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The genesis and morphology of some transitional Brunizem - Gray-Brown Podzolic soils

Everett M. White
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UMI®
THE GENESIS AND MORPHOLOGY OF SOME TRANSITIONAL BRUNIZEM - GRAY-BROWN PODZOLIC SOILS

by

Everett M. White

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:

Signature was redacted for privacy.

In Charge of Major Work

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Iowa State College

1953
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INTRODUCTION

Soil formation is dependent on the geologic parent material, the topography, the climate, the length of time the soil has been developing and the biological regime present during the soils formation. This study involves a change in the latter of these five factors of soil formation. However, the climatic factor may be involved since it influences the vegetative factor. The study is concerned with the soil changes which occur as prairies are invaded by deciduous forests. The problem is restricted to the biosequence formed in going from a Brunizem soil to a Gray-Brown Podzolic soil.

The problem was instigated to determine some of the steps in the genesis of the transitional Brunizem - Gray-Brown Podzolic soils and to determine which visible morphological properties should be used in their classification as is indicated by laboratory analysis.
HISTORICAL

History of the Series Classification of the "Transition Soils"

The classification of soils has developed in this country in the last half century. During this period the soil mapping units have constantly been revised as more knowledge about soils has been accumulated. The homogeneity of the members within a class and category has been increased by these revisions.

The Brunizem and Gray-Brown Podzolic soils were included in the Miami series in the Dubuque Area, 1902, (9)* which was the first soil survey in Iowa. The Miami series was later redefined and the Marshall series was established for the Brunizem soils (59). In the Dubuque County soil survey of 1920 (61), neither the Miami or Marshall series were used. The Brunizem and Gray-Brown Podzolic soils were divided into several different series. A unit, Tama silt loam, light colored phase, was used for the prairie-forest transition soils. This soil would now be included in the Downs series (46). The Downs series appears in the Tama County soil survey report of 1938 (1).

*Numbers in parenthesis refer to literature cited.
The transitional soils which occurred as narrow areas between the Brunizem and the Gray-Brown Podzolic soils apparently were included in series of both these Great Soil Groups. The Carrington and Tama soils were described by Brown (5) as being lighter colored than typical when they were in areas of forested soils. He describes Fayette silt loam as being darker in color on the more level areas and Clinton silt loam as being darker colored when associated with Tama and Muscatine soils but lighter colored when adjacent to Marion soils. The Calhoun series as mapped in Clark County, Iowa, (33), 1923, was a soil formed under trees, however, "... other small bodies too inextenisive to map were included, especially bordering the upland slopes, where the surface soil has a darker color."

Kellogg (20) in Wisconsin recognized the existence of these transitional soils. He states, "Although a few areas may be seen which represent transitional belts between the Prairie soils and those of other groups, in general the lines of demarcation are quite sharply drawn." He included the Miami series with Gray-Brown Forest soils although it had a darker surface than normal. Kellogg recognized the Thurston series as being an intrazonal soil between the Gray-Brown Forest and the Prairie soils although of limited area.

It appears the transitional soils were recognized as phases or inclusions of other series in the early mapping of
the soils. In surveys in which the transitional areas were of narrow width, the soils were included with both the Brunizem and Gray-Brown Podzolic soils.

Description and History of the Vegetational Forest-Prairie Tension Zones of the Midwest

Paleo-forest-prairie borders

The present forest-prairie tension zone apparently extends throughout the Brunizem soil area of the north central states and into the plains states. Gleason (12) believed the ancestral prairie species came into existence during the early Tertiary. He states, "... that the present climatic center of the Prairie Province in western Kansas and Nebraska and eastern Colorado has been occupied by the vegetation continuously since its origin."

The climate of the northern part of the United States has fluctuated during the Pleistocene. Sears (41) summarizes this information and concluded that forests predominated at the margins of the ice during the advance and retreat of each glacier. In the prairie area, the trees apparently receded and grass became a major part of the vegetation. Pollen analysis of peat beds in Iowa (22) indicate that grass was dominate in part of the Aftonian interglacial period.
Lane concluded that the coniferous vegetation dominated during the recession of the Nebraskan glaciation, was followed by deciduous trees, with grass becoming dominant in the interglacial period. With the advance of the Kansan glacier, the vegetation passed from grass to deciduous forests and then to coniferous species. However, in western Iowa the period of deciduous forest was apparently shorter than in eastern Iowa during the advance of the Kansan glacier. Voss (62) in Illinois found the Sangamon peats to be indicative of a climate favorable for coniferous species. However, in eastern Iowa, Lane (22) found a mixture of pine, oak, and grass pollen in the peats of the same stratigraphic position. The data of Lane (22) seem to indicate that a climatic tension zone may have existed across Iowa during the advance of the Kansan glacier. The data of Lane (22) and of Voss (62) seem to suggest that there may have been slight climatic differences between Illinois and Iowa during the Sangamon interglacial period. However, as Lane pointed out, the Sangamonian peat bed he studied may have formed in a fraction of the interval and that Voss's analysis may represent another segment of the interval.

Frye and Leonard (11) suggest that the fossil molluscs indicate there has been a gradual drying up of the Great Plains since Yarmouthian times. Thorp, et al., (55) think the buried Sangamon soils west of the Missouri River were
formed under grass vegetation, while those east were formed in part under forest vegetation. In Iowa, Simonson (45) concluded the prairie and forest vegetation following the Kansan glaciation was probably distributed in much the same pattern as today. His conclusion is based on the existence of grassland planosols. However, it may be these soils would not be invaded by encroaching forests (26).

Frye and Leonard (11) believe that in the Great Plains the climate was milder during the early substage than in the late substages of the Wisconsin glaciation. They interpret the fossil fauna as indicating that in post-Bradyan time, the climate was similar to that of today. The fossils found in a loess cut in Fremont County, Iowa (19) seem to indicate that the climate in late Mankato times was similar to that of the present. The molluscs preserved in the uppermost (Mankato) loess of the cut are forest-prairie border species.

Post-glacial forest-prairie borders

Lane (23) found the fossil pollen in a peat bog in Hancock County on Mankato drift indicated that the coniferous vegetation existed following the recession of the glacier. The coniferous vegetation was followed by deciduous forests and then by primarily grassland species. Thus, it seems
grassland species were the dominant vegetation of north central Iowa in the recent past.

The forests have encroached on the prairies of Iowa primarily along stream channels (48). The spread of trees into Nebraska and Kansas (12) has followed the rivers. The trees are spreading into the uplands of western Iowa (26). The prairie areas in Wisconsin (20) and Ohio (40) occurred in rather restricted areas in poorly drained sites or on relatively level divide areas. In Ohio the prairies were also found on sites with coarse textured sub-soils which may have been too dry for tree growth. Gleason (12) thinks the prairie has invaded into forested areas twice and that the forests are, in recent time, invading into the prairies.

Factors Which Preserve the Prairie Vegetation

There have been various opinions forwarded for the persistence of prairies in a climatic area suited for forest. The main reasons are probably related to climatic changes. There appear to be factors which retard the forest advance into prairie areas. Some of these are fires, factors inherent from the glacial period, and soil conditions in the prairie soil areas. All of these have probably had some influence on the spread of the forests into the prairie areas. However, the existence of transition soils indicates that invasion was occurring.
McComb and Loomis (26) have indicated that the role of fire has been over-stressed. The existence of deciduous trees following the retreat of the Mankato glacier would seem to indicate that factors inherent in the till which prevent forest invasion must be minimized. Thus, it seems factors involving climate and the soil differences are important.

The soil factors involved in retarding the advance of forests onto prairies have been presented (26) as (1) soil reaction of minimal Brunizems or Regosols derived from calcareous materials, (2) the high fertility of Brunizems favors dense grass and sod growth, and (3) soil aeration or oxidation-reduction potentials. Apparently a higher water table may exist with grass than with forest vegetation (64) (13). This in turn would influence aeration and the redox potential. Wilde, et al., (64) have pointed out that some cut over timber areas of Wisconsin may become wet enough to retard timber growth.

Post Glacial Climatic Influence on the Forest-Prairie Border

The fossil pollen in a peat bed in Hancock County, Iowa as analyzed by Lane (23) has been interpreted (26) as showing two distinct dry periods in the post-Mankatoan climate. The presence of weed pollen in two zones was used as indicators
of drought periods. Two weed zones have been reported in a peat bed in Illinois (16). Hansen (17) in the northwest part of the United States has interpreted his work on fossil pollen analysis as indicating only one dry period. However, his work was done primarily in an area supporting continuous forest vegetation. In his peat profiles which contained predominantly grass pollen, there are indications of a second dry period. Potzger (35) has interpreted his pollen analysis in the northern part of the United States as indicating there has been only one distinct dry period. His work is primarily in profiles containing forest pollen. Sears (42) has summarized work done on peat pollen analysis in the north and northeast part of the country and concluded there have been two dry periods. He used changes in the forest vegetation as shown by the fossil pollen as indicators of the dry periods.

Raup (36) in a summary article of recent climatic changes in the northeastern part of the country quotes Matthew's description of a New Brunswick peat bog. Matthew found the bog had twice dried enough for hardwoods to invade the bog. The latter invasion was followed by a fluctuating moist and dry climate with minor advances of trees. The uppermost part seems to indicate peat was encroaching on forests at the edge of the bog, thus indicating a cool, moist climate.

It seems that soil conditions around the peat beds analyzed by Hansen and Potzger in the forested areas may have
favored the persistence of tree species which would have masked the climatic conditions. Probably the forested species would advance into these wetter areas during dry periods. It appears by summarizing scattered data that there have been two dry periods which would favor the recession or stop the advance of forested species in Iowa since the last glaciation.

Dating of Post Glacial Climatic Changes

The dating of the respective dry periods is of interest since it would indicate the length of time available for soils to change from one type of profile to another. McComb and Loomis (26) have indicated the ages of the two possible dry periods referred to previously. Their calculations were based on geological evidence that the Mankato glacier receded some 20,000 years ago, but radioactive carbon dates (24) indicate that this recession occurred about 10,000 to 11,000 years ago. Correspondingly, the data of occurrence of the two dry periods might be reduced. On this basis, the first dry period occurred about 2,000 to 4,000 years ago and the second one about 200 to 1,000 years ago.

The first dry period seems to correspond to the first dry period which Hansen (17) has dated in the northwestern part of the United States. He has used the Mount Mazama volcanic ash as being 10,000 years old. A radioactive carbon date (24)
from a tree buried by the ash indicates the date should have been around 6,500 years ago. The dry period, adjusted to this date, is from 2,500 to 5,000 years ago. These dates correspond to those presented by Brooks (4) for the dry period following the "climatic optimum" of Europe. Brooks has also summarized climatic information during the Christian era and has not found consistent correlations from different parts of the world. However, the climate of this period has apparently been quite erratic. In the northwest part of the United States, the summary indicates that the climate was quite dry from about 1,100 to 1,800 years ago.

It appears the two periods which would favor the recession of forests occurred during the first half or middle of the Christian era and from about 2,000 to 4,000 years ago.
METHODS OF INVESTIGATION

Field Studies

Soils of the biosequences studied

Three sequences of soils have been used in investigating the transitional soils. The "transitional soils," as used in this text, means those soils formed by the encroachment of trees onto prairies. Soils formed due to the influence of different biotic factors of soil formation make up a biosequence. Winters (67) has discussed the genetic sequence concept. The soils of the three biosequences are in minimal, medial and maximal stages of profile development. The minimal-maximal concept of Thorp and Smith (56) indicates the degree of profile development of soils in the Great Soil Group.

The first sequence, the Fayette biosequence, consists of four profile samples from Tama County, Iowa. These samples were from a Tama silt loam, a Tama soil with some timber influence, a Downs silt loam and a Fayette silt loam. The Tama soils are medial Brunizems, the Fayette soil is a medial Gray-Brown Podzolic and the Downs soil is a transitional soil between the two. These soils are derived from Iowan (46) loess.

The second sequence, the Weller biosequence, consists of three profiles collected from Lucas County, Iowa. They are a
Grundy silt loam, a Pershing silt loam and a Weller silt loam which are respectively a maximal Brunizem, a transitional soil and a maximal Gray-Brown Podzolic soil. These soils have loess for parent material.

The third sequence, the Hayden biosequence, is from Polk County, Iowa. The soils are a Clarion fine sandy loam, a Lester loam and a Hayden loam. These are respectively a minimal Brunizem, a transitional soil, and a minimal Gray-Brown Podzolic soil. The parent material is Cary till (39) with a thin mantle of eolian sand. Due to the dual nature of the parent material, less analysis were made on this third sequence.

Possible vegetational changes of the biosequences

The soil sequences used in this study could have been influenced by a number of vegetational changes which have been summarized in Table 1. All of the sites could have been forested during the recession of the Cary glacier and during the advance and retreat of the Mankato glacier. All profiles of the Fayette and Weller biosequences may have been forested during the Tazwell glacial substage and following the retreat of the Iowan glacier. However, as will be discussed later in more detail, there are no apparent morphological indications
Table 1. Possible Past Vegetation of the Biosequences

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Glacial stage</th>
<th>Period soil formation started</th>
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<tbody>
<tr>
<td>Prairie-trees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie-trees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trees</td>
<td>Mankato</td>
<td>Hayden biosequence</td>
</tr>
<tr>
<td>Trees</td>
<td>Cary</td>
<td></td>
</tr>
<tr>
<td>Prairie (?)</td>
<td>(?), (Bradyan interval)</td>
<td>Fayette and Weller biosequence</td>
</tr>
<tr>
<td>Trees</td>
<td>Tazewell</td>
<td></td>
</tr>
<tr>
<td>Prairie (?)</td>
<td>(?), (Bradyan interval)</td>
<td>Fayette and Weller biosequence</td>
</tr>
<tr>
<td>Trees</td>
<td>Iowan</td>
<td></td>
</tr>
</tbody>
</table>

that the Brunizem soils studied in the sequences have been influenced by forest vegetation.

It is probable that the present soils of the Hayden biosequence were not influenced by trees immediately following the Cary or Mankato substages. Ruhe (39) has indicated there was no significant weathering interval between the Cary and the Mankato glacial substages. Thus, weathering of the Cary till is probably all post Mankatoan in age. Green (15) has reported that no apparent differences occurred between two Hayden soils formed from Cary and Mankato till. The morphological and chemical properties of Clarion soils, which are
Brunizems, reported on by Green and similar soils in this study have none of the characteristics generally attributed to forest influence. Thus, it appears prairie became the dominant vegetation of central Iowa shortly after the retreat of the Mankato glacier as is indicated by the work of Lane (23).

Ruhe (39) has indicated that there was no weathering interval between the Iowan and Tazwell glacial substages. Thus, it seems any profile development following the Tazwell substage would be from time zero and the soils of the Fayette and Weller biosequences were possibly calcareous Regosols at that time. The soils of the Fayette and Weller biosequences probably started to develop during the Bradyan interval. A buried loess derived soil (soil X) (38) found in western Iowa was later thought to have formed in the Bradyan interval (39). This buried soil appears to be a minimal Brunizem which suggests that prairie was the dominant vegetation during the Bradyan interval.

It is possible that the soils of the Fayette and Weller biosequences were forested during the Cary and during the Mankato glacial substages. However, no morphological evidence is found in the Brunizem soils of these biosequences which would indicate that trees had influenced significantly their past development. There are some soils in eastern Iowa which have B horizon development indicative of formation under trees but with thick dark A horizons of the Brunizem soils (48). It
is a mute question as to when these soils of eastern Iowa were influenced by tree growth.

It appears the Brunizem soils of the biosequences studied have had the majority of their development under the influence of prairie vegetation. It is not known whether the Gray-Brown Podzolic soils have been forested continuously since the retreat of the Mankato glacier or intermittently during the more moist climatic periods. In a similar fashion it is not known whether the development of the transitional soils has occurred in one encroachment of the prairie by trees or represents the cyclic advance of trees and prairies according to the climatic regime in the post Mankatoan period.

**Morphological descriptions of the soils investigated**

The soils used in this study were selected on criteria used to differentiate the profiles in field mapping. The Brunizem soils have profile characteristics as described by Smith, et al., (48). The Tama silt loam and Fayette silt loam profiles are the profiles discussed by these authors. They discussed the changes which occurred in a Brunizem soil hypothesized as prairie being invaded by trees, the first change being either an increase in the development of the structural aggregates in the B horizon of well-drained soils or the appearance of gray coatings in the lower A horizon of
the moderately well-drained soils. The morphological properties of the Gray-Brown Podzolic soils have been discussed by several authors (51) (25) (7) (37).

Tama Silty Clay Loam, P-27

| Location: | Site, 750 feet east, 185 feet north of the SW corner SW \( \frac{1}{2} \) SW \( \frac{1}{2} \) Sec. 28, T86N, R16W, Tama County, Iowa, on a 3 per cent west facing slope. |
| Vegetation: | Cultivated field, formerly prairie. |
| Samples collected: | August 23, 1938, R. W. Simonson. |
| Description: | August 17, 1953, E. M. White. |
| \( A_p \) 0-6 | Black to very dark-brown (10YR 2/1 to 2/2)* silty clay loam. Very dark-brown (10YR 2/2) crushed color. Clods which break into moderately weak fine granular structure.** |
| \( A_{12} \) 6-10 | Very dark-brown (10YR 2/2) silty clay loam with a very dark-brown (10YR 2/2) crushed color. Moderate medium granular structure. |
| \( A_3 \) 10-14 | Very dark-brown (10YR 2/2) silty clay loam. Very dark grayish-brown (10YR 3/2) crushed color. Moderate medium granular structure. |
| \( B_1 \) 14-18 | Very dark grayish-brown (10YR 3/2) silty clay loam. Dark grayish-brown to very dark grayish-brown (10YR 4/2 to 3/2) crushed color. Moderate medium granular to moderate very fine subangular blocky. Few pinholes. |

---

* Munsell color designation, moist soil unless otherwise stated.

** Structure terminology from Soil Survey Manual (60).
Dark grayish-brown (10YR 4/2) silt loam with a brown (10YR 4/3) crushed color. Moderate fine subangular blocky to coarse granular structure. Numerous pinholes.

Dark grayish-brown to brown (10YR 4/2 to 5/3) silt loam with a brown (10YR 4/3) crushed color. Moderate fine subangular blocky to coarse granular structure. Numerous pinholes.

Brown (10YR 4/3) light silt loam with a brown (10YR 4/3) crushed color. Moderately weak very fine subangular blocky structure. Numerous pinholes.


Brown (10YR 4/3) and dark grayish-brown (2.5Y 4/2) silt loam. Brown (10YR 5/3) crushed color. Common faint fine yellowish-brown (10YR 5/8) mottles and few distinct fine dark reddish-brown (5YR 2/2) diffused iron-manganese segregations. Very weak very fine subangular blocky to massive structure.

Dark grayish-brown (2.5Y 4/2) silt loam with a brown (10YR 5/3) crushed color. Many distinct fine yellowish-brown (10YR 5/6 to 5/8) mottles which occur in discontinuous veins. Few distinct fine dark reddish-brown (5YR 2/2) soft iron-manganese segregations. Massive structure.

**Tama Silt Clay Loam (Forested), P-427**

**Location:** Site 300 feet north and 200 feet east of the SE corner NE<sup>4</sup> SE<sup>4</sup> Sec. 26, T86N, R14W, on a 3 per cent northeast facing low ridge.

**Vegetation:** Oak, linden, elm, and hickory. Closed woods.
Sample collected and described: E. M. White and Homer Folks, April 4, 1953.

A₀₀
Thin layer of leaves and twigs.

A₀
Approximately one inch thick layer of decayed material.

A₁₁ 0-4
Very dark-brown (10XR 2/2) silty clay loam. Crushed color black to very dark-brown (10XR 2/1 to 2/2). Compound moderate fine subangular blocky and moderate very fine subangular blocky to medium granular structure.

A₁₂ 4-7
Very dark-brown (10XR 2/2) silty clay loam. Crushed color: black to very dark-gray (10XR 2/1 to 3/1). Moderate irregular very fine subangular blocky structure. Numerous pinholes.

A₁₃ 7-10
Black to very dark-gray (10XR 2/1 to 3/1) silty clay loam. Crushed color: very dark grayish-brown (10XR 3/2). Moderate very fine subangular blocky structure. Numerous pinholes.

A₃ 10-13
Very dark-gray to very dark grayish-brown (10XR 3/1 to 3/2) silty clay loam. Very dark grayish-brown (10XR 3/2) crushed color. Moderate very fine subangular blocky structure with some glossy ped surfaces. Some mixing due to rodents or tree roots. Numerous pinholes.

B₁ 13-16
Very dark-gray to very dark grayish-brown (10XR 3/1 to 4/2) silty clay loam. Very dark grayish-brown (10XR 3/2) crushed color. Some variation of color due to differences in organic matter distribution. Moderate very fine subangular blocky structure with numerous pinholes.

B₂₁ 16-20
Very dark grayish-brown (10XR 3/2) silty clay loam. Very dark grayish-brown to dark brown (10XR 3/2 to 4/3) crushed color. Moderate very fine subangular blocky structure with some very dark brown to very dark grayish-brown (10XR 2/2 to 3/2) stains of organic matter on the ped surfaces. Numerous pinholes.
B₂₂  20-24  Very dark grayish-brown to dark yellowish-brown (10YR 3/2 to 3/4) silty clay loam that is dark brown (10YR 4/3) when crushed. Moderate very fine subangular blocky structure with moderately shiny coatings and some organic stains. Numerous pinholes.

B₂₃  24-28  Dark brown (10YR 4/3) silty clay loam with a crushed color of dark yellowish-brown to dark brown (10YR 4/4 to 4/3). Moderate very fine subangular blocky structure which is not as well developed as in the above horizon. Some ped surfaces are very dark grayish-brown (10YR 3/2). Pinholes.

B₃₁  28-32  Dark brown (10YR 4/3) silty clay loam with a yellowish-brown (10YR 5/4) crushed color. Moderately weak very fine subangular blocky structure with numerous pinholes.

B₃₂  32-36  Dark brown (10YR 4/3) silty clay loam which is a yellowish-brown (10YR 5/4) when crushed. Moderately weak very fine subangular blocky structure. Occasional vertical cleavage surface with very dark grayish-brown (10YR 4/2) stains. Pinholes.

B₃₃  36-40  Dark brown (10YR 4/3) silty clay loam which is a yellowish-brown (10YR 5/4) loam when crushed. Weak very fine subangular blocky structure. Pinholes. A few soft very dark gray (10YR 3/1) manganese-iron accumulations.


C13 48-52 Yellowish-brown, dark yellowish-brown and brown (10YR 5/4, 5/6, 4/4, 5/3). A few distinct fine dark grayish-brown (10YR 4/2) and light brownish-gray to grayish-brown (2.5Y 6/2 to 5/2) mottles. Massive structure with some vertical cleavages. Few cleavage zones are stained very dark grayish-brown to very dark brown (10YR 3/2 to 2/2). Silty clay loam.

Downs Silt Loam, P-428

Location: NE 1/4 Sec. 5, R14W, T65N, Tama County, Iowa. Site 200 feet east and 990 feet north of center of section (100 feet north of east-west road). On a ridge top with 3 per cent east facing slope.

Vegetation: Oak, hickory, buck brush and bluegrass. Pastured open woods.

Sample collected and described: E. M. White and Ralph McCracken, April, 1953.

A1 0-3 Black to very dark grayish-brown (10YR 2/1 to 3/2) silty loam. Very dark grayish-brown (10YR 3/2) crushed. Compound very weak medium platy and moderate fine granular structure. Grass roots are mostly in the surface layer.

A21 3-6 Very dark brown and very dark brownish-gray (10YR 2/2 and 3/2) silty loam. Very dark grayish-brown (10YR 3/2) crushed color. Compound weak medium platy and moderately weak very fine subangular blocky structure. Numerous pinholes.

A22 6-9 Mixed colors of very dark grayish-brown (10YR 2/2) and dark yellowish-brown (10YR 4/4 to 4/3) with a small amount of very dark brown (10YR 2/2). The crushed matrix color is dark grayish-brown to very dark grayish-brown (10YR 4/2 to 3/2). Moderately weak very fine subangular blocky structure. Some gray coatings on the peds in this horizon. Silt loam.
A23 9-12 Color and texture similar to above horizon. Moderate (irregular sized) very fine subangular blocky structure. The irregular size of the peds is due to worm activity. There were many worm casts in various stages of being included into the horizon. Apparently the worms have transported material from the B horizon. The older casts have become moderate subangular peds with glossy surfaces. Part of the color differences arrive from the worm activity in this horizon and the adjoining horizons. Part of the peds have pinholes and a few grayish surfaces.

A31 12-15 Very dark grayish-brown (10YR 3/2), dark grayish-brown (10YR 4/2) with a small amount of very dark brown (10YR 2/2). Crushed color is mixed dark brown (10YR 4/3) and yellowish-brown (10YR 5/4). Moderate very fine subangular blocky structure. There are small areas of this horizon which are dark brown (2.5YR 4/4). This is also the matrix color of these areas. The structure is similar to the rest of the horizon but the surfaces are more glossy. A few peds are grayish in color and form the darker part of the main matrix. Silty clay loam.

B1 15-18 Brown (10YR 4/3) silty clay loam with a crushed color of yellowish-brown (10YR 5/4). Some ped surfaces are very dark grayish-brown to dark grayish-brown (10YR 3/2 to 4/2). Moderate very fine subangular blocky structure. Some areas of dark brown (7.5YR 4/4) as in above horizon.

B21 18-22 Dark brown to dark yellowish-brown (10YR to 7.5YR 4/3 to 4/4) silty clay loam. Yellowish-brown (10YR 5/4) crushed color. Channels of dark brown (7.5YR 4/2) which follow patterns like old root channels. These channels have slightly stronger peds with glossy surfaces like the B2 horizon of a Gray-Brown Podzolic soil. The structure of these channels and the rest of the horizon is a moderate very fine subangular blocky. Part of the matrix peds have glossy coatings.
Fayette Silt Loam, P-32

Location: Site 550 feet west, 100 feet south of the NE corner NE SW Sec. 2, T83N, R16W, Tama County, Iowa. 3 per cent south facing slope.

Vegetation: Oak, hickory, buck brush and bluegrass. Pastured woodland.

Samples collected: August 24, 1938, R. W. Simonson.

Description: E. M. White, August 17, 1953.

A\text{1} \quad 0-3 \quad \text{Very dark gray (10YR 3/1) silt loam. Very dark gray (10YR 3/1) crushed color. Weak thin platy structure. Grass roots concentrated in this horizon.}

B_{22} \quad 22-26 \quad \text{Dark yellowish-brown to dark brown (10YR to 7.5YR 4/4 to 4/3) silty clay loam. Crushed color of yellowish-brown (10YR 5/4). Moderate very fine subangular blocky structure. Cylindrical channels of material with colors more on the 7.5YR chart and with slightly stronger structure.}

B_{3} \quad 34-40 \quad \text{Dark brown to dark yellowish-brown (10YR 4/3 to 4/4) silty clay loam, which is yellowish-brown (10YR 5/4) when crushed. Some coatings on the peds of brown (10YR 5/3) and stains of organic matter. Moderately weak very fine (irregular) subangular blocky structure.}

C_{1} \quad 40-46 \quad \text{Dark brown to brown (10YR 4/3 to 5/3) silty clay loam. Few yellowish-brown (10YR 5/8) fine distinct mottles. Manganese-iron mottles of very dark brown (10YR 2/2) and having diffused irregular boundaries. Massive with some vertical cleavage. Cleavage faces are in part stained with dark brown (7.5YR 4/4 to 4/3) organic matter or iron-manganese material. Occasional cleavage face areas dry out to pale-brown (10YR 6/3).}
A21  3-6  Dark grayish-brown (10YR 4/2) silt loam. Very
dark grayish-brown (10YR 3/2) crushed color.
Weak thin platy structure with prominent light
brownish-gray (10YR 6/2) coatings when horizon
is dry.

A3    6-12  Very dark grayish-brown (10YR 3/2) silt loam
with a dark grayish-brown (10YR 4/2) crushed
color. Compound very weak medium platy and
weak fine granular structure. Some grayish
surface on the peds. Numerous pinholes.

B1    12-17  Dark grayish-brown (10YR 4/2)* heavy silt loam
with a dark brown (10YR 4/3) crushed color.
Moderately weak very fine subangular blocky
structure. Dry peds have some light brownish-
gray (10YR 6/2) coatings. Numerous pinholes.

B21   17-23  Dark brown (10YR 4/3) silty clay loam with a
dark brown (10YR 4/3) crushed color. Moderate
very fine subangular blocky structure with
some faint grayish coatings.

B22   23-33  Dark brown (10YR 4/3) silty clay loam with a
dark brown (10YR 4/3) crushed color. Moderately
strong very fine and fine subangular blocky
structure. Numerous pinholes.

B31   33-40  Dark brown (10YR 4/3) silty clay loam with a
dark brown to dark yellowish-brown (10YR 4/3 to
4/4) crushed color. Moderate very fine to fine
subangular blocky structure with stronger
vertical than horizontal cleavage. Numerous
pinholes.

B32   40-46  Dark brown to dark yellowish-brown (10YR 4/3 to
4/4) silty clay loam. Dark brown to dark yel-
lowish-brown (10YR 4/3 to 4/4) crushed colors.
Few very faint fine yellowish-brown (10YR 5/8)
mottles. Weak irregular fine subangular blocky
to massive structure with some strong vertical
cleavages.

*The colors of the uncrushed soil are on the 7.5YR side
of the 10YR colors shown in the 12 inch to 46 inch horizons.
B_{33} (C_l?) 46-56

Light olive-brown (2.5Y 5/4) and dark brown (10YR 4/3) heavy silt loam. Common faint fine yellowish-brown (10YR 5/7) mottles with indistinct boundaries. Massive with some strong vertical cleavages which have dark glossy coatings.

Grundy Silt Loam, P-3

**Location:** Site 210 feet north, 515 feet east of SW corner SE_{1/4} NE_{1/4} Sec. 21, T71N, R22W, Lucas County, Iowa, on a 3 per cent southeast facing slope.

**Vegetation:** Cultivated field, formerly prairie.

**Samples collected:** September 28, 1938, R. W. Simonson and E. W. Riley.

**Description:** August 15, 1953, E. M. White.

A_{p} 0-6

Very dark gray (10YR 3/1). Dries to dark grayish-brown (10YR 4/2). Silt loam. Moderately weak fine granular structure which forms large hard clods in the dry condition.

A_{12} 6-10

Very dark gray (10YR 3/1) silt loam with a very dark gray to very dark grayish-brown (10YR 3/1 to 3/2) crushed color. Silt loam. Moderate fine granular to very fine subangular blocky structure.

A_{3} 10-14

Very dark gray (10YR 3/1) with some areas (due to worm action?) of dark grayish-brown and brown (10YR 4/2 and 5/3). Dark grayish-brown (10YR 4/2) crushed color. Moderate very fine subangular blocky structure. Silty clay loam.

B_{l} 14-18

Dark grayish-brown (10YR 4/2) with some very dark gray and brown (10YR 3/1 and 5/3). Brown to dark grayish-brown (10YR 5/3 to 4/2) crushed color. Very few faint fine yellowish-brown (10YR 5/8) mottles. Compound moderately weak fine subangular blocky and moderate very fine subangular blocky. Peds have some glossy coatings. Silty clay loam.
B21 18-24 Dark grayish-brown (10YR 4/2) with some grayish-brown and brown (10YR 5/2 and 5/3). Brown (10YR 5/3) crushed color. Few distinct fine yellowish-brown (10YR 5/8) and common distinct fine strong brown (7.5YR 5/8) mottles with diffuse boundaries. Compound moderate fine subangular blocky structure and moderate very fine blocky structure. The horizon was quite dry and strong vertical cracking had formed coarse prismatic units of the peds. The peds have glossy coatings. Silty clay.

B22 24-30 Structure and color similar to above horizon except ped coatings are not as evident. Krotovina. There were many fine strong brown (7.5YR 5/8) mottles with indistinct boundaries. Few iron-manganese buckshot concretions. Silty clay.

B31 30-38 Grayish-brown and light olive-brown (2.5Y 5/2 and 5/4) silty clay loam. Light olive-brown (2.5Y 5/4) crushed color. Many distinct strong brown (7.5YR 5/8) mottles with diffused boundaries, often in more less continuous veins. Moderately weak very fine subangular blocky structure with stronger vertical than horizontal cleavages.

B32 38-46 Grayish-brown (2.5Y 5/2) compact silty clay loam. Light olive-brown (2.5Y 5/4) crushed color. Many prominent yellowish-brown (10YR 5/6) mottles with diffuse boundaries. Few iron-manganese buckshot concretions. Very weak fine subangular blocky to massive structure.

C1 46-54 Grayish-brown (2.5Y 5/2) silty clay loam with a light olive-brown (2.5Y 5/4) crushed color. Many prominent yellowish-brown (10YR 5/6) mottles with indistinct boundaries.

Pershing Silt Loam, P-429

Location: 400 feet west and 10 feet south of the NE corner of the SE1 NE1 Sec. 4, T72N, R21W, Lucas County, Iowa, on a 5 per cent southwest facing slope.
Vegetation: Oak, hickory, buck brush and bluegrass. Open woodland pasture.


A1 0-6 Very dark gray (10YR 3/1) which grades to a dark grayish-brown (10YR 4/2) at the base of the horizon. Silt loam. Compound very weak medium platy and moderate fine granular structure. Bluegrass roots form a mat in the upper one inch of the horizon.

A2 6-12 Dark grayish-brown (10YR 4/2) with some areas of very dark gray (10YR 3/1) and grayish-brown (10YR 5/2) with a few faint fine yellowish-brown (10YR 5/4 to 5/8) mottles. Compound weak medium platy and moderately weak fine granular structure. Grades from a heavy silt loam with depth in the horizon.


B21 15-22 Brown (10YR 5/3) with some dark grayish-brown (10YR 4/2) and yellowish-brown (10YR 5/4). Common distinct fine strong brown (7.5YR 5/8) mottles. Silty clay. Compound moderate very fine subangular blocky (approximately 5 mm) and moderate very fine subangular blocky (1-2 mm) structure. Some peds have dark gray (10YR 4/1) coatings.

B22 22-30 Brown (10YR 5/3) and dark grayish-brown (10YR 4/2) silty clay. Many distinct fine strong brown (7.5YR 5/8 and 5/6) mottles. Compound moderate very fine subangular blocky (approximately 5 mm) and moderate very fine subangular blocky (1-2 mm) structure. Some peds have dark gray (10YR 4/1) coatings.

B31 30-40 Grayish-brown (10YR 5/2) and some brown (10YR 5/3) and dark grayish-brown (10YR 4/2). Texture grades from a light silty clay to a heavy silty clay loam in this horizon. Many distinct fine
strong brown (7.5YR 5/6) mottles. Common distinct fine iron-manganese buckshots. Moderately weak very fine subangular blocky structure. Some dark gray (10YR 4/1) coatings but less frequent than in above horizon.

B<sub>32</sub> 40-52
Grayish-brown (2.5Y 5/2) silty clay loam. Common distinct fine strong brown (7.5YR 5/6) to yellowish-brown (10YR 5/6) mottles. Common distinct fine iron-manganese buckshots. Weak very fine subangular to massive structure. Some dark gray (10YR 4/1) coatings but restricted mainly to the stronger vertical cleavages.

C<sub>1</sub> 52-58
Grayish-brown (2.5Y 5/2) silty clay loam. Common to many distinct fine yellowish-brown (10YR 5/8) mottles. Some very dark gray (10YR 3/1) staining on the vertical cleavage of the massive structure.

Weller Silt Loam, P-4

Location: Site 265 feet south, 130 feet west of NE corner NW<sup>1</sup> NW<sup>1</sup> Sec. 9, T72N, R20W, Lucas County, Iowa, on a 3 per cent south slope.

Vegetation: Oak, hickory, buckbrush and bluegrass. Open woodland pasture.


Description: August 15, 1953, E. M. White.

A<sub>1</sub> 0-3
Dark grayish-brown (10YR 4/2) which is also the crushed color. The dry color is grayish-brown (10YR 5/2). Weak very thin platy structure. Grass roots are primarily within this horizon. Silt loam.

A<sub>2</sub> 3-7
Dark brown (10YR 5/3) with a brown (10YR 5/3 to 4/3) crushed color. Pale brown (10YR 6/3) when dry. Moderately weak very thin platy structure. Silt loam.
A₃  7-11  Yellowish-brown (10YR 5/4) to brown (7.5YR 5/4) silt loam. Yellowish-brown (10YR 5/4) to strong brown (7.5YR 5/6) crushed color. Light yellowish-brown (10YR 6/4) when dry. Moderately weak very fine subangular blocky structure. Peds somewhat flattened parallel to the horizontal plane. Numerous pinholes.

B₁₁  11-15  Yellowish-brown (10YR 5/4) silty clay loam. Yellowish-brown (10YR 5/4) crushed color. Light brown (7.5YR 6/4) to light yellowish-brown (10YR 6/4) with some light gray (10YR 7/2) flecks are the dry colors. Moderate very fine subangular blocky structure with a few pinholes.

B₁₂  15-20  Yellowish-brown (10YR 5/4) silty clay loam. Yellowish-brown (10YR 5/4) crushed color. Peds coatings are brown (10YR 5/3) (60 per cent) and white (10YR 8/1) (40 per cent) when dry. Compound moderate fine subangular blocky and moderate very fine subangular blocky.

B₂₁  20-26  Yellowish-brown (10YR 5/4) silty clay. Yellowish-brown (10YR 5/4) crushed color. Compound moderately strong fine subangular blocky and moderately strong very fine subangular blocky structure.

B₂₂  26-32  Similar to above horizon except the structure is slightly weaker.


B₃₂  38-44  Yellowish-brown (10YR 5/4) and grayish-brown (2.5Y 5/2) silty clay loam. Yellowish-brown (10YR 5/4) crushed color. Common fine distinct strong brown (7.5YR 5/8) mottles.

B₃₃  44-54  Brown (10YR 5/3) and light olive-brown (2.5Y 5/4) with a few channels (1-2 cm diameter) which appear to be old root channels which are filled with brown (7.5YR 5/4) material. Many fine distinct strong brown (7.5YR 5/8) and
yellowish-brown (10YR 5/8) mottles. Numerous veins (1 mm) of dark colored organic matter and/or iron-manganese concentrations which form a discontinuous network in the matrix. Massive, with pronounced vertical cleavage zones, to weak irregular fine subangular blocky structure. Silty clay loam.

Clarion Fine Sandy Loam, P-403

Location: NW¼ NW¼ NW¼ Sec. 27, T81N, R25W, Polk County, Iowa, 200 feet north of State Highway 60 on east side of N-S gravel road at the edge of the road cut. A 3 per cent slope (to the north) at site.

Vegetation: Bluegrass (original vegetation was prairie grass).

Sample collected and described: W. D. Shrader, Dean Einspahr, and Ralph McCracken, November 29, 1951.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_p</td>
<td>0-8</td>
<td>Very dark brown (10YR 2/2) very friable medium granular fine sandy loam.</td>
</tr>
<tr>
<td>A_3</td>
<td>8-12</td>
<td>Very dark grayish-brown (10YR 3/2) very friable moderate medium granular fine sandy loam.</td>
</tr>
<tr>
<td>B_12</td>
<td>12-19</td>
<td>Brown (10YR 4/3) friable, moderate medium granular fine sandy loam.</td>
</tr>
<tr>
<td>B_12</td>
<td>19-26</td>
<td>Brown (10YR 4/3) firm, moderate fine subangular blocky sandy clay loam.</td>
</tr>
<tr>
<td>B_2</td>
<td>26-32</td>
<td>Dark yellowish-brown (10YR 4/4) firm moderate medium subangular blocky sandy clay loam.</td>
</tr>
<tr>
<td>B_3</td>
<td>32-39</td>
<td>Yellowish-brown (10YR 5/4) friable, weak fine to medium blocky sandy clay loam.</td>
</tr>
<tr>
<td>C_1</td>
<td>39-45</td>
<td>Mottled dark yellowish-brown (10YR 4/4), brown (10YR 5/3) and dark brown (10YR 4/3), friable massive loam, few line concretions.</td>
</tr>
<tr>
<td>C_2</td>
<td>45-50</td>
<td>Similar to above horizon but lime concretions more numerous.</td>
</tr>
</tbody>
</table>
Lester Loam, P-430

Location: Site 170 feet south and 120 feet west of the NE corner of the NW-1/4 NW-1/4 NE-1/4 Sec. 28, T81N, R25W, Polk County, Iowa. On a 3 per cent northwest facing slope.

Vegetation: Oak, hickory and bluegrass. Open woodland pasture.

Samples collected and described: E. M. White, Ralph McCracken, and Orval Friedrich, March, 1953.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₀</td>
<td>1</td>
<td>Leaf and bluegrass foliage remains.</td>
</tr>
<tr>
<td>A₁</td>
<td>0-4</td>
<td>Very dark gray (10YR 3/1) with some very dark grayish-brown (10YR 3/2) fine sandy loam or loam. Moderately weak fine granular structure. Grass roots in upper inch of horizon.</td>
</tr>
<tr>
<td>A₂</td>
<td>4-9</td>
<td>Dark grayish-brown (10YR 4/2) with some very dark grayish-brown (10YR 3/2) and very dark gray (10YR 3/1). Numerous very dark brown (10YR 2/2) worm casts. Moderately weak medium granular structure units which are somewhat flattened parallel to the horizontal axis. Few faint fine dark brown (10YR 4/3) mottles. Loam.</td>
</tr>
<tr>
<td>A₃</td>
<td>9-14</td>
<td>Very dark grayish-brown (10YR 3/2) with some very dark gray (10YR 3/1) and dark grayish-brown (10YR 4/2). Loam. Few faint fine dark yellowish-brown (10YR 3/4 to 4/4) mottles. Compound irregular weak coarse granular and weak fine granular structure.</td>
</tr>
<tr>
<td>B₁</td>
<td>14-18</td>
<td>Dark brown to very dark grayish-brown (10YR 4/3 to 3/2). Very dark brown (10YR 2/2). Very dark brown (10YR 2/2) worm casts. Loam. Weak medium granular to very fine subangular blocky structure.</td>
</tr>
<tr>
<td>B₂₁</td>
<td>18-24</td>
<td>Dark brown (7.5YR 3/2) loam to light clay loam with a very dark grayish-brown (10YR 3/2) crushed color. Few faint fine dark yellowish-brown (10YR 4/4) mottles. Moderate fine subangular blocky structure.</td>
</tr>
</tbody>
</table>
**B_{22} 24-30** Dark brown to dark yellowish-brown (10YR 4/3 to 4/4) with a numerous coatings of dark brown (7.5YR 3/2). Loam. Moderate medium subangular blocky structure.

**B_{31} 30-36** Brown to yellowish-brown (10YR 4/3 to 5/4) with few dark brown (7.5YR 3/2) ped coatings. Few iron-manganese buckshot concretions. Moderate medium and coarse subangular blocky structure. Loam.

**B_{32-C1} 36-42** Light olive-brown (2.5Y 5/4) with some surface of very dark grayish-brown (10YR 3/2). Few fine prominent yellowish-red (5YR 5/8) mottles. Massive with some moderately developed vertical cleavages which have dark colored staining. Many pinholes. Loam.

**C_{ca} 48 +** Yellowish-brown (10YR 5/4) calcareous loam with some coarse veins of light brownish-gray (2.5Y 6/2) in the mass color. Few very dark grayish-brown (10YR 3/2) stains of organic matter or iron-manganese segregations. Common distinct yellowish-red (5YR 5/6 to 5/8) mottles.

**Hayden Loam, P-402**

**Location:** SE_{1} NE_{1} SE_{1} Sec. 28, T81N, R25W, Polk County, Iowa. On a narrow ridge top (150 feet wide) with 3 per cent slope and with 25 per cent side slopes, immediately above the Des Moines River flood plain.

**Vegetation:** Area was formerly forested, scattered stumps and tree remains. Present cover of thin blue-grass with some buckbrush.

**Sample collected and described:** W. D. Shrader, Dean Einspahr, and Ralph McCracken, November 29, 1951.

**A_{1} 0-3** Very dark grayish-brown (10YR 3/2) very friable, light loam; grass roots numerous (horizon frozen - no structure determination possible).

**A_{2} 3-8** Brown (10YR 5/3) very friable, weak fine platy, light loam.
A3  8-12  Dark brown (10YR 4/3), lightly coated with pale brown (10YR 6/3), friable, moderate medium subangular blocky loam.

B1  12-14  Dark yellowish-brown (10YR 4/4), firm, strong medium to coarse subangular blocky loam.

B21  14-18  Dark yellowish-brown (10YR 4/4), firm, strong medium to coarse subangular blocky loam.

B22  18-23  Dark yellowish-brown (10YR 4/4) firm, to very firm moderate coarse subangular blocky clay loam.

B23  23-29  Dark yellowish-brown (10YR 4/4), yellowish-brown (10YR 5/4) when crushed, very firm moderate coarse blocky clay loam.

B31  29-36  Yellowish-brown (10YR 5/4) with some dark yellowish-brown (10YR 4/4) stainings on structural faces, firm, weak coarse blocky clay loam.

B32  36-42  Mottled dark yellowish-brown (10YR 4/4) and dark brown (10YR 4/3), firm to friable, massive sandy clay loam.

B33  42-48  Mottled dark yellowish-brown (10YR 4/4) and dark brown (10YR 4/3) friable, massive sandy clay loam, occasional lime concretions.

Cca  48-52  Brown (10YR 5/3) friable, massive loam, calcareous with lime concretions.

Laboratory Studies

Methods for laboratory determination

Sample preparation. The bulk samples used for mechanical analysis, exchangeable cations, total carbon and total nitrogen consisted of material which passed a 2 millimeter screen.
The free iron oxides were determined on a fraction of the less than 2 millimeter bulk sample which was carefully crushed in an agate mortar so that soil aggregates and concretions would pass through a 40 mesh screen. The sand fraction retained on the screen was mixed with the material which passed the screen. Thus, the determination was made on a whole soil basis.

**Mechanical analysis.** Duplicate determinations were made on 10 gram air-dry samples which were first oven dried (110°C.) to determine the moisture content. The organic matter was destroyed with hydrogen peroxide. The samples were placed on an end over end shaker for 24 hours with sodium hexametaphosphate as the dispersing agent (57). The less than 20 and 2 micron fractions were determined with a 25 milliliter pipette at a 10 centimeter depth and the proper time interval (32) (53). The greater than 50 micron fraction was determined by sedimentation and decantation. The fraction obtained was collected on a 300 mesh screen to determine whether the finer material had been removed. No corrections were made for the organic matter content of the soil so that most of the organic matter would be shown in the 20 to 50 micron fraction.

**Exchangeable cations.** The exchangeable hydrogen was determined by the barium acetate method (2). Duplicate 10 gram samples were placed on a shaker for 20 minutes with 50
milliliters of the normal neutral barium acetate solution before leaching on a Buchner funnel. The hydrogen in the leachate was neutralized to a phenolphthalein end point with standard 0.1 N sodium hydroxide.

The exchangeable bases were extracted and prepared for determination as outlined by Pech (34). The duplicate samples were placed in flasks with 50 milliliters of neutral normal ammonium acetate and shaken for 20 minutes before leaching.

Calcium and magnesium were determined by the method outlined by Black (2). The calcium was determined volumetrically by a permanganate titration of the oxalate. The magnesium was precipitated as the ammonium phosphate and determined volumetrically with standard acid and base. Manganese was not removed prior to the determination of the calcium and magnesium. With a single oxalate precipitation of the calcium, the magnesium separation is incomplete (65). Thus, it seemed the positive error introduced by the manganese being present was negligible in comparison to the loss of magnesium caused during the calcium precipitation.

The exchangeable potassium was determined with the Perkins Elmer Model No. 52C flame photometer. The procedure utilized the lithium internal standard technique as outlined by Black (65).

**Total nitrogen and carbon.** The gravimetric dry combustion procedure was used for total carbon. The total nitrogen was
determined by a modified Gunning procedure using a piece of copper wire as the catalyst in the sulfuric acid - anhydrous sodium sulfate digestion. The ammonia was distilled into standard hydrochloric acid after the sulfuric acid was neutralized with sodium hydroxide which contained potassium sulfide. The excess acid in the distillate was titrated to methyl red-methylene blue endpoint with standard base.

**Free iron.** The free iron was determined on a 1 gram sample as outlined by Swenson (52). The method consists of the reduction of iron to the ferrous form in an oxalic acid-potassium oxalate buffered solution with magnesium ribbon. The method was altered to the extent that the final period of heat was at 87° C. instead of the 90° - 95° C. temperature which was unattainable in the water bath. The iron was determined by the colorimetric orthophenanthroline method (49), using an Evelyn colorimeter. Standard iron wire was prepared by washing in either dilute hydrochloric acid and water or in ether and dried at 110° C. before being used to make up standard solutions.

**Measurement of pH.** The pH measurements were made with a Leeds and Northrup instrument. The measurements were made on a 1:1 soil-water ratio (25 gm. to 25 milliliters). The solutions were stirred immediately following the addition of the
water and allowed to stand for 29 minutes. They were stirred again and the pH was determined 30 minutes after the addition of the water.

**Laboratory studies of the Fayette biosequence**

**Mechanical analysis** (Fayette biosequence). The less than 2 micron fraction clay is the most interesting fraction in the mechanical analysis data of this sequence (Table 2, Figure 1). The Tama profile, P-27, displays the least difference in clay distribution within the upper solum. The lower clay content of the lower layers may reflect the influence prairie has on soil development since it has been reported that the subsoils of Brunizem soils are less weathered than their Gray-Brown Podzolic equivalents (47). The Tama profile with the slight forest influence, P-427, does not have the rapid decrease in clay content in the subsoil. The clay content of the upper 10 inches of P-27 and P-427 are practically parallel, suggesting that the profiles have been developing in the same pattern. The surface difference is 1.2 per cent clay while the differences between the maximum clay contents is 1.6 per cent. P-27 has a thicker horizon of clay accumulation than P-427 although of a similar pattern. The maximum of P-427 occurs higher in the solum than does the maximum of P-27. It seems the difference of P-27 and P-427 could have been caused by
Figure 1. Distribution of Clay with Depth in the Profiles of the Fayette Biosequence
Table 2. Mechanical Analysis of the Profiles of the Fayette Biosequence

<table>
<thead>
<tr>
<th>Tama silty clay loam, P-27</th>
<th>Tama silty clay loam, P-427</th>
<th>Downs silt loam, P-428</th>
<th>Fayette silt loam, P-32</th>
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<td>Inches</td>
<td>Per cent</td>
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<td>&gt;50&lt;2μ</td>
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1Data reported by Smith, et al. (48).
the erosion of the surface layers of P-427 at some early date in its development. Thus, the weakly developed \( B_2 \) horizon could now be the A horizon of the present soil. Any clay moving by mechanical means from the surface horizons could be trapped in the upper part of the present B horizon since this layer would be more impermeable due to the previous soil formation processes. Consequently, a thinner \( B_2 \) horizon with a higher maximum clay content but not a higher total clay content could form. Such might be one explanation for the difference in the clay content of the upper solum of P-27 and P-427.

It would appear from the thinner zone of maximum clay content in the Downs profile, P-428, that it also may have undergone truncation. The lower layers of P-427 and P-428 are practically identical in clay contents. This suggests that the lower content of clay in the A horizon of forested soils as compared to Brunizem soils can be explained by a lack of clay formation or a complete breakdown of the colloid and primary minerals in the A horizon. The movement of clay by mechanical means from the A to the B horizon is apparently negligible. The relative differences between the A and B horizons of P-27 and P-32 also indicates the destruction of the clay or the lack of its formation in the A horizon of P-32.
The silt size fraction increases with a decrease in clay content of all the profiles. The sand size fraction is quite uniform in each of the profiles. A large portion of the sand fraction of P-427 and P-428 consisted of iron-manganese concretions. Some of the finer concretions which would have been retained on a 300 mesh screen were less dense and were decanted from the fraction. It seems the differences in the sand content of P-32 and P-27 as compared to P-427 and P-428 is due to differences in fractionation techniques. P-27 and P-32 have a per cent or more sand than is reported for other similar soils (1).

Total carbon and nitrogen (Fayette biosequence). The percent of total carbon and nitrogen (Table 3, Figures 2 and 3) in each profile vary directly with each other. The lower amount of carbon and nitrogen in the A horizon of P-27 is likely a result of cultivation. An average figure for the loss of organic matter from a Brunizem soil by cultivation is one-third (46) (58). Whiteside and Smith (63) found no differences between the cultivated and uncultivated sites below a depth of 12 inches. Thus, P-27 probably had an original organic matter content equal to that found in the A horizon of P-427.

The loss of organic matter due to forest encroachment on prairies apparently occurs first in the lower A and upper B
Table 3. Chemical Properties of the Profiles of the Fayette Biosequence

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<th>Sum of cations</th>
<th>% Base saturation Ca/Mg</th>
<th>Ratio Ca/Mg iron</th>
<th>% Free iron N</th>
<th>Per cent C</th>
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\(^1\)Data, except free iron, reported by Smith, et al. (48).
### Table 3. (Continued)

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Downs silt loam, P-428
Table 3. (Continued)

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Fayette silt loam, P-32:

|            | 0-1.5 | 1.5-4 | 4-7 | 7-10 | 10-13 | 13-16 | 16-19 | 19-22 | 22-25 | 25-28 | 28-31 | 31-34 | 34-37 | 37-40 | 40-43 | 43-46 | 46-49 | 49-54 |
|------------|-------|-------|-----|------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| pH         | 5.5   | 4.1   | 3.75| 3.9  | 4.2   | 4.4  | 4.4   | 4.4   | 4.4   | 4.4   | 4.4   | 4.4   | 4.5   | 3.9   | 4.7   | 4.7   | 4.6   | 4.6   | 4.6   |
| Milliequivs | 18.3  | 5.4  | 2.3 | 2.4  | 2.3   | 6.9  | 6.9   | 11.2  | 6.1   | 6.8   | 6.8   | 6.9   | 6.9   | 6.8   | 6.8   | 6.7   | 6.7   | 6.7   | 6.7   |
| % Base     | 0.29  | 0.48  | --  | 0.32 | --    | 0.42 | --    | --    | --    | 0.62  | --    | 0.55  | --    | --    | --    | --    | --    | 0.49  | 0.49  | 0.49  |
| Ratio      | 5.9   | 11.0  | --  | 7.5  | --    | 4.6  | --    | --    | --    | 5.6   | --    | 5.6   | --    | --    | --    | --    | --    | 4.5   | --    | --    |
| % Free iron| 28.1  | 19.2  | 11.2| 12.7 | 15.8  | 22.3 | 79.8  | 1.8   | 5.2   | 25.8  | 1.9   | 25.8  | 1.8   | 1.34  | 1.3   | 1.4   | 1.4   | 1.9   | 1.9   |
| Per cent   | 79.0  | 42.4  | 4.9 | 40.9 | 70.9  | 79.8 | 1.8   | 1.1   | 1.3   | 78.3  | 1.3   | 78.3  | 1.8   | ---   | ---   | ---   | ---   | 24.9  | 24.9  |

Free iron by Green (15), other data reported by Smith, et al. (48).
Figure 2. Distribution of Total Carbon with Depth in the Profiles of the Fayette Biosequence
Figure 3. Distribution of Total Nitrogen with Depth in the Profiles of the Fayette Biosequence
horizons since the nitrogen and carbon curves of P-27 and P-427 are almost the same below the 20 inch depth (Figures 3 and 4). It is assumed here that trees have become established on the site of P-427 in recent times. The similarity of these nitrogen and carbon curves below 20 inches suggests that if erosion had occurred at the site of P-427 that a Brunizem A horizon had developed in the exposed material which was formerly as high in organic matter as that of P-27.

From a study of the nitrogen and carbon curves for profiles P-27, P-427 and P-428, one can conclude that the A₁ horizon becomes thinner as the length of time increases since forestation, if the assumption is correct that P-27 has formed under prairie, and that forest encroachment on P-427 has been more recent than on P-428. The Downs and Fayette profiles appear to have a slight accumulation of carbon in the upper B horizon.

Profile pH (Fayette biosequence). The pH of the profiles in this biosequence indicates that the C horizon acidity of the transition profile is intermediate to the end members of the sequence (Figure 4 and Table 3). The upper A₁ horizon apparently becomes more alkaline as the forest encroaches on to the prairie. The Tama profile, P-27, has been cultivated but it appears that cultivation does not consistently alter the pH of Brunizem soils (54). The pH of the forested soils of
Figure 4. Distribution of pH with Depth in the Profiles of the Fayette Biosequence
the Fayette biosequence have their highest pH in the A horizons. There is less variation among horizons in the pH of profile P-27 than in the other soils.

The pH values of the B₂ horizon of P-427 are lower than that of P-428. This may result from the formation of a large quantity of organic acid in the initial decomposition of organic matter. The lower part of profile P-228 has a lower pH than P-227 which may indicate that the initial release of acids becomes distributed throughout the solum. Smith (47) found that forested soils had less carbonate in the subsoil than the equivalent prairie soil. The sequence follows this pattern in that increased forest influence results in a lower pH of the lower horizons.

**Exchangeable cations** (Fayette biosequence). The exchangeable calcium in the Tama profile, P-27, increases irregularly with depth to a maximum in the lower B horizon (Table 3). The other profiles in the sequence have their maximum exchangeable calcium in the surface layers. The calcium content of the A horizon decreases with increasing A₂ horizon development, as shown by the profile descriptions on pages 17 to 33, and reaches a minimum in the A₂ of the Fayette profile. The exchangeable magnesium tends to follow the same distribution pattern as the exchangeable calcium. However, the amount of magnesium in the A₂ horizon tends to increase
in proportion to the calcium with increased $A_2$ horizon development. The calcium-magnesium ratio in the subsoil apparently does not follow any set pattern (Figure 5). More will be said about the Ca-Mg ratio in a later section.

The content of exchangeable potassium in the A horizon decreases in going from the Brunizem end to the Gray-Brown Podzolic end of the sequence (Table 3). The potassium in the lower part of the profiles appears to decrease or be equal in P-27 and P-427, reaches a minimum in P-428 and increases in P-32.

The exchangeable hydrogen is approximately inversely related to the exchangeable calcium and pH. The exchangeable hydrogen in the lower solum increases progressively from the Brunizem to the Gray-Brown Podzolic soil of the sequence. The ratio of hydrogen to the bases as shown by the per cent base saturation (Figure 6) follows the pH. The increase in hydrogen in the B horizon of P-427 may result from organic acid formation as has been discussed.

**Per cent free iron** (Fayette biosequence). The free iron content, shown in Table 3 and Figure 7, is apparently directly related to the distribution of clay within each of the profiles of the sequence. The transitional profiles, P-428 and P-427, have a higher amount of free iron, about which more will be written in the summary section.
Figure 5. Exchangeable Calcium-Magnesium Ratios with Depth in the Profiles of the Fayette Biosequence
Figure 6. Per Cent Base Saturation with Depth in the Profiles of the Fayette Biosequence
Figure 7. Distribution of Free Iron with Depth in the Profiles of the Fayette Biosequence
Laboratory studies of the Weller biosequence

**Mechanical analysis** (Weller biosequence). From the data on the less than 2 micron fraction given in Table 4 and Figure 8, the less than 2 micron clay in the surface layers decreased from the Brunizem to the Gray-Brown Podzolic profile of the sequence. The maximum clay content of the Grundy and Pershing profiles occurs at the same depth, however, at a more shallow depth than in the Weller profile. It may be that the slight increase of clay in the maximum of P-429 over that of P-4 results from a mechanical trapping of some clay moving from the A horizon. In some Gray-Brown Podzolic soils, it has been interpreted that a destruction of clay occurs in the upper B horizon (51) so that the B2 horizon may be moving to lower depths. It is not known whether this is the explanation for the deeper clay maximum in the Weller profile, but it seems plausible.

The sand fraction, greater than 50 microns, is not available for the Grundy profile. However, in P-4 and P-429, the sand fraction consists primarily of iron-manganese buckshot concretions. The fraction indicates that there are more concretions in the upper layers of the Pershing profile than of the Weller profile. However, the amount of sand size material is quite similar and small in the two profiles.
### Table 4. Mechanical Analysis of the Profiles of the Weller Biosequence

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<th>Weller silt loam, P-4</th>
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<td>Inches / Per cent</td>
<td>Inches / Per cent</td>
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<td>&gt; 0.02μm / &lt; 2μm</td>
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1 Unpublished data, Iowa Agricultural Experiment Station.

2 Data reported by Green (15).
Figure 8. Distribution of Clay with Depth in the Profiles of the Weller Biosequence
**Total carbon and nitrogen** (Weller biosequence). Carbon and nitrogen are similarly distributed within each profile of the Weller biosequence as is shown by data in Table 5 and Figures 9 and 10. The organic matter of the transition profile, P-429, is intermediate to that of P-4 and P-3 in the subsurface (A$_3$ or A$_2$) horizon. However, the transitional soil has the most nitrogen and carbon in the lower portion of the solum. This may indicate that part of the decrease of organic matter in the surface layers is due to a movement into the lower layers. The lower amount of nitrogen and carbon in the surface layer of P-3 is likely due to cultivation, as has been discussed for the Tama profile, P-27.

**Profile pH** (Weller biosequence). The pH of the surface layers of the transition profile is higher than those of either the Brunizem or Gray-Brown Podzolic members of the sequence (Table 5 and Figure 11). However, the pH of the lower layers of the transition profile is intermediate to the other profiles. It suggests that the acidity of the A horizon is decreased while that of the lower solum increases. However, in comparing P-429 and P-4, it seems the pH decreases throughout the profile as the transition soil becomes a Gray-Brown Podzolic.
Table 5. Chemical Properties of the Profiles of the Weller Biosequence

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1 Unpublished data, Iowa Agricultural Experiment Station.
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<td>10.5</td>
<td>0.64</td>
<td>4.0</td>
<td>27.7</td>
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</table>

1Data reported by Green (15).
Figure 9. Distribution of Total Carbon with Depth in the Profiles of the Weller Biosequence
Figure 10. Distribution of Total Nitrogen with Depth in the Profiles of the Weller Biosequence
Figure 11. Distribution of pH with Depth in the Profiles of the Weller Biosequence
**Exchangeable cations** (Weller biosequence). From Table 5 it seems the quantity of exchangeable calcium is highest in the Brunizem profile, namely the Grundy, P-3, intermediate in the transitional profile (Pershing, P-429), and lowest in the Gray-Brown Podzolic profile (Weller, P-4). The exchangeable magnesium follows the same general distribution as the exchangeable calcium but increases proportionally in going from P-3 to P-429 as is indicated by the calcium-magnesium ratios (Figure 12). However, in the profiles developed under or influenced by forest the exchangeable calcium increases in proportion to the magnesium in the A horizon as compared to the Grundy profile, which developed under prairie.

The exchangeable hydrogen is inversely related to the exchangeable calcium in this sequence of profiles with P-4 > P-429 > P-3 in total quantity of exchangeable hydrogen. The per cent base saturation (Figure 13) indicates exchangeable bases tend to accumulate in the surface layer of the forested profiles while the amount of exchangeable hydrogen increases in the B and C horizons. The per cent base saturation of the profiles follows the same general pattern as the pH, exchangeable calcium and the calcium-magnesium ratios. The exchangeable potassium is variable in the profiles of the sequence. However, there appears to be a slight decrease in the upper part of the solum and an increase in the lower part in going from the Brunizem to the Gray-Brown Podzolic profiles.
Figure 12. Exchangeable Calcium-Magnesium Ratios with Depth in the Profiles of the Weller Biosequence
Figure 13. Percent Base Saturation with Depth in the Profiles of the Weller Biosequence
Per cent free iron (Weller biosequence). The per cent free iron is apparently related to the clay distribution in each of the profiles of this biosequence. The transitional profile, P-429, has the largest amount of free iron, P-4 has an intermediate amount, and P-3 has the lowest amount (Figure 14).

Laboratory studies of the Hayden biosequence

The Clarion profile, P-403, and the Hayden profile, P-402, were samples collected by others, and the Lester profile, P-430, was collected for this study in the same area as the other two profiles. It was found that the soils of this area were formed from two parent materials consisting of Cary till covered by a thin mantle of eolian sand, as is shown by the high sand content of the 0 to 19 inch layer of the Clarion profile (Table 6). Thus, information gained from this sequence would be difficult to evaluate in a genesis study.

The Lester profile, P-430, was analyzed for total nitrogen, exchangeable hydrogen and pH with the view that they would be comparable with the Hayden and Clarion profiles. The pH of the Lester profile reached a minimum in the 30 to 36 inch depth which suggests the Cary till contained some weathered material or that root activity had disturbed this horizon. Thus, no more analyses were made on this biosequence and
Figure 14. Distribution of Free Iron with Depth in the Profiles of the Weller Biosequence
Table 6. Mechanical Analysis of the Clarion and Hayden Profiles

| Inches depth | Clarion fine sandy loam, P-403 | | | Hayden loam, P-402 | | |
| | Per cent | | | Per cent | | |
| | >50 µ | 50-2 µ | <2 µ | >50 µ | 50-2 µ | <2 µ |
| 0-8 | 67.4 | 18.7 | 13.9 | 0-3 | 48.8 | 39.2 | 12.0 |
| 8-12 | 66.2 | 17.9 | 15.9 | 3-8 | 48.5 | 40.3 | 11.2 |
| 12-19 | 63.8 | 17.3 | 18.9 | 8-12 | 45.8 | 36.3 | 17.9 |
| 19-26 | 53.1 | 20.8 | 26.1 | 12-14 | 44.1 | 33.0 | 22.9 |
| 26-32 | 47.0 | 24.0 | 29.0 | 14-18 | 44.1 | 29.3 | 26.6 |
| 32-39 | 49.4 | 24.5 | 26.1 | 18-23 | 43.0 | 27.6 | 29.4 |
| 39-45 | 47.8 | 28.8 | 23.4 | 23-29 | 39.2 | 28.6 | 30.2 |
| 45-50 | 40.1 | 41.1 | 18.8 | 29-36 | 44.7 | 26.2 | 29.1 |
| 36-42 | 50.2 | 22.6 | 27.2 | 36-42 | 50.2 | 22.6 | 27.2 |
| 42-48 | 50.4 | 23.8 | 25.8 | 36-42 | 50.2 | 22.6 | 27.2 |
| 48-52 | 45.3 | 34.6 | 20.1 | 42-48 | 50.4 | 23.8 | 25.8 |

1Unpublished data, Soil Survey Division, Bureau of Plant Industry.
efforts were directed toward the more uniform loess derived soils.

The nitrogen content (Table 7 and Figure 15) of the A horizon of the Lester profile is intermediate to that of the Clarion and Hayden profiles. The Clarion profile was collected from a road ditch bank and apparently was cultivated at one time so that the nitrogen value in the surface layer is low. Exchangeable hydrogen within the profiles of this biosequence is apparently greatest in the Hayden, intermediate in the Lester, and lowest in the Clarion (Table 7). The maximum is found in the surface layers of the Lester and Clarion profiles and in the B horizon of the Hayden profile. The Lester profile has a second maximum in the lower part of the solum.

The per cent base saturation (Table 7) of the Hayden profile is slightly lower than the Clarion profile. The calcium-magnesium ratio is higher in P-403 as compared to P-402. The exchangeable potassium and per cent free iron are higher in P-402 than in P-403 (Table 7).
<table>
<thead>
<tr>
<th>Inches depth</th>
<th>pH</th>
<th>Milliequivalents/100 gms</th>
<th>Sum of cations</th>
<th>% Base saturation</th>
<th>Ratio Ca/Mg</th>
<th>% Free iron</th>
<th>Per cent N</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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Table 7. Chemical Properties of the Profiles of the Hayden Biosequence
Table 7. (Continued)

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<tr>
<th>Inches depth</th>
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<th>Milliequivalents/100 gms</th>
<th>Sum of cations</th>
<th>% Base saturation</th>
<th>Ratio Ca/Mg</th>
<th>% Free iron</th>
<th>Per cent N&lt;sup&gt;1&lt;/sup&gt;</th>
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Lester loam, P-430

1 Reported on air dry bases.
Table 7. (Continued)

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<th>Milliequivalents/100 gms. H</th>
<th>Sum of cations</th>
<th>% Base saturation Ca/Mg</th>
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<th>% Free iron</th>
<th>Per cent N</th>
<th>Per cent C</th>
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<td>0.82</td>
<td>0.028</td>
<td>1.72</td>
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Hayden loam, P-402
Figure 15. Distribution of Total Nitrogen with Depth in the Profiles of the Hayden Biosequence
DISCUSSION AND SUMMARY

Discussion of Laboratory Results of the Three Biosequences Studied

As has been discussed, the individual biosequences are different in their degree of profile development. The profiles of the Hayden biosequence have minimal development, those of the Fayette biosequence have medial development, and those of the Weller biosequence have maximal development.

Clay distribution in the profiles

The Pershing and Downs profiles are intermediate to their associated Brunizem and Gray-Brown Podzolic profiles in the content of clay in the surface layers. Shrader (43) has reported that the transitional soils have intermediate clay contents in the surface horizons. The maximum clay contents of the respective profiles in the Fayette and Weller biosequences occurs in the $B_2$ horizons at approximately the same depth, namely at about 22 inches. The minimum clay content of the $A$ horizons of the Weller, Pershing, Fayette and Downs profiles are quite similar but the latter two have about 12 per cent less clay than the former two profiles in the maximum clay zone of the $B_2$ horizon. The Brunizem profiles of biosequences
I and II have less clay in the lower horizons \((B_2-C_1)\) than the respective associated forested soils which suggests the rate and depth of weathering of these horizons is increased under forest as compared to prairie.

A ratio of the minimum clay content of the A horizon and the maximum clay content of the \(B_2\) horizon apparently are indications of the degree of development in these profiles of the Fayette and Weller biosequences. The comparison probably is valid only in soils which would tend to form zones of accumulation of clay as in a \(B_2\) horizon whether by illuviation, formation in situ or by both processes. This ratio appears to be a measure of the extent to which these processes have proceeded.

The clay ratio has been calculated for a number of profiles (Table 8). The three Tama soils have similar ratios of about 0.8. For two Downs profiles, the ratios are 0.65 and 0.68. The two Fayette profiles (P-32 and an unnamed profile) have different ratios, 0.58 and 0.46, respectively. One of the Fayette profiles has a ratio quite similar to the ratio of the Traer silt loam profile which has a ratio of 0.44. The clay contents for these two profiles were taken from graphs presented in the Tama County Soil Survey Report (1). No description is given of the topography of the sampling sites of these profiles. It is possible that this Fayette profile was collected on a nearly level site and might be included with the Stronghurst series had it been used in the county.
Table 8. Ratio of the Minimum Clay Content in the A Horizon to the Maximum Clay Content of the B Horizon of Some Soils

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Profile number</th>
<th>Ratio</th>
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<tr>
<td><strong>Fayette biosequence</strong></td>
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<td></td>
</tr>
<tr>
<td>Fayette silt loam</td>
<td>P-32</td>
<td>0.58</td>
</tr>
<tr>
<td>Downs silt loam</td>
<td>P-428</td>
<td>0.65</td>
</tr>
<tr>
<td>Tama silty clay loam</td>
<td>P-427</td>
<td>0.80</td>
</tr>
<tr>
<td>Tama silty clay loam</td>
<td>P-27</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Analysis in Tama County Soil Survey Report (1)**

<table>
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<tr>
<th>Profile type</th>
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<th>Ratio</th>
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</thead>
<tbody>
<tr>
<td>Traer silt loam</td>
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<td>0.441</td>
</tr>
<tr>
<td>Fayette silt loam</td>
<td>---</td>
<td>0.46</td>
</tr>
<tr>
<td>Downs silt loam</td>
<td>---</td>
<td>0.68</td>
</tr>
<tr>
<td>Tama silt loam</td>
<td>---</td>
<td>0.85</td>
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</table>

**Weller biosequence**

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</tr>
<tr>
<td>Pershing silt loam</td>
<td>P-429</td>
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<tr>
<td>Grundy silt loam</td>
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**Analysis reported by Ulrich (58)**

<table>
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<th>Profile type</th>
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<tr>
<td>Marion silt loam</td>
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<td>0.27</td>
</tr>
<tr>
<td>Edina silt loam</td>
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**Hayden biosequence and analysis reported by Green (15)**

<table>
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<tr>
<th>Profile type</th>
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<tr>
<td>Clarion fine sandy loam</td>
<td>P-402</td>
<td>0.372</td>
</tr>
<tr>
<td>Clarion loam</td>
<td>P-49</td>
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</tr>
<tr>
<td>Hayden loam</td>
<td>P-403</td>
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<tr>
<td>Hayden silt loam</td>
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</tr>
<tr>
<td>Hayden loam</td>
<td>P-396</td>
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1 Estimated from graph.
2 Slight development, value = 1 (?).
The ratios of the profiles in the Weller biosequence are lower than the equivalent profile in the Fayette biosequence. The transitional soils appear to be intermediate in the value of the ratio as compared to the Brunizem or Gray-Brown Podzolic soil of the same biosequence.

The Edina, Marion and Traer soils are classified with the Argipan Planosols. The first two are formed under prairie and forest, respectively, with similar other factors of soil formation. The Edina profile has a higher ratio than the forested Marion profile. The Traer is also a forested Argipan but its effective weathering period is assumed to be shorter than that of the Marion profile.

The Hayden and Clarion profiles belong to minimal Gray-Brown Podzolic and Brunizem soils, respectively, and are formed from Cary or Mankato glacial till. The parent material from which these soils are formed is quite heterogeneous so that the derived ratios are less useful for genesis studies.

The ratio of the clay content in the $A_1$ and/or $A_2$ horizon to the clay content in the $B_2$ horizon appears to be a useful indicator of the degree of profile development for the medial and maximal Brunizems, transition soils or Gray-Brown Podzolic soils and of their Argipan associates if the parent material is a relatively uniform material such as loess. The ratio becomes lower as the degree of development increases in these soils.
Total carbon and nitrogen data of the profiles

The total carbon and nitrogen values for the three sequences studied indicate that the organic matter content of the transitional profiles is intermediate to the associated Brunizem and Gray-Brown Podzolic soils. Organic matter decreases in the lower part of the A horizon following encroachment of forest on a Brunizem soil. The $A_1$ horizon of the transition soils, as indicated by the nitrogen and carbon data (Figures 2, 3, 9, 10 and 15), becomes thinner as the time since forest encroachment increases. The transitional soil apparently loses the most organic matter in the basal portion of the $A_1$ horizon as it becomes a Gray-Brown Podzolic soil.

The nitrogen values of the profiles in the Fayette and Hayden biosequences indicate that there is less nitrogen in the lower B horizon of the transitional soils than in either the Brunizems or Gray-Brown Podzolic soils. The Pershing profile has more nitrogen and carbon in the lower B horizon than the Grundy and Weller profiles. However, as only one profile of each series has been sampled and as trends in nitrogen are not readily apparent, variations in the data may be due to variations in the sample sites.
Exchangeable bases of the profiles

The pH curves (Figures 4 and 11) and per cent base saturation curves (Figures 6 and 13) are closely related in each profile. Forest vegetation apparently returns more bases to the surface layers than the prairie as the transitional soils have a higher base status in the surface layers than the Brunizem soils. The Brunizem soils of these sequences have been cultivated which may alter their base status. Whiteside and Smith (63) have studied changes caused by the cultivation of Brunizem soils and found the exchange capacity of the surface layer may decrease due to a loss of organic matter caused by cultivation but the base saturation was little affected. No consistent differences have been reported in the pH of cultivated and undisturbed Brunizem soils.

Apparently very few chemical analyses have been made of prairie plants. Fraps and Fudge (10) report that little blue stem contains 0.75 per cent lime (0.53 per cent calcium). Stansel, et al. (50) report that the foliage in a pasture, largely of little blue stem with some big blue stem and bushy blue stem, yielded 3,896 pounds of air dry material containing about 0.37 per cent calcium. They reported a few percentages for magnesia (MgO) which ranged from 0.37 to 0.47 per cent. Kik (21) found big and little blue stem aerial parts contain approximately the same percentages of calcium, with a
range of about 0.2 to 0.3 per cent, and an average of about 0.24 per cent.

The top growth of tallgrass prairie has been estimated as being from 1,600 to 4,400 pounds per acre (18). This range includes the yield reported for the pasture consisting primarily of little blue stem. The maximum yield (4,400 pounds) with the highest percentage of lime (0.53 per cent calcium) would contain 23 pounds of calcium. With an average percentage (0.37 per cent) the calcium content for the higher yield would be 16 pounds of calcium per acre of grass forage. The magnesium content seems to be slightly lower with an estimated average of 0.25 per cent. Thus, the maximum yield would contain 11 pounds of magnesium.

Metz (30) has reported the calcium and magnesium percentage in leaves of various trees: leaves of white oak, *Q. alba*, contained 1.69 per cent calcium and 0.3 per cent magnesium; leaves of post oak, *Q. stellata*, contained 0.96 per cent calcium and 0.22 per cent magnesium. Some of the other plants had higher calcium and magnesium contents so that the total calcium and magnesium returned to the soil may be higher than could be expected under Iowa conditions. He found that hardwood forests returned from 75 to 102 pounds of calcium and from 16 to 23 pounds of magnesium in the leaf fall. The average weight of leaf fall from three hardwood stands was 3,800 pounds per acre. If one assumes all of this material was post oak
leaves, then there would be 45 pounds of calcium and 11 pounds of magnesium in the leaf fall per acre in one year. Thus it seems that calcium returned to the surface soil layers by the leaf fall of a representative deciduous forest might be about double that returned by a representative prairie vegetation. However, the magnesium content of the maximum prairie grass yield and of post oak would appear to be about equal. Chandler (6) found slightly lower quantities of bases were returned by the leaves of deciduous forests as compared to Metz's data. However, the quantity of calcium returned was higher than could be expected from prairie vegetation if the available data are used.

The higher pH and base status of the surface layer of the transitional soils apparently could be due to a greater return of bases to the surface layer by hardwood leaves than by the aerial parts of prairie grass. This conclusion assumes that the addition of woody tissue by the death of trees would be at a minimum in the transitional soils. The addition of woody tissue, low in bases, may account in part for the lower base status of the transitional and Gray-Brown Podzolic B and C horizons as compared to that of the Brunizem soils. It may be that the woody tissue of the aerial parts of the trees decay above ground with very little influence on the base status of the soil. The maintenance of a high base status of the $A_1$
horizon of the forested soils appears to be due to the annual return of bases by leaf decay.

The ratio of exchangeable calcium to magnesium in the surface layers of the Fayette and Weller biosequence (Figures 5 and 12) suggests that more calcium is returned to the surface with forest vegetation than with prairie vegetation. This is in agreement with the estimates of the amount of calcium and magnesium in the non-woody aerial parts of the vegetation.

In the lower part of the solum of the Weller biosequence, this ratio of calcium to magnesium decreases from the Grundy profile to the Pershing profile and is lowest in the Weller profile. Apparently the quantity of calcium decreases in proportion to the magnesium on the exchange system as profile development progresses (3) (58). Thus the Ca/Mg ratio indicates that the transitional soil of the Weller biosequence is more weathered than the Brunizem associate and less weathered than the Gray-Brown Podzolic associate. This relationship is less definite in the solum of the profiles of the Fayette biosequence, possibly due to the younger effective age of these soils. However, in the A horizon of the forested profiles of the Fayette biosequence, the ratio becomes less with increased development of the A₂ horizon.

Both the Ca/Mg ratio (Figure 5 and 12) and the ratio of the clay in the A horizon to the clay in the B horizon (Table 8) are useful as indicators of degree of profile development.
The two ratios are in better agreement in the maximally developed Weller biosequence than in the medially developed Fayette biosequence. In the latter, the clay ratio seems a better indicator of the amount of profile development than the base ratio.

Free iron distribution in the profiles

The method used in this study for the extraction of iron has been used as a measure of the free iron oxide content of soil (52) (15). It is possible that any partially decomposed primary minerals or freshly formed secondary minerals with imperfect lattice structures might release iron during the extraction procedure used in this study. Apparently, nontronite will be decomposed by some methods of iron oxide extraction (44). Swenson (52) thought the method employed in this study had little effect on nontronite minerals. Deb (8) has compared several methods for extracting iron and found that more iron was released by repeated extractions. Matelski (29) has demonstrated petrographically that some primary minerals are attacked by the nascent hydrogen procedures for the removal of iron oxides.

Several iron solutions were allowed to stand for 15 days to see if there would be a continued release of iron. Table 9 is a summary of this release.
Table 9. Apparent Per Cent of Free Iron in Soil with an Increase in Time Since Extraction

<table>
<thead>
<tr>
<th>Solution</th>
<th>Days since extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>0.57</td>
</tr>
<tr>
<td>3</td>
<td>0.56</td>
</tr>
<tr>
<td>4</td>
<td>0.78</td>
</tr>
<tr>
<td>5</td>
<td>0.74</td>
</tr>
<tr>
<td>6</td>
<td>0.79</td>
</tr>
</tbody>
</table>

\(^1\)Values are high since no corrections were made for the aliquot taken from the solution for the previous determinations.

From the above discussion, it seems the method employed for free iron is empirical. However, several samples analyzed by Green (15) were reanalyzed and the results were very similar so that it appears duplication is possible by different analysts.

The free iron distribution within any one profile seems to be related to the clay distribution. The transitional soils of the Fayette and Weller biosequences have more free iron in the profile than the associated Brunizem or Gray-Brown Podzolic profiles. This might result from an accelerated release of iron in the decomposition of minerals, particularly in the formation of the A\(_2\) horizon. By the time a Gray-Brown Podzolic soil is formed, it is postulated this mineral decomposition
rate would slow down sufficiently so that some of the free iron would be removed from the solum or be fixed more firmly in secondary aluminosilicate minerals.

There appear to be a number of factors which are different in the soils of a biosequence which may effect the movement of iron. It has been reported that forest soil organic matter has a greater reducing capacity than prairie soil organic matter (31). This may favor the removal of iron from the solum of the forested soils since ferrous iron is considered to be more mobile than ferric iron (66). If the water table is lower under forest vegetation than under grass, it would appear better aeration conditions should exist in the forested soils to increase the amount of oxidation of ferrous iron to the ferric form and reduce the movement of iron. A lowering of the water table might cause any iron released, or complexed in a soluble form, to be leached from the soil.

The brighter solum colors of the Gray-Brown Podzolic soils as compared to their transitional associates might be related to the form of the free iron present. Possibly, the iron oxides in the Gray-Brown Podzolic soils are in a more dehydrated form to give a more reddish shade than is found in the transitional soils.
Profile Characteristics of the Transitional Soils

The visible profile features of the transitional soils are different from those of the associated Brunizem and Gray-Brown Podzolic soils as is evident from the descriptions given of the profiles studied. The development of the light colored $A_2$ horizon seems to be the best observable feature in distinguishing the transition soils from the Brunizem soils. The development of the $A_2$ horizon also appears to be correlated with the chemical changes which take place in the transformation of a Brunizem to a Gray-Brown Podzolic soil. In the initial development of the $A_2$ horizon, the $A_1$ horizon may have a higher base status than its Brunizemic associate so that the increase of acidity in the lower layers is not as serious to crop growth in at least the first few years of cropping. According to McCracken (27), some farmers in Polk County say they have little trouble in establishing stands of legumes on the transitional soils. Measurements of available potassium and phosphorus were not made so that it is not possible to say here what influences these factors would have on crop plants.

There is little difference between the textures of B horizons of the Brunizem, transitional and Gray-Brown Podzolic soils of the biosequences studied so that it seems that B horizon textures cannot be used consistently as a criteria for the separation of the soils of a biosequence. There appears to be
a decrease in the amount of subsoil mottling in going from the Brunizem soil to the transitional soil to the Gray-Brown Podzolic soil. The lower B and C horizons appear to have a more uniform matrix color with increased forest influence. The increase in the homogeneity of the color of the lower layers is more apparent in the more poorly aerated Pershing soils than in the Downs or Lester soils.

The chief difference in the moist subsoil colors of the transitional to Gray-Brown Podzolic soils occurs between the matrix colors of the peds and the reddish cast of the ped coatings. Under dry conditions, some coatings frequently appear quite grayish. It seems that soil development in the lower part of the profile occurs more rapidly under forest than under prairie.

The dark colored $A_1$ horizon of the Brunizem is probably the horizon feature retained longest under forest vegetation. The horizon progressively becomes thinner but apparently retains its color until the final stages of the transformation of the Brunizem into the Gray-Brown Podzolic soil. The $A_2$ horizon apparently becomes lighter textured and lighter colored progressively after some of the initial Brunizemic organic matter is lost.

The $A_2$ horizon develops stronger platy structure with an increase of time since forestation. The B horizon structure apparently is slightly stronger in the transitional soils than
in the Brunizem soils. However, the Gray-Brown Podzolic soils of the Fayette and Weller biosequences have much stronger B horizon structure than the associated transitional soils.

It seems the A horizon color and texture change is the best guide for the field mapping of transitional soils. The A horizon apparently is the first horizon to undergo change with either an invasion of forest on prairie or of prairie on forested soils. Smith, et al. (48) have reported that some Tama soils in eastern Iowa have the A horizon of the Brunizems but B horizon structure of Gray-Brown Podzolic soils. In these soils, the B horizon structure may be a relict from a previous forest influenced soil which had been reinvaded by prairie. On the whole, it would seem the A horizon is the best guide for recent vegetative changes. But the B horizon may be more valuable as an indicator of older vegetative shifts.

The Genesis of a Brunizem - Gray-Brown Podzolic Transitional Soil

The encroachment of trees on a Brunizem soil brings about a simultaneous (1) loss of organic matter in the lower A horizon, (2) a decrease in pH in the upper B and lower A horizons, and (3) an increase in the pH, per cent base saturation and ratio of exchangeable calcium to exchangeable bases in the surface layer. The $A_1$ horizon becomes thinner and more acid
as the forest influence becomes greater. From this study, the lighter textured \( A_2 \) horizon forms after the loss of organic matter is readily observable in the field. The slight increase in clay content of the B horizon of the forested soils as compared to the Brunizem associate occurs during the initial steps of the formation of the light textured \( A_2 \) horizon.

The formation of stronger structural peds with a more reddish color occurs after the soil transformation has progressed to the Gray-Brown Podzolic side of the transition. This \( B_2 \) horizon change apparently occurs in voids left by the decomposition of tree roots. The decrease in base saturation or pH in the lower part of the solum apparently is initiated during the beginning stages of the transformation of the Brunizem soil.

The platy structure of the A horizon probably develops rapidly as clay is lost from the horizon. It has been observed in this study that the down facing surface of these platy peds is darker colored than the up facing surfaces of the peds. However, as the \( A_2 \) horizon becomes more developed both surfaces become lighter in color and less different. Traces of iron oxides become attached to the basal portion of the peds in some cases. A petrographic study has been made by McMillan and Mitchell (28) of the \( A_2 \) horizons of some Canadian soils. They found some platy \( A_2 \) horizons which had the darker colored side facing upward in the horizon. This may mean that under certain
conditions the $A_2$ horizon may be destroyed possibly by a change of vegetation or of the water table level of the soil.

**Classification of the Transitional Brunizem - Gray-Brown Podzolic Soils**

The Russian soil scientists were apparently the first to become interested in the changes induced in a grassland soil by the encroachment of forests. Some Chernozem soils of Russia had undergone forestation and had intermediate properties between the forested soils and the Chernozems.

According to Glinka (14), Siberceff used the zonal concept of soil geography for classification purposes. The Zonal soils are those developed under the predominant so-called active soil forming factors of the area. The Intrazonal soils originated by local conditions of soil formation which predominate over the zonal forces. The Azonal soils, according to Siberceff, are incompletely developed soils found on the borders of true soil zones and which could not be referred to any particular zone.

Siberceff's Zonal Gray Forest soils may have included the transitional forest-Chernozem intergrades. The Gray Forest soils of Russia have been interpreted as being equivalent to the Gray Wooded soils of western Canada and the United States (56). However, it appears these transitional soils could have
been included with Imperfectly Developed Azonal soils. According to Glinka

In his first works Dokutschajeff considered the forest soils as independent types with characteristics of their own developed in the Steppe region independent of the Tschernosems and under the influence of special conditions.

The word, "type," in this case means approximately the same as the present Great Soil Group. Glinka's classification scheme included the forest-Chernozem transitional soils (degraded Tschernosems) in his "Podsolic soils of secondary origin" which is a substage of the Ektodynamomorphic soils developed with average moisture conditions. The individual varieties (series ?) were identified according to the degree of podzolization.

Kellogg (20) called the Gray-Brown Forest-Prairie transitions "intra-zonal" soils. This usage of the word "intra-zonal" means that these soils occurred between the zones of Gray-Brown Forest (G. B. Podzolic) and Prairie (Brunizem) soils and had some profile characteristics of both groups. The profile descriptions and analysis of the biosequences in this present study indicate the intermediate nature of the Brunizem - Gray-Brown Podzolic transition soils. The forest influenced grassland soils appear to occur in all topographic positions in Iowa (46). Some of the biosequences found on different topographic conditions are shown in Table 10. There are probably transitional soils for all the topo-sequence
Table 10. The Series Forming Some Soil Biosequences of Iowa

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Prairie</th>
<th>Prairie - trees</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tama (B)1</td>
<td>Downs</td>
<td>Fayette (GB)1</td>
<td></td>
</tr>
<tr>
<td>Muscatine (B)</td>
<td>Atterbury</td>
<td>Stronghurst (GB)</td>
<td></td>
</tr>
<tr>
<td>Garwin (W)</td>
<td>Walford</td>
<td>Traer (P)</td>
<td></td>
</tr>
<tr>
<td>Dickinson (B)</td>
<td>----2</td>
<td>Lamont (GB)</td>
<td></td>
</tr>
<tr>
<td>Clarion (B)</td>
<td>Lester</td>
<td>Hayden (GB)</td>
<td></td>
</tr>
<tr>
<td>Nicollet (B)</td>
<td>LeSuer</td>
<td>----2</td>
<td></td>
</tr>
<tr>
<td>Webster (W)</td>
<td>(Dundas ?)</td>
<td>Ames (P)</td>
<td></td>
</tr>
<tr>
<td>Grundy (B)</td>
<td>Pershing</td>
<td>Weller (GB)</td>
<td></td>
</tr>
<tr>
<td>Haig (W)</td>
<td>Belinda</td>
<td>Marion (P)</td>
<td></td>
</tr>
<tr>
<td>Otley (B)</td>
<td>Ladoga</td>
<td>Clinton (GB)</td>
<td></td>
</tr>
<tr>
<td>Mahaska (B)</td>
<td>Given</td>
<td>Keomah (GB)</td>
<td></td>
</tr>
<tr>
<td>Taintor (W)</td>
<td>Rubia2</td>
<td>Berwick (P)</td>
<td></td>
</tr>
</tbody>
</table>

1(B) - Brunizem; (GB) - Gray-Brown Podzolic; (W) - Wiesenboden; (P) - Planosol.

2No series recognized.

associates of the major Brunizem and Gray-Brown Podzolic soil series. The total area of these transitional soils will undoubtedly be very small in many cases. The mapping of them will be difficult and probably many will be included with other series for cartographic convenience.

The classification of these transitional soils of the Brunizems and Gray-Brown Podzolics has been neglected in the
published work. Thorp and Smith (56) recognized "soils of the forest-grassland transition" at the sub-order level. They have listed Degraded Chernozems and Non-calcic Brown or Shantung Brown soils at the Great Soil Group level. There are numerous of these transitional Brunizem - Gray-Brown Podzolic soils established at the series level as has been pointed out. Thus, there appears to be a void in the classification of these soils at the Great Soil Group level.

The analytical data presented for the transitional profiles indicate that they are not clearly members of either of the established Great Soil Groups. One can reason that if they are not one or the other, then they must be something new. Of course, this same sort of reasoning can be carried to the extreme that only one finite point on the soil landscape is clearly a unit by itself.

If one uses the intergrade concept of soils as used by Cline (7), then there would be (1) transitional soils more like the Brunizems than like the Gray-Brown Podzolic and (2) transitional soils more like the Gray-Brown Podzolic than like the Brunizems in the Brunizem soils which have been forested. However, due to the narrow areas of these transitional soils, it would not be feasible to recognize these soils at the series level. The cartographic and field mapping detail would have to be increased to show this two-fold separation within these transitional soils. It appears impractical if not impossible
to use a two-fold intergrade concept in these transitional soils. The inclusion of the transitional soils with either the Gray-Brown Podzolic or the Brunizem at the Great Soil Group level would be equally undesirable if one considers only the morphology of the soils. Only half of most areas would be more like the Brunizem than like the Gray-Brown Podzolic or vice versa.

The transitional soils may be considered as being Gray-Brown Podzolics by reasoning that the Brunizem soil traits are relic and are in the parent material of the soil which is now being formed. The transitional soils could then be considered as forming a litho-chronosequence with the Gray-Brown Podzolic soils and not necessarily as a biosequence. However, it has been reported (26) that certain trees are more capable of invading prairie than are other trees so that a biosequence may exist in tree species between the Gray-Brown Podzolic and transitional soils.

The inclusion of the transitional soils with the Gray-Brown Podzolics would widen the range of soil characteristics in this Great Soil Group. If one considers that the transitional soils must be included with either the Gray-Brown Podzolics or Brunizems, then there is probably more justification for the inclusion of them with the former. The assumptions are that the biotic factor of soil formation is constant or weakly expressed between the transitional soils and the Gray-
Brown Podzolics and that they form a strong litho-chronosequence.

The transitional soils probably differ from the established Great Soil Groups as much as the Degraded Chernozems do from their associated Great Soil Groups. Presumably the criteria for the separation of the Degraded Chernozems from their associated Great Soil Groups would be similar to the criteria used in the separation of the transitional soils from the Brunizems and Gray-Brown Podzolics. There appears to be no justification for the recognition of the Degraded Chernozems as a Great Soil Group (56) if they are included under the suborder of the Forest-Grassland Transition soils and the non-recognition of the transitional Brunizem - Gray-Brown Podzolic soils as a Great Soil Group under the same suborder.

It seems advisable that a new Great Soil Group should be established for the transitional Brunizem - Gray-Brown Podzolic soils. A new Great Soil Group would indicate what the soils are without any bias as to their Brunizemic past or to, presumably, their Gray-Brown Podzolic future. A sound natural classification scheme probably should be based on the present state of the system with no inferences being made of what the members have been or will be other than in understanding how they have come to be in the present state.

A subtle way of establishing a new Great Soil Group would be to recognize the Brunizem - Gray-Brown Podzolic intergrade
soils at the Great Soil Group level. This designation would carry a bias as to the relationship of these intergrades to the established categories. Two sub-groups (families ?) could be placed below this intergrade unit, one for the soils formed by the action of trees on Brunizem soils, and the second for the soils formed by grass invading onto the Gray-Brown Podzolic soils such as apparently occurred in eastern Iowa (48). It may be that many of the so-called Brunizem soils in the states east of Iowa would also fall into the second sub-group.

The establishment of a Great Soil Group, or its equivalent, for the transitional Brunizem - Gray-Brown Podzolic soils would seem to be a temporary way of overcoming the obstacle to their classification. It does not solve the basic weakness of the present classification system, to wit, the separation of the soil continuum into discrete intervals without recognizing that intergrade areas will always exist between any possible separations of that continuum.

Revisions will have to be made in the basic assumptions of the soil classification scheme before this fault can be eliminated. The present system is based on the assumption that intergrade soils can be assigned to the proper category on their being more similar to the modal of one category than to the modal of the other category. It seems in a matter of time that any grouping of members based on this practice will fail since soils will be found which have a modal that will
be on the exact border between the modals of the next higher category.

A classification method should be devised to show members of a category which are intermediate to the recognized modals. The field mapper has to make decisions as to the natural soil units which can be separated at the series level and below. Thus, it is the field mappers' responsibility to make the decision as to what ranges of soil properties are in the natural lower categories. Intergrade areas between the units which he establishes will be assigned to one of these established units. Probably, in most instances, these intergrade areas will occur on the boundary of "modal" areas of the units in question. It seems the natural soil units which the soil mapper recognized in the field may be composed of soils with a population median which is exactly between the recognized modals of the higher categories. Thus, it seems the truly natural units of the classification scheme are the soil units which are recognized in the mapping units. The higher categories are synthesized from these units.

There is little published information of the family classification of soils. The families which have been formed, apparently, consist of series which have similar profiles but are geographically separated and may be derived from different types of parent material. The population median of the series in the family is apparently about the same in regard to their
relationship to the Great Soil Group. Thus, it seems the discussion of the intergrade area concerns mainly the relationship of the series to the Great Soil Group.

It is postulated that a new term should be coined for the "series" which are intergrades between Great Soil Groups. These intergrades are natural units on the soil landscape and have a population median which is intermediate to the modals of the Great Soil Groups. The population median should not be thought of as being a finite point but as being a narrow range which includes the members of the population which occur most frequently. The extent of the range in the median members is probably dependent on the number of independent variables which are considered in classifying the population. The distribution of the soil characteristics as independent variables may all follow that of a normal population. However, the occurrence of one of the variables does not indicate the presence or absence of the other variables. It is fortunate that the characteristics of the natural soil units vary normally as dependent variables so that the presence of one will generally require the presence or absence of others and the median members will have a narrow range of characteristics. The population median will depend on several different characteristics at the lower levels of the classification scheme but it will depend on fewer of these characteristics at higher categorical levels.
It seems the word "sequence" might be suitable for the series equivalent in the intergrade area between Great Soil Groups. It has a genetic bias from its previous use and would imply that there was a genetically formed gradation in the members of the "sequence" between the Great Soil Groups. The "sequence" would differ from the complex in that it is a natural soil unit which cannot be divided into smaller categories while the complex can be divided into smaller recognized units at the series level but, due to the complexity of their occurrence in the area, it is deemed not cartographically feasible to do so. The population median of the "sequence" would occur at the center region between the modals of the Great Soil Groups so that the soil population on either side of the median range would belong to different Great Soil Groups.

The dual character of the "sequence" would have to be carried into the family category. Possibly the use of "sequence families" and "series families" would be adequate to differentiate between soils found between Great Soil Groups and those within a group. The "sequence family" would consist of several "sequences" which had similar development conditions. It appears the original definition presented for the "sequence" restricts the "sequence family" from having a wide range of properties which would influence the classification of the family category into Great Soil Groups. The "sequence family"
would have to be shown under both of the Great Soil Groups or in some intermediate sub-position between them if the arrangement were shown diagrammatically. The soil individuals within the "sequence families" would have a population median which was identical to the end member range of the Great Soil Groups. Thus, on either side of the individual soil members which occupied the exact center of the "sequence family" population median, there would be members of two different Great Soil Groups. Undoubtedly, the exact median would never be known since it would be very difficult to place this individual due to the lack of having the soil classification categories established on a range of characteristics. That is, the present Great Soil Groups are not accurately defined with regard to the range of characteristics which are permissible within them.

It appears the same sort of a scheme would have to be used in the classification of the sub-orders and orders. Very little written material is available as to the criteria used in the classification of the higher categories. It seems that these higher categories would also form a continuum which could not be considered as being composed of discrete categorical members.

The introduction of a term for the intergrade soils which cannot be assigned to a definite Great Soil Group appears to be one method of preserving more of the "natural continuum" of
soils in their classification. The present system seems to lack a method for preserving the "continuum." Although the use of a category such as "sequence" may add to the number of units below the Great Soil Groups, it may be possible to eliminate some of the doubtful Great Soil Groups, such as the Degraded Chernozems and the Brown Podzolics. It may be a way of classifying the soils which are developing due to a change of one of the soil forming factors, such as climate. The relic Gray-Brown Podzolic profiles which appear to have Podzols developing in them could probably be classified in such a system which preserved more of the "continuum."

Several methods have been presented which could be used in the classification of the transitional Brunizem - Gray-Brown Podzolic soils. Each of the proposed methods have certain disadvantages and advantages. Undoubtedly, the perfect system for the classification of natural bodies will not be found until all knowledge has been accumulated. Presumably, this will not occur in the immediate future. Any method of classifying soils will have certain disadvantages until this idealistic period is attained.
The study was made of three soil biosequences to determine some of the profile changes which occur as Brunizem soils are transformed to Gray-Brown Podzolic soils by the encroachment of forests. The first changes apparently are: (1) a decrease in the organic matter content, pH, base saturation, and Ca/Mg ratio of the lower A horizon; (2) an increase in the pH, base saturation, and Ca/Mg ratio of the upper A horizon; and (3) a decrease in the pH, an increase in clay content, and a decrease of the base saturation of the B horizon. The second stage in the transformation is: (1) a continuation of the above processes operating in the lower A horizon, a loss of clay with the formation of platy structure in the A₂ horizon, and a narrowing of the thickness of the A₁ horizon; (2) a continuation of the processes operating in the B horizon but with no increase in the maximum clay content and with the development of stronger structural peds with reddish coatings. The third step of transformation of the transitional soil to the Gray-Brown Podzolic soil is a continuation of the processes in step two with particular emphasis on the development of stronger structural peds in the B horizon, increased platiness in the A₂ horizon structure, and the gradual loss of the dark colored Brunizem A₁ horizon.
The loss of organic matter as indicated by the color and thickness of the $A_1$ horizon is probably the best criterion to use in mapping the transitional Brunizem - Gray-Brown Podzolic soils. The color change apparently occurs simultaneously with the chemical changes as measured in the laboratory.

The transitional soils have chemical and morphological properties intermediate to the equivalent Brunizem and Gray-Brown Podzolic soils. It appears the establishment of a new Great Soil Group would simplify the classification of these soils.
LITERATURE CITED


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