (7.5YR 4/4); silty clay loam; firm; strongly developed medium subangular blocky structure; common soft fine dark concretions; rather thick nearly continuous clay films; pH 5.1.

B23 25-29" Yellowish brown (10YR 5/4) with coatings of brown (7.5YR 4/4); silty clay loam; firm; moderately developed medium subangular blocky structure; common soft fine dark concretions; thick discontinuous clay films.

B3 29-34" Brown (10YR 5/3) and dark brown (10YR 4/3) with common mottles of pale brown (10YR 6/3); silty clay loam; firm weakly developed coarse subangular blocky structure; common soft fine dark concretions; a few thin discontinuous clay films; pH 5.3.

C11 34-43" Yellowish brown (10YR 5/4) and pale brown (10YR 6/3) with common reddish yellow (7.5YR 6/6) mottles which seem to be Fe segregations; silt loam; friable; massive structure.

C12 43-60" Yellowish brown (10YR 5/4) with numerous mottles of pale brown (10YR 6/3) and of reddish yellow (6.5YR 6/6); silt loam; friable; massive structure; common Fe "pipestems"; pH 5.5.

Flagler* Sandy Loam (P491)

Location: Site located in NE 1/4 NW 1/4 SW 1/4, Section 12, T. 79 N., R. 25 W., Webster Township, Polk County, Iowa. Samples taken from a pit about 200 feet west of the Pioneer Hybrid Company laboratory building.

Vegetation: Native vegetation presumed to have been prairie grasses; now farmed intensively in corn-small grain-meadow rotation.

Parent material: Late Wisconsin glacial outwash.

Slope: Gradient of 3 percent to west.
Physiography: Nearly level outwash plain adjacent to Beaver Creek.

Samples taken by Ralph McCracken in October, 1953.

**Ap 0-8"** Very dark grayish brown (10YR 3/2) with coatings of very dark brown (10YR 2/2); sandy loam; very friable; weakly developed coarse granular structure; pH 6.1.

**AB 8-12"** Very dark grayish brown (10YR 3/2); sandy loam; very friable; very weakly developed coarse granular structure; pH 5.8.

**B1 12-19"** Dark brown (10YR 3/3 and 7.5YR 3/2); sandy loam; very friable; very weakly developed coarse subangular blocky structure.

**B2 19-25"** Dark brown (7.5YR 3/2 and 10YR 3/3); sandy loam; very friable; weakly developed coarse subangular blocky structure; pH 6.1.

**B3 25-30"** Very dark grayish brown (10YR 3/2) with coatings of dark brown (7.5YR 3/2 and 10YR 3/3) with some spots of brown (10YR 5/3); sandy loam; very friable; single grain structure.

**C1 30-44"** Brown (10YR 5/3) and pale brown (10YR 6/3); sandy loam or loamy sand; very friable and loose; single grain structure; pH 6.3.

**C12 44-60"** Pale brown (10YR 6/3) and light yellowish brown (10YR 6/4) with some reticulate mottles and faintly developed bands of strong brown (7.5YR 5/6) and yellowish brown (10YR 5/6) which seem to be concentrations of Fe; sandy loam or loamy sand; loose; single grain structure; pH 6.2.

**Gara Loam (P497)**

Location: Site located in SW 1/4 NW 1/4 NW 1/4, Section 15, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit about 250 feet east of a point on north-south gravel road about 300 feet north of cemetery.

Vegetation: Native vegetation assumed to be mixed trees and prairie grasses in prairie-forest border. Present vegetation
is bluegrass with scattered trees, used for pasture but apparently never cultivated.

Parent material: Kansan glacial till, underlain by Des Moines shale (Pennsylvanian) approximately 5 feet below surface.

Slope and aspect: Gradient is 9 percent to north along small intermittent stream.

Physiography: Uplands, on slope topographically below loess mantle on ridgetop.

Collected by Ralph McCracken and Lothlor Grant on July 31, 1953.

Ap 0-8" Dark grayish brown (10YR 4/2); loam; friable; weakly developed medium granular structure; pH 5.6.

Ae 8-11" Dark grayish brown (10YR 4/2) with numerous thin coatings of light brownish gray (10YR 6/2); loam; friable; very weakly developed coarse platy structure which readily breaks to weakly developed medium granular structure; pH 5.4.

B1 11-14" Dark grayish brown (10YR 4/2) and dark yellowish brown (10YR 4/4) with some coatings of light brownish gray (10YR 5/2); clay loam; firm; weakly developed fine and medium subangular blocky structure; pH 5.4.

B21 14-19" Brown (10YR 4/3) and yellowish brown (10YR 5/4); clay loam; firm; moderately developed fine and medium subangular blocky structure; pH 4.9.

B22 19-24" Yellowish brown (10YR 5/4) with some coatings of brown (7.5YR 4/4); clay loam or silty clay; very firm; moderately developed medium subangular blocky structure; pH 4.6.

B3 24-30" Yellowish brown (10YR 5/4) with common coarse mottles of brownish yellow (10YR 6/6); clay loam or silty clay; very firm; weakly developed coarse subangular blocky structure.

C1 30-40" Brown (10YR 5/3), pale brown (10YR 6/3) and dark grayish brown (10YR 4/2); clay loam or silty clay loam; firm; massive structure; common soft medium-size dark concretions apparently ferro-manganese; pH 4.8.
C12 40-60" Colors as in above horizon but with common coarse mottles of strong brown (7.5YR 5/6); clay loam or silty clay loam; firm; massive; common shale fragments; pH 4.8.

Gilbert® Loam (P496)¹

Location: Site located in NE 1/4 NW 1/4 NE 1/4 Section 15, T. 81 N., R. 25 W., Madison Township, Polk County, Iowa. Samples taken from fresh cut made for gravel pit.

Vegetation: Native vegetation assumed to have been prairie grasses; area farmed intensively for corn and soybeans prior to opening of gravel pit in 1953.

Parent material: Late Wisconsin glacial outwash, with loamy "overburden".

Slope: About 1 percent gradient to west.

Physiography: Late Wisconsin glacial outwash terrace along Big Creek.

Collected by Ralph McCracken October 9, 1953.

Ap 0-9" Very dark gray (10YR 3/1) and very dark grayish brown (10YR 3/2); loam; friable; weakly developed fine and medium granular structure; pH 5.6.

AB 9-13" Very dark brown (10YR 2/2) with coatings of very dark gray (10YR 3/1); loam; friable; weakly developed medium and coarse granular structure; diffuse transition to next lower horizon; pH 5.8.

B1 13-17" Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1) which are more prominent in upper part of horizon; loam; friable; weakly developed medium and coarse subangular blocky structure; pH 5.7.

B21 17-21" Very dark and dark grayish brown (10YR 3/2-4/2), with a few coarse mottles of very dark gray

¹An alternative classification is as depth phase of Kato series.
(10YR 3/1); loam; friable; weakly developed medium and coarse subangular blocky structure; pH 5.7.

B2g 21-24" Very dark and dark grayish brown (10YR 3/2-4/2); loam with some gravel; friable; weakly developed coarse and medium subangular blocky structure; pH 5.5.

B3 24-28" Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3); gravelly sandy loam; very friable; very weakly developed coarse subangular blocky structure; pH 5.4.

D1 28-42" Dark brown (10YR 3/3) with some stains of brown (10YR 4/3) on pebbles and sand grains; gravelly loamy sand; loose; single grain structure; pH 5.6.

D2 42-96" Yellowish brown (10YR 5/4) and light brownish gray (10YR 6/2); stratified sands and gravel; a few pebbles are calcareous below 48 inches depth; pH 7.1.

Glencoe Silty Clay Loam

Parent material: Translocated material from Cary till and Cary till.

Native vegetation: Prairie.

Profile summary:
Ah 0-20" Black, granular, silty clay loam.
B2g 20-33" Olive gray, weakly blocky, silty clay.
Cg 33-45"+ Olive gray, massive, silty clay loam.

Gosport Silt Loam

Parent material: Des Moines shale.

Native vegetation: Forest

Profile summary:
Ah 0-3" Very dark grayish brown, weakly granular, silt loam.
Ae 3-6" Grayish brown, weakly granular, silt loam.

BC 15-30" Yellowish brown, weakly blocky, silty clay loam or silty clay.

C 30-36" Yellowish brown-brownish gray, massive, silty clay loam or silty clay with many shale fragments.

Gravity Silty Clay Loam

Parent material: Slope-wash in region of loess-derived soils formed under prairie.

Native vegetation: Prairie.

Profile summary:

Ah 0-15" Very dark grayish brown, weakly granular, silty clay loam.

B 15-36" Dark grayish brown, weakly blocky, silty clay loam.

C 36-45"+ Dark grayish brown-gray, massive, silty clay loam.

Harpster Loam (P476)

Location: Site is located in SE 1/4 SW 1/4 SW 1/4 SE 1/4 Section 7, T. 81 N., R. 24 W., Lincoln Township, Polk County, Iowa. Samples taken from pit located about 150 feet north of east-west gravel road.

Vegetation: Native vegetation assumed to be some type of moisture-loving prairie grass; present vegetation is bluegrass pasture.

Parent material: Late Wisconsin (Cary) glacial till.

Slope: About 1 percent gradient.

Physiography: Edge of slight depression in Late Wisconsin till plain.

Collected by Ralph McCracken, September 23, 1953.
Ah 0-6" Gray (10YR 5/1); loam; very friable; moderately developed fine and medium granular structure; highly calcareous.

Ah₂ 6-11" Dark gray (10YR 4/1); loam; very friable; moderate fine granular structure; highly calcareous.

B₁ 11-16" Dark gray (10YR 4/1) with common coarse mottles of grayish brown (2.5Y 5/2); loam; slightly firm; weakly developed coarse subangular blocky structure readily breaking to fine and medium granular structure; calcareous.

B₂₁ 16-21" Grayish brown (2.5Y 5/2); loam; slightly firm; weakly developed coarse subangular blocky structure breaking to granular structure; calcareous.

B₂₂ 21-25" Olive gray (5Y 5/2) with a few mottles of pale olive (5Y 6/3); loam; slightly firm; weakly developed coarse subangular blocky structure; calcareous.

B₃ 25-28" Pale olive (5Y 6/3) with a few fine mottles of strong brown (7.5YR 5/6); loam; slightly firm; very weakly developed coarse subangular blocky structure; calcareous.

C₁ 28-38" Pale olive (5Y 6/3) with a few mottles of strong brown (7.5YR 5/6); loam; slightly firm; massive structure; common calcium carbonate concretions 5-10 mm. in diameter.

C₂ 38-50" Pale olive (5Y 6/3) with common coarse mottles of strong brown (7.5YR 5/6); loam; friable; massive structure; common calcium carbonate concretions, and a few soft dark concretions, apparently of ferro-manganese.

Huntsville* Loam (P477)

Location: Site located in NW 1/4 SW 1/4 Section 30, T. 81 N., R 22 W., Washington Township, Polk County, Iowa. Samples taken from pit about 300 feet west-northwest of a point which is 300 feet north of Skunk River bridge on gravel road in this area.

Vegetation: Scattered trees, shrubs, bluegrass.
Parent material: Alluvium recently deposited by Skunk River.

Slope: Nearly level, with some microrelief due to levees and sloughs along former stream channel meanders.

Physiography: Floodplain of Skunk River.

Collected by Ralph McCracken on July 24, 1953.

Ah 0-5" Very dark gray (10YR 3/1); loam; friable; moderately developed fine and medium granular structure.

AB 6-12" Very dark gray (10YR 3/1) and very dark grayish brown (10YR 3/2); loam; friable; weakly developed medium granular structure.

BC 12-19" Very dark grayish brown (10YR 3/2); loam; very weakly developed medium and coarse subangular blocky structure.

Cl1 19-34" Very dark and dark grayish brown (10YR 3/2 and 4/2); loam; very friable; massive structure.

Cl2 34-56" Very dark gray (10YR 3/1) and dark grayish brown (10YR 4/2); loam with a few thin lenses of sandy loam and sand.

Huntsville Loam (P478)

This sample site was selected as representing an area in which post-Pleistocene river alluvium shows soil development approaching that of soils developed on parent materials of Late Wisconsin age.

Location: Site located in SW 1/4 NE 1/4 Section 25, T. 78 N., R. 23 W., Four Mile Township, Polk County, Iowa. Samples taken from a pit located 550 feet west of the dirt lane which extends north-south through this area and about 1,000 feet south of the Wabash Railroad.

Vegetation: Native vegetation assumed to have been shrubs and trees; presently farmed in corn-oats-meadow rotation.

Parent material: Des Moines River alluvium, post-Pleistocene.
Slope: About 1 percent gradient to south.

Physiography: Des Moines River floodplain; this area not flooded except during highest floods.

Collected by Ralph McCracken on October 5, 1953.

Ap 0-9" Very dark gray (10YR 3/1); silt loam; friable; weakly developed fine and medium granular structure.

AB 9-14" Very dark gray (10YR 3/1) with a few coarse mottles of very dark grayish brown (10YR 3/2); silt loam; friable; very weakly developed medium subsangular blocky structure which breaks readily to granular structure.

BC1 14-18" Very dark grayish brown (10YR 3/2) with thin discontinuous coatings of very dark gray (10YR 3/1); silt loam; friable; very weakly developed fine and medium subsangular blocky structure.

BC2 18-27" Very dark grayish brown (10YR 3/2) with thin discontinuous coatings of very dark gray (10YR 3/1); silt loam; friable; weakly developed medium and coarse subsangular blocky structure.

BC3 27-32" Dark and very dark grayish brown (10YR 4/2-3/2); loam; friable; very weakly developed coarse subsangular blocky structure.

C 32-60" Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3); stratified loam to fine sandy loam; very friable; massive.

Judson Silt Loam

Parent material: Slopewash in loess-mantled region.

Native vegetation: Prairie.

Profile summary:

Ah 0-15" Very dark brown, granular, silt loam.

B 15-36" Dark brown-dark grayish brown, weakly blocky, silt loam.
C 36-45"+ Dark grayish brown–dark brown, massive silt loam.

*Kato* Silt Loam (P407)

Location: Site located in NE 1/4 SW 1/4 SW 1/4 Section 19, T. 80 N., R. 24 W., Madison Township, Polk County, Iowa. Samples taken from a pit located about 50 feet west of a point on gravel road about 1500 feet south of the north boundary of Section 19.

Vegetation: Native vegetation assumed to be prairie grasses; present use is in corn-oats-meadow rotation.

Parent material: Late Wisconsin glacial outwash with loamy upper portion.

Slope: About 1 percent gradient to west.

Physiography: Late Wisconsin glacial outwash terrace along Des Moines River; this is higher terrace level, about 30 feet above floodplain level.

Collected by Dean Einspahr and Ralph McCracken on November 20, 1951.

Ah 0-12" Very dark brown (10YR 2/2); silt loam; friable; weakly developed medium granular structure; pH 6.8.

B1 12-20" Very dark grayish brown (10YR 3/2) with a few spots and mottles of very dark gray (10YR 3/1); silt loam; slightly firm; weakly developed medium granular structure; pH 6.5.

B2 20-32" Very dark grayish brown (10YR 3/2); loam; firm; weakly developed medium and coarse granular structure; pH 6.6.

C11 32-45" Dark brown (10YR 4/3); loam; slightly firm; massive structure; pH 6.4.

C12 45-52" Dark brown (10YR 4/3) and dark grayish brown (10YR 4/2) with some coarse mottles of strong brown (7.5YR 5/6); loam; firm; massive structure; pH 6.0.
D 52-60" Dark brown (10YR 4/3); coarse sandy loam and loamy sand; friable; single grain structure; pH 5.4.

Kato-Silt Loam (P406)

Location: Site located in NE 1/4 SW 1/4 SW 1/4 Section 34, T. 81 N., R. 25 W., Union Township, Polk County, Iowa.

Vegetation: Native vegetation assumed to be prairie grasses, now used intensively for corn and soybeans.

Parent material: Mankato glacial outwash or recent river alluvium.

Slope: Gradient of 1 percent on undulating surface.

Physiography: Low terrace along Des Moines River.

Collected by Dean Einspahr and Ralph McCracken on November 19, 1951.

Ah 0-16" Very dark gray (10YR 3/1); silt loam; firm; moderately developed medium granular structure; pH 5.9.

B1 16-22" Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1); silt loam; firm; weakly developed medium and coarse granular structure; pH 5.7.

B2 22-36" Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3); loam; firm; very weakly developed subangular blocky structure; pH 5.8.

C11 36-45" Dark grayish brown (10YR 4/2); loam; friable; massive structure; pH 5.9.

C12 46-60" Brown (10YR 4/3); loam; friable; massive structure; pH 6.0.

D 60-72" Brown (10YR 4/3); sandy loam and loamy sand.
Ladoga Silt Loam (P475)

Location: Site is located in NW 1/4 NE 1/4 SW 1/4 Section 31, T. 78 N., R. 25 W., Bloomfield Township, Polk County, Iowa. Samples taken from a pit about 1/4 mile south of the bluffs above Raccoon River floodplain and about 1/4 mile southwest of dam at Des Moines Waterworks Reservoir, about 150 feet east of the Waterworks Reservoir park boundary and 200 feet south of east-west gravel road.

Vegetation: Native vegetation assumed to be mixed trees and prairie grasses in prairie-forest border; present vegetation is bluegrass pasture with scattered white oak trees.

Slope: Gradient of 3 percent to east on flank of convex ridgetop.

Physiography: Loess-mantled upland, convex narrow ridgetop, at edge of dissected region along Raccoon River valley.

Collected by Ralph McCracken on August 31, 1953.

Ah 0-4" Very dark grayish brown (10YR 3/2) with coatings of very dark brown (10YR 2/2); silt loam; very friable; weakly developed medium granular structure; pH 6.5.

Ae 4-8" Dark grayish brown (10YR 4/2) with thin nearly continuous coatings and seams of grayish brown (10YR 5/2); silt loam; friable; weakly developed medium granular structure; pH 6.1.

B1 8-13" Dark brown (10YR 3/3) with thin discontinuous coatings of grayish brown (10YR 5/2); silt loam; friable; weakly developed fine and medium granular structure; pH 6.0.

B21 13-17" Yellowish brown (10YR 5/4) with some coatings of brown (10YR 4/3) and a few thin coatings and seams of grayish brown (10YR 5/2); silty clay loam; firm; moderately developed medium subangular blocky structure; pH 5.9.

B22 17-22" Yellowish brown (10YR 5/4) with some thin coatings of brown (10YR 4/3); silty clay loam; firm; moderately developed medium subangular blocky structure; thin nearly continuous clay films on most structural faces; pH 5.8.
B23 22-29"  Yellowish brown (10YR 5/4) with some coatings of brown (10YR 4/3); silty clay loam; firm; moderately developed medium and coarse subangular blocky structure; some thin discontinuous clay films; a few fine soft dark concretions, apparently ferro-manganese; pH 5.6.

B3 29-36"  Light yellowish brown (10YR 6/4) and yellowish brown (10YR 5/4) with some coatings of brown (10YR 4/3); silty clay loam; firm; moderately developed coarse subangular blocky structure; a few fine soft dark concretions; pH 5.2.

C11 36-48"  Light yellowish brown (10YR 6/4) with discontinuous coatings of brown (10YR 4/3) and a few spots of light brownish gray (10YR 6/2); silt loam; slightly firm; massive; pH 5.3.

C12 48-60"  Light yellowish brown (10YR 6/4) with common spots and streaks of light brownish gray (10YR 6/2); silt loam; massive; pH 5.8.

Lagonda Loam

Parent material: Paleosol formed in Kansan till or translocated material from Kansan till.

Native vegetation: Prairie.

Profile summary:

Ah 0-6"  Very dark grayish brown, granular, loam-silt loam.

B 6-30"  Dark grayish brown-dark gray, blocky, silty clay.

C 30-45"+ Dark grayish brown-olive brown, massive, clay loam.

Lakeville Gravelly Loam

Parent material: Cary glacial drift.

Native vegetation: Prairie.

Profile summary:
Ah 0-6"  Dark grayish brown, weakly granular, gravelly loam.

B 6-24"  Brown, weakly blocky, gravelly loam.

C 24-36"+ Yellowish brown, loose, gravelly loam-sandy loam.

Note - Loam and sandy types also recognized.

Lamont Fine Sandy Loam

Parent material:  Wind-modified or aeolian sandy loam.

Native vegetation:  Forest.

Profile summary:

Ah 0-3"  Dark grayish brown, weakly granular, fine sandy loam.

Ae 3-9"  Grayish brown-gray, weakly granular, fine sandy loam.

B 9-27"  Yellowish brown, very weakly blocky, fine sandy loam-loam.

C 27-42"  Yellowish brown, massive, fine sandy loam.

LeSueur Silt Loam (P489)

Location:  Site is pit located in NW 1/4 NE 1/4 SW 1/4 Section 21, 300 feet north and 250 feet east of junction of Iowa route 60 and county gravel road.  T. 80 N., R. 24 W., Crocker Township, Polk County, Iowa.

Vegetation:  Presently cultivated in corn-oats-meadow; original vegetation is prairie-forest transition.

Parent material:  Cary glacial till.

Slope:  Two percent gradient to east.

Physiography:  Cary till plain, near large reservoir.

Collected by Ralph McCracken on October 1, 1953.
Ap 0-8" Dark gray (10YR 4/1) with spots and coatings of very dark gray (10YR 3/1); silt loam; friable; moderately developed medium granular structure.

Ae 8-11" Dark gray (10YR 4/1) with very dark gray (10YR 3/1) coatings; silt loam; friable; weakly developed medium granular structure.

AB 11-15" Color and coatings as above; silty clay loam; friable; very weak fine subangular blocky structure; few fine soft dark concretions.

B1 15-19" Dark grayish brown (10YR 4/2) with nearly continuous thin coatings of very dark grayish brown (10YR 3/2) and a few thin coatings of dark gray (10YR 4/1); silty clay loam; slightly firm; weakly to moderately developed fine subangular blocky structure; a few fine soft dark concretions.

B2 19-24" Dark grayish brown (10YR 4/2) with thin discontinuous coatings of very dark grayish brown (10YR 3/2) and a few fine mottles of pale brown (10YR 6/3) and light yellowish brown (10YR 6/4); clay loam; firm; moderately developed medium subangular blocky structure; a few thin discontinuous clay films.

B2 24-29" Dark grayish brown (10YR 4/2) and (2.5Y 4/2) and light brownish gray (10YR 6/2) with common fine mottles of strong brown (7.5YR 5/6); clay loam; firm; moderately developed medium subangular blocky structure; common soft fine dark concretions.

B3 29-35" Dark grayish brown (10YR 4/2) and (2.5Y 4/2) and light brownish gray (2.5Y 6/2) with a few medium mottles of strong brown (7.5YR 5/6); clay loam; firm; weakly developed coarse subangular blocky structure.

C1 35-41" Light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/4); clay loam; firm; massive; a few fine soft dark concretions.

C2 41-60" Light brownish gray (2.5Y 6/2), light yellowish brown (2.5Y 6/4), and olive yellow (2.5Y 6/6); clay loam; friable to slightly firm; massive; calcareous.
Marshan* Silty Clay Loam (P467)

Location: Site located in NW 1/4 NE 1/4 Section 10, T. 81 N., R. 22 W., Washington Township, Polk County, Iowa. Samples taken from a pit located 100 feet south of east-west gravel road in this area.

Vegetation: Native vegetation assumed to have been moisture-loving prairie grasses; present use is bluegrass pasture though believed to have been cultivated in the past.

Parent material: Late Wisconsin glacial outwash with some overburden.

Slope: Gradient of 1/2 percent on side of slight depression.

Physiography: Slightly depressional area in Late Wisconsin low outwash terrace along Indian Creek.

Collected by Ralph McCracken October 7, 1953.

Ah 0-13" Black (10YR 2/1); silty clay loam; firm; moderately developed medium and fine granular structure; pH 6.2.

AB 13-17" Black (10YR 2/1); silty clay loam; firm; very weakly developed medium subangular blocky structure which breaks readily to medium granular structure; pH 6.6.

B61 17-22" Very dark grayish brown (2.5Y 3/2) with thick continuous coatings of black (10YR 2/1); silty clay loam; firm; weakly developed medium subangular blocky structure; pH 6.8.

Bg2 22-27" Very dark grayish brown (2.5Y 3/2) with thin discontinuous coatings of black (10YR 2/1); silty clay loam; firm; weakly developed medium subangular blocky structure; pH 6.9.

Bg3 27-31" Very dark grayish brown (2.5Y 3/2) and olive gray (5Y 4/2) with thin discontinuous coatings of black (10YR 2/1); silty clay loam or clay loam; firm; very weakly developed coarse and medium subangular blocky structure; pH 7.1.

Gg 31-40" Olive gray (5Y 4/2) and light olive brown (2.5Y 5/6); gravelly clay loam; firm; massive structure;
pH 7.2.

**D 40-54"** Light olive brown (2.5Y 5/6), yellowish brown (10YR 5/6) and dark olive gray (5Y 3/2); gravelly sandy loam; very friable and loose; single grain structure; pH 7.4.

**Marshall Silty Clay Loam,**
24-30" to sand and gravel (P492)

**Location:** Site located in NE 1/4 NE 1/4 NE 1/4 Section 10, T. 81 N., R. 22 W., Washington Township, Polk County, Iowa. Samples taken from a pit located about 50 feet southwest of the northeast corner of Section 10.

**Vegetation:** Native vegetation assumed to have been moisture-loving prairie grasses; present use is bluegrass pasture which may have been cultivated at one time.

**Parent material:** Late Wisconsin glacial outwash with some overburden.

**Slope:** About 1 percent gradient to west.

**Physiography:** Slightly depressional area in Late Wisconsin outwash terrace along Indian Creek.

**Collected by Ralph McCracken October 7, 1953.**

**Ah 0-13"** Black (10YR 2/1); silty clay loam; firm; moderately developed medium granular structure; very diffuse boundary to next lower horizon; pH 6.7.

**AB 13-16"** Black (10YR 2/1); silty clay loam or clay loam; firm; weakly developed medium subangular blocky structure which breaks readily to medium granular structure; pH 6.2.

**Bg1 16-21"** Very dark grayish brown (2.5Y 3/2) with thick continuous coatings of black (10YR 2/1); clay loam; weakly developed medium and coarse subangular blocky structure; pH 6.5.

**Bg2 21-24"** Very dark grayish brown (2.5Y 3/2) with thin but nearly continuous coatings of black (10YR 2/1) with a few faint mottles of light olive brown (2.5Y 5/4); gravelly clay loam; firm; weakly
developed medium and coarse subangular blocky structure; pH 6.5.

Bg3 24-27" Very dark grayish brown (2.5Y 3/2) with a few thin coatings of black (10YR 2/1); gravelly loam; slightly firm; very weakly developed coarse subangular blocky structure; pH 6.1.

Cg 27-30" Very dark grayish brown (2.5Y 3/2) and light olive brown (2.5Y 6/4) with common spots of brownish yellow (10YR 6/6); gravelly loam; slightly firm; massive structure; a few fine soft dark concretions; pH 6.3.

D 30-48" Olive (5Y 5/3) and dark grayish brown (2.5Y 4/2) with common spots of brownish yellow (10YR 6/6) which seem to be iron segregations; gravelly sandy loam; friable; single grain structure; a few fine soft dark ferro-manganese concretions; pH 6.5.

Muscatine Silt Loam (P474)

Location: Site located in NE 1/4 NW 1/4 Section 1, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit on ridgetop about 250 feet south of Highway 163.

Vegetation: Native vegetation assumed to be prairie grasses; present use is in corn-oats-red clover rotation.

Parent material: Early Wisconsin (?) loess.

Slope: About 2 percent gradient on slightly convex ridgetop about 500 feet wide.

Physiography: Ridgetop, slightly convex and about 500 feet wide, in loess-mantled landscape. Loess assumed to be 100 or more inches thick over Kansas till.

Collected by J. F. Corliss and Ralph McCracken September 24, 1953.

Ah 0-14" Very dark gray (10YR 3/1); silt loam or silty clay loam; slightly firm; moderately developed medium and fine granular structure; pH 5.4.

AB 14-18" Very dark grayish brown (10YR 3/2) with thick continuous coatings of very dark gray (10YR 3/1);
silty clay loam; slightly firm; moderately developed medium and fine granular structure; pH 5.7.

B1 18-22" Very dark grayish brown (10YR 3/2) with thin discontinuous coatings of very dark gray (10YR 3/1); silty clay loam; weakly developed medium subangular blocky structure which breaks readily to granular structure; pH 5.7.

B21 22-26" Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3); silty clay loam; firm; weakly developed fine and medium subangular blocky structure; a few thin discontinuous clay films; a few fine soft dark concretions, apparently ferro-manganese; pH 5.8.

B22 23-29" Brown (10YR 4/3) and very dark grayish brown (10YR 3/2); silty clay loam; firm; weakly developed fine and medium subangular blocky structure; thin discontinuous clay films; a few fine soft dark concretions; pH 5.6.

B3 29-34" Dark brown (10YR 4/3) with common mottles of pale brown (10YR 6/3) and a few mottles of strong brown (7.5YR 5/6); silty clay loam; firm; weakly developed medium and coarse subangular blocky structure; a few fine soft dark concretions; pH 5.6.

C11 34-45" Yellowish brown (10YR 5/4) with common mottles of pale brown (10YR 6/3) and strong brown (7.5YR 5/6); silty clay loam or silt loam; slightly firm; massive structure; a few soft fine dark concretions; pH 5.9.

C12 45-56" Yellowish brown (10YR 5/4) and light yellowish brown (10YR 6/4) with common mottles of pale brown (10YR 6/3) and strong brown (7.5YR 5/6); silt loam; friable; massive; a few soft fine dark concretions; pH 6.0.

C13 56-80" As above horizon, but fewer strong brown mottles and fewer dark concretions; pH 6.1.
**Nicollet Loam (P472)**

**Location:** Site located in SW 1/4 SW 1/4 Section , T. 80 N., R. 24 W., Crocker Township, Polk County, Iowa. Samples taken from pit in field about 250 feet east and 50 feet north of Highway 60.

**Vegetation:** Native vegetation assumed to be prairie grasses; presently intensively used for corn and soybean production with some small grain and meadow.

**Parent material:** Gary glacial till.

**Slope:** Gradient of 2 percent to north.

**Physiography:** Undulating Gary till plain.

**Collected by Ralph McCracken September 29, 1953.**

**Ah 0-13"** Very dark gray (10YR 3/1); loam; friable; moderately developed medium granular structure; pH 6.2.

**AB 13-17"** Very dark grayish brown (10YR 3/2) with coatings of very dark gray (10YR 3/1); loam; friable; very weakly developed medium and fine subangular blocky structure readily breaking to granular structure; pH 5.9.

**B21 17-23"** Very dark grayish brown (10YR 3/2) with thin discontinuous coatings of very dark gray (10YR 3/1); loam; slightly firm; weakly developed fine and medium subangular blocky structure; pH 6.2.

**B22 23-30"** Very dark and dark grayish brown (10YR 4/2-3/2) with a few spots of brown (10YR 4/3) and some thin discontinuous coatings of very dark gray (10YR 3/1); loam; slightly firm; weakly developed fine and medium subangular blocky structure; slight concentration of gravel noted in this horizon; pH 6.9.

**B3 30-33"** Brown (10YR 4/3) with mottles and coatings of very dark grayish brown (10YR 3/2) with some spots of yellowish brown (10YR 5/4); loam; slightly firm; very weakly developed medium and coarse subangular blocky structure; pH 6.8.
Cl 33-40"  Yellowish brown (10YR 5/4) with a few spots of pale brown (10YR 6/3) a few coarse mottles of strong brown (7.5YR 5/6); loam; slightly firm; massive; pH 7.0.

C2 40-60"  Brown (10YR 5/3) and yellowish brown (10YR 5/4) with common coarse mottles of strong brown (7.5YR 5/6); loam; friable; massive structure; calcareous with common small (about 1 mm. diameter) calcium carbonate concretions; pH 8.0.

Rolfe Loam

Parent material: Cary till.

Native vegetation: Prairie.

Profile summary:
Ah 0-6"  Black, granular, loam.
Ae 6-12"  Gray, granular-platy, loam.
Bg 12-33"  Dark gray-olive gray, blocky, silty clay-loam.
C 33-45"+  Olive gray, massive, clay loam.

Runnells* Silt Loam (P489)

Location: Site at SE 1/4 NW 1/4 NE 1/4 Section 13, T. 78 N., R. 23 W., Camp Township, Polk County, Iowa. Profile site is 300 feet south of cemetery in this vicinity, 25 feet west of fence along gravel road.

Vegetation: At the time of sampling was scattered white oaks and grass, used as pasture; original native vegetation presumed to be forest, dominantly white oak and hickory.

Slope: Site had slope of 8 percent gradient to south.

Physiography: Loess-mantled dissected uplands.

Parent material: Loess about 18 inches thick over material presumed to be Kansan till remnant about 15 inches thick over weathered Des Moines shale.
Collected by Ralph McCracken September 10, 1953.

1Ah 0-5" Very dark gray (10YR 3/1) with some coatings and spots of very dark grayish brown (10YR 3/2); silt loam; friable; moderate fine and medium granular structure; pH 6.2.

1Ae 5-9" Dark grayish brown (10YR 4/2) with numerous coatings and spots of grayish brown (10YR 5/2); silt loam; friable; weak fine to medium platy structure; pH 6.1.

1B1 9-13" Dark brown (10YR 3/3) with common coatings of dark grayish brown (10YR 4/2); silt loam to silty clay loam; slightly firm; weak medium subangular blocky structure; pH 5.8.

2B2 13-18" Brown (10YR 5/3) with a few coatings and spots of dark grayish brown (10YR 4/2); "light" silty clay loam; firm; moderate medium subangular blocky structure; a few fine soft dark concretions apparently ferro-manganese; a few thin clay films on aggregates; pH 5.7.

2B22 18-23" Yellowish brown (10YR 5/4) with thin aggregate coatings of dark brown (7.5 YR 4/3); silty clay loam or clay loam; firm; moderate to strong medium subangular blocky structure; a few fine soft concretions; clay films on aggregates common; pH 5.3.

2B3 23-35" Dark brown (7.5YR 4/4) with some coatings of brown (10YR 4/3); clay loam; firm; moderate to strong coarse subangular blocky structure; some discontinuous clay films on aggregates; pebbles 1/2 to 1 inch in diameter common; pH 5.4.

D 35-48" Dark yellowish brown (10YR 4/4) and brown (7.5YR 4/4) with thick coatings of pale brown (10YR 6/3) and with spots of yellowish red (5YR 5/4); silty clay; massive structure with irregular cleavage; presumed to be weathered shale; pH 5.4.

Sarpy Loamy Sand

Parent material: Fresh Des Moines River alluvium.
Native vegetation: Mixed grasses, shrubs, trees.

Profile summary:

Ah 0-6" Grayish brown, loose, loamy sand.
C 6-36"+ Yellowish brown-gray, loose, loamy sand.

Sawmill* Silty Clay Loam (P494)

Location: Site located in NW 1/4 SW 1/4 Section 22, T. 78 N., R. 23 W., Allen Township, Polk County, Iowa. Samples taken from a pit located 200 feet south and 25 feet east of road junction in this area.

Vegetation: Marsh grasses. This area has never been cultivated.

Parent material: Des Moines River alluvium.

Slope: Nearly level area, a filled-in former "oxbow" pond.

Physiography: This site is nearly a half-mile from present Des Moines River channel and is site of former oxbow or cut-off meander which has been filled. Water "backs up" into this area only during highest floods.

Collected by Ralph McCracken October 5, 1953.

1. 0-8" Very dark grayish brown (10YR 3/2) and black (10YR 2/1) with some fine mottles of yellowish red (5YR 4/6); silty clay loam; firm; very weakly developed coarse subangular blocky structure; a few calcareous snail shell fragments; pH 7.3.

2. 8-16" Very dark gray (2.5Y 3/2) and black (5Y 2/1) with common fine mottles of yellowish red (5YR 4/6); silty clay loam; firm; massive structure; pH 7.2.

3. 16-54" Very dark grayish brown (2.5Y 3/2) and very dark gray (5Y 3/1); silty clay loam; firm; massive structure; pH 7.6.
Saylor* Fine Sandy Loam (P473)

Location: Site located in NW 1/4 NE 1/4 Section 12, T. 79 N., R. 25 W., Webster Township, Polk County, Iowa. Samples taken from a pit about 150 feet east of Pioneer Hybrid Chick Research Building and about 50 feet south of Highway 60.

Vegetation: Native vegetation presumably prairie grasses; present vegetation mixed legumes and grass, has been cultivated.

Parent material: Late Wisconsin glacial outwash.

Slope: Gradient of about 1/2 percent on side of slight depression.

Physiography: Slight depression in Late Wisconsin glacial outwash plain, along Beaver Creek.

Collected by Ralph McCracken September 24, 1953.

Ah 0-11" Very dark gray (10YR 3/1); fine sandy loam; very friable; weakly developed fine and medium granular structure; pH 6.4.

AB 11-16" Very dark brown (10YR 2/2) with thin continuous coatings of very dark gray (10YR 3/1); fine sandy loam; very friable; weakly developed medium and coarse granular structure; pH 5.7.

B21 16-21" Very dark gray (10YR 3/1) with common mottles of very dark grayish brown (10YR 3/2); fine sandy loam; very friable; very weakly developed medium subangular blocky structure readily breaking to granular structure; pH 5.8.

B22 21-26" Dark brown (7.5YR 3/2) with a few fine mottles of strong brown (7.5YR 5/6); fine sandy loam; very weakly developed coarse subangular blocky structure; pH 5.8.

B3 26-31" Dark brown (10YR 3/3) and very dark grayish brown (10YR 3/2) with a few fine mottles of strong brown (7.5YR 5/6); fine sandy loam to sandy loam; very friable; single grain structure; a few fine soft dark concretions, apparently ferro-manganese; pH 5.8.
**C11 31-43"** Brown (10YR 4/3-5/3) with mottles of very dark grayish brown (10YR 3/2) and a few fine mottles of strong brown (7.5YR 5/6); sandy loam; loose; single grain structure; a few fine soft dark concretions; pH 6.4.

**C12 43-60"** Pale brown (10YR 6/3) and brown (10YR 5/3) with highly contrasting coarse mottles of strong brown (7.5YR 5/6) which show some tendency towards horizontal bands; sandy loam; loose; single grain structure; pH 6.0.

**Sharpsburg Silt Loam (P408)**

Location: Site located in NE 1/4 SE 1/4 SW 1/4 Section 26, T. 78 N., R. 25 W., Bloomfield Township, Polk County, Iowa. Samples taken from a pit 1,000 feet north and 75 feet west of the road junction on the south section line.

Vegetation: Native vegetation assumed to be prairie grasses, dominantly big bluestem; present use is in corn-soybean-oats-meadow sequence.

Parent material: Loess, presumably Early Wisconsin from Missouri River source.

Slope: Gradient of about 3 percent to west.

Physiography: Slightly convex ridgetop about 1,000 feet wide in loess-mantled region, presumably underlain by Kansan till at 100 or more inches in depth below surface.

Collected by Dean Einspahr and Ralph McCracken December 6, 1951.

**Ap 0-10"** Very dark grayish brown (10YR 3/2); silt loam; firm; moderately developed medium granular structure; pH 6.4.

**AB 10-13"** Very dark and dark grayish brown (10YR 3/2 and 4/2); silt loam; moderately developed medium granular structure; pH 5.2.

**Bt 13-18"** Dark brown (10YR 4/3); silty clay loam; firm; moderately developed medium granular structure; pH 5.6.
B21 18-22" Dark brown (10YR 4/3); silty clay loam; firm; moderately developed fine and medium subangular blocky structure; some thin discontinuous clay films on some aggregates; pH 5.6.

B22 22-25" Dark brown (10YR 4/3); silty clay loam; firm; moderately developed medium subangular blocky structure; thick discontinuous clay films on many aggregates; pH 5.6.

B23 25-29" Dark brown (10YR 4/3); silty clay loam; firm; weakly developed medium subangular blocky structure; thin discontinuous clay films on some aggregates; pH 5.6.

B3 29-33" Dark brown (10YR 4/3) with a few spots of light yellowish brown (10YR 6/4) and a few faint mottles of strong brown (7.5YR 5/6); silty clay loam; firm; weakly developed medium subangular blocky structure; a few thin discontinuous clay films on a few aggregates; pH 5.7.

C11 33-48" Yellowish brown and light yellowish brown (10YR 5/4-6/4) with a few faint mottles of strong brown (7.5YR 5/6); silty loam; friable; massive structure; pH 5.8.

C12 48-60" Yellowish brown (10YR 5/4) with mottles of light yellowish brown (2.5Y 6/4) and reddish yellow (7.5YR 6/6); silt loam; firm; massive structure; pH 5.9.

Shelby Loam (P468)

Location: Site located in SE 1/4 SW 1/4 Section 6, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit about 300 feet north of the south section line and about 300 feet east of a small stream flowing through this area.

Vegetation: Native vegetation assumed to be prairie grasses; present vegetation is bluegrass pasture, but has been cultivated.

Parent material: Kansan glacial till, presumably underlain by Des Moines shale at approximately 6 feet in depth below surface, as judged from nearby roadcut.
Slope: About 10 percent gradient to northwest.

Physiography: Dissected uplands, site is on slope along small stream topographically below loess-mantled ridgetop. This area is less than a mile from the southern boundary of the Late Wisconsin till plain.

Collected by Ralph McCracken September 21, 1953.

Ap 0-7" Very dark grayish brown (10YR 3/2) with thin coatings of very dark brown (10YR 2/2); loam; friable; moderately developed medium and coarse granular structure; pH 5.3.

B1 7-11" Very dark grayish brown (10YR 3/2) with thin coatings of very dark gray (10YR 3/1); loam; slightly firm; weakly developed medium subangular blocky structure which breaks readily to granular structure; pH 5.3.

B21 11-15" Brown (10YR 5/3) with thin discontinuous coatings of dark grayish brown (10YR 4/2); clay loam; firm; weakly developed medium to coarse subangular blocky structure; a few thin discontinuous clay films on some aggregates; pH 5.5.

B22 15-22" Brown (10YR 5/3) with thin coatings of dark grayish brown (10YR 4/2); clay loam; very firm; moderately developed medium subangular blocky structure; thin discontinuous clay films on many aggregates; pH 5.6.

C(?) 29-48" Yellowish brown and light yellowish brown (10YR 5/4-6/4) with common fine mottles of reddish yellow (6.5YR 6/6); clay loam; firm; massive structure; a few fine dark concretions; pH 6.2.

Storden Loam

Parent material: Cary till.

Native vegetation: Prairie.

Soil profile summary:

Ah 0-6" Dark grayish brown, weakly granular, loam.

C 6-36" Yellowish brown, massive, loam.
Tama Silt Loam (P482)

Location: Site located in Se 1/4 SW 1/4 Section 1, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit about 500 feet west and 100 feet north of road junction at midpoint of south section line.

Vegetation: Native vegetation assumed to have been prairie grasses, dominantly big bluestem; present use is for corn-oats-red clover rotation.

Parent material: Early Wisconsin loess, dominant source may have been from Early Wisconsin till plain to north.

Slope: Gradient of 5 percent to south.

Physiography: Loess-mantled upland of undulating and hilly slopes.

Collected by Ralph McCracken August 8, 1956.

Ap 0-9" Very dark brown (10YR 2/2); silt clay loam; friable; moderately developed medium granular structure; pH 5.6.

B1l 9-13" Brown (10YR 4/3) with thin nearly continuous coatings of very dark brown (10YR 2/2); silt clay loam; friable; weakly developed medium granular structure; pH 5.6.

B12 13-17" Brown (10YR 4/3) with thin coatings of very dark greyish brown (10YR 3/2) and of very dark brown (10YR 2/2); silty clay loam; slight firm; weakly developed medium subangular blocky structure; a few thin discontinuous clay films; pH 5.7.

B21 17-21" Brown (10YR 4/3); silty clay loam; slightly firm; weakly developed fine subangular blocky structure; thin discontinuous clay films on many aggregates; pH 5.7.

B22 21-25" Brown (10YR 4/3) with a few faint mottles of light brownish gray (10YR 6/2) and of reddish yellow (7.5YR 6/6); silty clay loam; slightly firm; moderately developed fine and medium subangular blocky structure; thin discontinuous clay films on some aggregates; pH 5.9.
Brown (10YR 5/3) with common mottles of light brownish gray (10YR 6/2) and of strong brown (7.5YR 5/6); silty clay loam; slightly firm; very weakly developed coarse subangular blocky structure; a few fine soft dark concretions; pH 6.0.

Yellowish brown (10YR 5/4) and light brownish gray (10YR 6/2) with common mottles of strong brown (7.5YR 5/6); silty clay loam; slightly firm; massive structure; a few fine soft dark concretions; pH 6.1.

Yellowish brown and light yellowish brown (10YR 5/4-6/4) with common coarse mottles of strong brown (7.5YR 5/6); silt loam; friable; massive structure; pH 6.3.

Terril Loam (P488)

Location: Site located in NW 1/4 NE 1/4 SE 1/4, Section 36, T. 31 N., R. 23 W., Elkhart Township, Polk County, Iowa. Samples taken from a fresh roadcut made during road widening.

Vegetation: Native vegetation assumed to have been prairie grasses; site was in field and intensively for corn and soybeans before road widening.

Parent material: Slopewash from soils developed from Late Wisconsin glacial till.

Slope: Gradient of 3 percent to northeast.

Physiography: Gently sloping "pediment" or footslope deposit at edge of Skunk River floodplain in area of Late Wisconsin glaciation.

Collected by E. M. Richlen and Ralph McCracken October 10, 1953.

Ah 0-12" Very dark gray (10YR 3/1); loam; friable; weakly developed medium granular structure; pH 7.6.

AB 12-16" Very dark gray (10YR 3/1); loam; friable; very weakly developed medium subangular blocky structure which breaks readily to granular structure; pH 7.8.
Very dark grayish brown (10YR 3/2) with thin coatings of very dark gray (10YR 3/1); loam; friable; weakly developed fine and medium subangular blocky structure; pH 7.8.

Dark and very dark grayish brown (10YR 4/2-3/2); loam; friable; weakly developed coarse subangular blocky structure; pH 7.8.

Very dark grayish brown (10YR 3/2) with coatings and seams of very dark brown (10YR 2/2); loam; friable; massive structure.

Very dark grayish brown (10YR 4/2) with some coatings and seams of very dark brown (10YR 2/2); loam; friable; massive structure.

Wabash Silty Clay (P499)

Location: Site is located in SE 1/4 SW 1/4 NW 1/4 Section 4, T. 78 N., R. 22 W., Camp Township, Polk County, Iowa. Samples taken from a pit located about 300 feet west of Mud Creek and 100 feet north of gravel road along south section line.

Vegetation: Native vegetation assumed to have been moisture-loving grasses, also trees and shrubs; present use is for corn, oats, and some meadow in rotation.

Parent material: Alluvium, dominantly derived from soils developed from loess and to a lesser extent, Kansan till.

Slope: Level or slightly depressional.

Physiography: Floodplain of Mud Creek.

Collected by Ralph McCracken July 27, 1953.

Black (10YR 2/1) with common mottles of dark and very dark grayish brown (10YR 4/2-3/2); silty clay or silty clay loam; firm; moderately developed medium granular structure; pH 5.7.

Black (10YR 2/1 and 2/5Y 2/0) with coatings of dark gray (10YR 4/1); silty clay loam or silty clay; firm; moderately developed fine and medium granular structure; pH 6.0.
Waukegan* Silt Loam (P470)

Location: Site located in NW 1/4 NW 1/4 SW 1/4 Section 10; T. 81 N., R. 22 W., Washington Township, Polk County, Iowa. Samples taken from a pit in edge of field located about 3/4 mile south of Indian Creek and 25 feet east of the west section line and 250 feet south of the northern boundary of the southwest quarter of Section 10.

Vegetation: Native vegetation assumed to have been prairie grasses; present use is in corn-oats-meadow rotation.

Parent material: Late Wisconsin glacial outwash with loam overburden.

Slope: Gradient of 3 percent to north.

Physiography: Late Wisconsin low outwash terrace along Indian Creek.

Collected by Ralph McCracken October 13, 1953.

Ap 0-8" Very dark grayish brown (10YR 3/2) with numerous thin nearly continuous coatings of very dark
brown (10YR 2/2); silt loam; friable; moderately developed medium granular structure; pH 5.5.

**AB 3-12"**

Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) with thin nearly continuous coatings of very dark brown (10YR 2/2); silt loam; friable; weakly developed medium granular structure; pH 5.3.

**B1 12-15"**

Very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) with a few thin discontinuous coatings of very dark brown (10YR 2/2); loam or silt loam; friable; weakly developed fine and medium subangular blocky structure; pH 5.5.

**B21 15-19"**

Dark brown (10YR 3/3) with a few thin discontinuous coatings of very dark grayish brown (10YR 3/2); loam or silt loam; friable; weakly developed fine and medium subangular blocky structure; pH 5.5.

**B22 19-22"**

Dark brown (10YR 3/3) with a few thin discontinuous coatings of very dark grayish brown (10YR 3/2); loam; friable; weakly developed fine and medium subangular blocky structure; pH 5.4.

**B31 22-28"**

Dark brown (10YR 3/3); loam; friable; weakly developed fine and coarse subangular blocky structure; pH 5.2.

**B32 28-34"**

Dark brown (10YR 3/3) and yellowish brown (10YR 5/4); loam; friable; very weakly developed coarse subangular blocky structure; pH 5.1.

**C 34-40"**

Brown (10YR 4/3) and yellowish brown (10YR 5/4); fine sandy loam; very friable; massive structure; pH 5.3.

**D 40-78"**

Yellowish brown (10YR 5/6) and dark yellowish brown (10YR 4/4); stratified loamy sand and sand with some gravel; pH 5.4.

**Webster Silty Clay Loam (F466)**

**Location:** Site located in SW 1/4 SW 1/4 SW 1/4 Section 19, T. 81 N., R. 24 W., Lincoln Township, Polk County, Iowa. Samples taken from a pit 50 feet northeast of the southwest corner of Section 19.
Vegetation: Native vegetation assumed to have been moisture-loving prairie grasses; present vegetation bluegrass pasture, believed to have been cultivated at one time.

Parent material: Translocated material derived from Cary glacial till.

Slope: Gradient of 1/2 percent to northeast in slight depressional area.

Physiography: Slight depression or "swale" on Cary till plain surface.

Collected by J. F. Corliss and Ralph McCracken September 26, 1953.

Ah 0-12" Black (10YR 2/1); silty clay loam; firm; moderately developed medium and fine granular structure; pH 7.4.

AB 12-15" Black (10YR 2/1) with a few mottles of dark greyish brown (2.5Y 4/2); silty clay loam; firm; moderately developed medium granular structure; pH 7.5.

Bg1 15-20" Dark greyish brown (2.5Y 4/2) with thick, nearly continuous coatings of black (10YR 2/1); silty clay loam; firm; moderately developed medium subangular blocky structure; pH 7.6.

Bg2 20-24" Dark greyish olive grey (5Y 3/2) and some brown (2.5Y 4/2) with thin discontinuous coatings of black (10YR 2/1); silty clay loam; firm; moderately developed medium subangular blocky structure; pH 7.8.

Bg3 24-29" Olive grey (5Y 4/2-5/2) with a few thin coatings of black (10YR 2/1); silty clay loam; firm; weakly developed medium and coarse subangular blocky structure; a few fine and medium size dark concretions; pH 7.8.

Cg1 29-36" Olive grey (5Y 4/2) and light olive grey (5Y 6/2) with a few coarse mottles of strong brown (7.5YR 5/6); silty clay loam or clay loam; firm; massive; common fine and medium size dark concretions; common calcium carbonate concretions; weakly calcareous; pH 7.8.
Cg2 36-60" Olive gray (5Y 6/2) and light olive gray (5Y 6/2) with common coarse mottles of strong brown (7.5YR 5/6); calcareous but lacking the calcium carbonate concretions of horizon above this one; pH 6.0.

Zearing* Loam

Parent material: Alluvium, Skunk River floodplain.

Native vegetation: Prairie.

Profile summary:

Ah 0-15" Very dark gray, weakly granular, loam.

BC 15-24" Dark gray-dark grayish brown, weakly granular loam-clay loam.

C 24-45" Dark gray, massive, clay loam.

Zook* Silty Clay (p484)1

Location: Site located in SE 1/4 SW 1/4 Section 14, T. 81 N., R. 23 W., Elkhart Township, Polk County, Iowa. Samples taken from a pit a little more than 1/4 mile east of the west boundary of the section and 250 feet north of the south boundary of the section.

Vegetation: Native vegetation assumed to be marsh grasses; presently intensively used for corn and soybean production.

Parent material: Skunk River alluvium.

Slope: Depressional.

Physiography: This site is in a slightly depressional area in the broad Skunk River floodplain; located more than 1/4 mile west of the new man-made Skunk River channel and over a mile west of the old Skunk River channel.

1An alternative classification is with the Wabash series.
Collected by B. A. Barnes and Ralph McCracken July 14, 1953.

Ap 0-8" Black (10YR 2/1); silty clay; very firm; weakly developed coarse and medium granular structure; pH 6.6.

AB 8-14" Black (10YR 2/1) with coatings of very dark gray (2.5Y 3/1); silty clay; very firm; weakly developed medium subangular blocky structure which readily breaks to granular structure; pH 6.7.

Bg1 14-23" Black (5Y 2/1) and very dark gray (5Y 3/1); silty clay; very firm; weakly developed medium blocky structure which readily breaks to granular structure; pH 6.4.

Bg2 23-31" Very dark gray (5Y 3/1) with some thin coatings of dark gray (5Y 4/1); silty clay; very firm; very weakly developed medium subangular blocky structure; pH 6.4.

Cgll 31-38" Very dark gray (5Y 3/1) with a few mottles of olive brown (2.5Y 4/4); silty clay or clay loam; very firm; massive structure; pH 6.7.

Cg12 38-50" Very dark gray (5Y 3/1) with numerous coarse mottles of olive brown (2.5Y 4/4); silty clay; very firm; massive structure; pH 6.4.