GENESIS OF LOESS-DERIVED SOILS
IN SOUTHEASTERN IOWA

by

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Pedologists have been attempting to relate soil properties to conditions of the five soil forming factors since the mid-1800's when Russian soil scientists first proposed a broad hypothesis suggesting that soils are products of the conditions and interactions of climate, vegetation, parent rock, relief and age. Many soil classification schemes define soil groups, in part at least, in terms of conditions of certain soil forming factors. Numerous efforts to fabricate classification schemes that interrelate soils in terms of genetic properties have given impetus to studies of soil genesis.

In 1941, Jenny (28) proposed that soils be studied within a framework which recognized and emphasized the continuous variability of conditions of the genetic factors and of the resulting soils. The term "sequence" was proposed to encompass a group of soils related but varying in certain properties as a consequence of variation of conditions of one soil forming factor. Soil sequences dealt with by Jenny generally were assumed to be groups of soils in which only one of the five factors varied, but examination of examples used suggests that groups of soils in which more than one factor varied were not uncommon.

Jenny (28) considered the five soil forming factors as independent variables and proposed that the influence of a single soil forming factor on any soil property may be appraised by a factorial equation; this equation applies only if constancy of all other factors can be established with absolute certainty. Recent workers (50) (14) (23) have noted that there may be interactions among the supposedly "constant" soil forming factors when more than one factor is varied. Those studies suggest that interactions among the assumed "constant" factors can be more significant in determining soil properties than influences attributable solely to the one factor presumed to be independently variable.

Trends in certain soil properties associated with interactions among "constant" soil forming factors, and/or definable variation in the biotic, topographic (or hydrologic) and geographic location factors will be considered in this study.

The purposes of the study are: (a) to demonstrate and evaluate relationships among certain properties of soils in sequences of changing native vegetation, slope (or natural drainage), and geographic location, and (b) to consider possible causes of differential soil properties associated with varying conditions of these factors.

THE SEQUENCE APPROACH IN STUDIES OF SOIL GENESIS

Taxonomy, the grouping of individual soils into categories defined in terms of natural characteristics or other natural relationships, is an important aid in studying soils. Soil groups, defined in terms of conditions of the genetic factors, implement the understanding of soil forming processes and interrelationships among the resulting soils.

A classification scheme based on a single feature of soil morphology is exemplified by a system proposed by de Sigmond (54). That system separates soils on the basis of quantity and form of organic materials in the soil profile. It permits orderly grouping of soils on the basis of a specified property, but fails to provide logical arrangements among soils in terms of conditions of the soil forming factors and relations of those conditions to the genesis of the various kinds of soils identified in the system of classification; soils of greatly contrasting total morphology developed under highly contrasting conditions of the genetic factors are in the same class.

Jenny (28) has proposed that the soil population be comprehended primarily through genetic factor relationships, related to conditions of the soil forming factors, and has suggested bio-, topo-, chrono-, litho-, and climo-sequences of soils. Sequences as conceived by Jenny are composed of groups of soils isolated according to differential conditions of specified soil forming factors.

Certain soil characteristics associated with major differences in conditions of the soil forming factors have been used as criteria in defining great soil groups as segments of the continuum of soils. It is not within the purpose or scope of this study to delimit the great soil groups. The generally accepted criteria for definition of great soil groups encompassing the soils in this study are briefly summarized as follows:

Prairie soils (called Brunizem soils in this study) are defined (59) as follows: "A zonal group of soils having a dark colored, granular A_1 horizon 6 inches or more thick, resting on brown, yellowish brown, or grayish brown subsoil frequently mottled, commonly having a blocky structure, and usually higher in silicate clay content than the adjoining horizons. The organic matter content in the surface horizon decreases gradually with depth and has a C/N ratio of approximately 11:2 [11:1]. The exchange complex contains less exchangeable H than other cations. They are usually developed under grass vegetation in a humid to semi-humid temperate climate."

The Wiesenboden or Humic-Gley soils in Iowa (48) have developed under conditions of periodically high water tables. These soils are defined as possessing the following distinctive properties: "A deep black A horizon, usually about 16 to 20 inches thick, a slightly developed B horizon (of clay illuviation), usually of darker color in the upper part, and a gley horizon (light olive gray, often strongly mottled) below the middle or lower B horizon."

The Planosol great soil group in Iowa (48) includes soils that display a genetic claypan B horizon and distinct "bleached" A_2 horizon. Planosols, developed under both grass and forest vegetation, have been described in Iowa (56). Thorp and Smith (63) defined Planosols as intrazonal soils having one or more horizons abruptly separated from, and sharply contrasting to an adjacent horizon because of cementation, compaction or high clay content. (This definition includes soils outside the range of the limited concept of the Planosol group as used in this study, namely---the Ground-Water Podzols and Ground-Water Laterites.)

The Gray Brown Podzolic soils are defined (65) as follows: "A zonal group of soils having a comparatively thin organic covering and organic-mineral layers over a grayish brown leached layer which rests upon an illuvial brown horizon; developed under deciduous forest in a temperate moist climate."

Members of each of these great soil groups can be related to one another in terms of contrasts in the condition of one or more of the soil forming factors, within a sequence framework. If vegetation varies, with conditions of all other soil forming factors held constant, a biosequence of soils would result. In Table 1 below, a biosequence of

Table 1. Bio-toposequences of great soil groups

		Topographic (Topo) sequences		
		Moderately sloping 3 to 7 per cent	Gently sloping 1 to 3 per cent	Level 0 to 1 per cent
Vegetation (Bio) sequences	Grass	Brunizem	Brunizem	Brunizem
	Forest-grass transition	Brunizem-Gray Brown Podzolic intergrade	Brunizem-Gray Brown Podzolic intergrade	Wiesenboden-Gray Brown Podzolic intergrade
	Forest	Gray Brown Podzolic	Gray Brown Podzolic	Planosol

great soil groups would be: Wiesenboden to Wiesenboden-Gray Brown Podzolic intergrade to forested Planosol, where slope, the other variable in Table 1, is held constant. A topo-sequence in which vegetative type and all other factors are held constant is arrayed horizontally in Table 1.

Soils form a continuum on a given landscape. In the area with which this study is concerned conditions of certain soil forming factors, such as slope and/or vegetation, often vary significantly on relatively small landscape segments, with the result that a range of soil profiles reflecting differences caused by contrasts in these factors can be expected.

The profiles may grade from those typical of one great soil group to other great soil groups in Table 1. Soils that are intermediate between certain recognized great soil groups have been subdivided into intergrades in this area. For example, transitional profiles displaying properties between forested soils and grassland soils and between level and moderately sloping topographic positions (soil profiles displaying influences of a drainage variable) have been recognized.

White (74) has suggested intergrades between great soil groups to embrace profiles displaying intermediate effects of the vegetation variable. His scheme is diagrammatically presented in Figure 1. The range of characteristics in any intergrade depends on the nature of the characteristics that are changing in proceeding from one kind of vegetation and one great soil group to the other between which the transition lies. Planosols, for the most part, have been held quite closely to the modal concept in Iowa, but Brunizems have been allowed to range rather widely in certain soil characteristics. The intergrades have ranges in non-differentiating characteristics corresponding to the allowable ranges of the related great soil groups.

Soil associations have been described in terms of dominant soil series in Iowa. Simonson, et al (56) have grouped geographically associated soils developing on progressively thinning loess in southeastern Iowa are shown in Figure 2. The loess derived Brunizem, Planosol and

Great soil group "A"		Great soil group "B"		Great soil group "C"
great soil group characteristics	intergrade characteristics	great soil group characteristics	intergrade characteristics	great soil group characteristics
modal	modal	modal	modal	modal
series family (high / low)	sequence family*	series family (high / low)	sequence family	series family (high / low)
series	sequence**	series	sequence	series

*Perhaps the term intergrade family may be more meaningful.

**Perhaps the term intergrade series may be more meaningful.

Figure 1. Array of great soil groups and intergrades (74)

Wiesenboden soils, components of the Tama-Muscatine, Mahaska-Taintor and Grundy-Haig soil associations, have been studied in several separate studies (22) (13) (58) (50). Those investigators concluded that a loess-thickness relationship to certain soil properties exists in these soil associations in southeastern Iowa.

In the natural scheme, soil series are members of a single great soil group. Such series show differences in texture, color, structure, thickness, arrangement of horizons and other properties that permit their identification as discrete population segments representing specific great soil groups and transitions between great soil groups. They have a greater number of distinguishing characteristics than is true of the great soil group and are useful in evaluating differences in intensity of the operative soil forming factors. Each of the bio-toposequences in the three soil association areas with which this study is concerned have defined series for each great soil group and transitional great soil group shown in Table 1.

Previous Sequence Studies in Iowa

Workers in Iowa have studied numerous soil populations on various landscapes within the framework of Jenny's concepts of sequences of the five soil forming factors.

Relationships of soil properties to variations in one or more soil forming factors have been studied by attempting to hold some of the factors constant while others are varied.

White (74) has studied biosequences from Brunizem to Gray Brown Podzolic soils as well as the intergrades between these two great soil groups. Profiles of well drained and imperfectly drained Brunizem, Gray Brown Podzolic and intergrade soils developed from both thick and thin loess were compared. The soil series studied (Table 5) were Tama, Downs and Fayette (well drained and on thick loess) and Grundy, Pershing and Weller (imperfectly drained and on thin loess).

White (74) stated that soils undergo three stages or types of changes as Brunizem soils are transformed to Gray Brown Podzolic soils as a consequence of grassland encroachment by forest. The first changes in soil profile characteristics are: (a) a decrease in the carbon content, nitrogen content, pH, base saturation, and Ca/Mg ratio of the lower A horizon; (b) an increase in pH, base saturation and Ca/Mg ratio of the upper A horizon; and (c) a decrease in pH and base saturation and an increase in clay content of the B horizon. The second stage in the transformation is: (a) continuation of the aforementioned processes operating in the lower A horizon, a loss of clay and formation of platy structure in the middle A, and a decrease in A_1 horizon thickness; (b) a continuation of the processes operative in the B horizon with development of stronger peds with reddish coatings. Clay content in the B horizon does not increase from stage one to stage two. The third step includes continuation of stage two processes with development of strong structural peds in the B horizon, distinct platiness of the A_2 and gradual graying of the upper part of the dark, Brunizem A horizon. The color and thickness changes of the A_1 horizon seem to occur simultaneously with the chemical changes in the profile (74) (75).

Cain (13) has described and presented chemical and physical data supporting a loess thickness sequence of forested Planosols (Traer to Berwick to Beckwith) in southeastern Iowa. His data included physical and chemical soil characteristics of Planosols on loess of varying thickness and varying distance from source. The soils studied by Cain (13) and others (74) showed a trend suggesting free iron accumulation in the A_2 or upper B horizon, but no such trend for the middle or lower B horizon. Using the clay distribution in the profiles (magnitude of differences in clay content between A and B horizons) as an index to degree of development, Cain found that the contents of organic phosphorus and total nitrogen decrease more rapidly within the profile as the clay in the profile becomes more strongly stratified. He also found more pronounced secondary zones of accumulation of organic phosphorus and total nitrogen in the B horizon as profiles became more strongly developed. The forested

Planosols studied by Cain (13) were more acid and had a lower percent base saturation than the Wiesenboden profiles studied by Schafer (50), but were less acid and had higher percent base saturation than the Gray Brown Podzolic profiles studied by White (74). Cain (13) also found increasing capillary and total porosity, and decreasing aeration porosity and bulk density as the degree of horizon differentiation of the Planosols increased.

Schafer (50) found sequential changes related to drainage in certain properties among three Wiesenboden soils: Garwin, Taintor and Haig. The clay content of the B_2 horizon varied in the order: Garwin $<$ Taintor $<$ Haig. The Garwin soil had a lower percent base saturation than Taintor or Haig soils. Schafer has also shown high base saturation and slight clay movement within the Taintor profile. This was correlated with the presence of a depression in the surface of the underlying Kansan till. He proposed that this condition contributed to poor subprofile drainage in the soil developed from the overlying loess. Schafer points out that the Haig soil is found on two distinct geographic positions. In the northern part of the Grundy-Haig soil association, the Haig soils associated with the Taintor are found at the edges of the broad ridges, where distance to surface drainage is not great. Farther to the southeast in the Grundy-Haig soil association area, the ridges are narrower and flat areas of poor natural drainage are less extensive. Haig soils are common to the entire area of the upland flats in the latter area. The percent base saturation and the pH were higher in the Taintor than in the Haig soil. He proposed that less water percolated through the Taintor soil with the result that base depletion is less intense. Clay formation had been active in both Taintor and Haig soils; there was less evidence of clay translocation in the Taintor than in the Haig, probably due to the smaller volume of water movement through the solum of the former soil.

Hunter (22) found increasing volume weight and clay content of the B horizons and decreasing aeration porosity, total porosity, permeability and water storage capacity in the order: Tama < Otley < Grundy. He considered differences in particle size of parent material and effective time of weathering as major factors accounting for differences among the soils.

Implications of Genetic Groupings

The working concept for genetic grouping of soils assumes relation of variations in profile characteristics to the causative factor or combination of factors of soil formation. Studies of these functional relationships not only give clearer understanding of the processes and their effects, but aid in defining the taxonomic units at all levels of generalization.

CONDITIONS OF THE SOIL FORMING FACTORS IN THE STUDY AREA

The five soil forming factors have acted together to yield the present soil, the product of soil formation. As has already been stated, in a sequence study the investigator attempts to deal with defined segments of the total range of conditions of one or more factors while holding the remaining factors constant. Constancy of the remaining factors is assumed, but not necessarily assured. The soils and conditions of the soil forming factors in this study represent only a small segment of the total range of the variability for the total world soil population; major similarities in certain soil properties exist in this limited population segment. This study will be, therefore, concerned primarily with differences in soil properties as a function of variability of conditions of the soil forming factors within a limited population segment.

The location and extent of the study area in southeastern Iowa is indicated in Figure 3. The area is about 120 miles long in a northwest-southeast direction, extending roughly from Gladbrook in Tama County to Hillsboro in Lee County. Soil sites were chosen within a range of 30 miles east or west of a line connecting the two terminal points.

Climate

The present climate of Iowa is an extreme mid-continental (47) type with warm summers, occasionally strong, hot and sometimes dry winds and periods of prolonged high temperatures. The winters are rather cold and dry. The rainfall is moderate; the average annual relative humidity is 72 per cent. Northwest winds prevail in winter; southerly winds are most common from April to October.

The range of certain elements of climate for the study area, summarized from two sources, are in Table 2. Data for two stations, Grundy Center, Iowa and Kirksville, Missouri, which lie beyond the limits of the study area to the northwest and southeast respectively, have been included.

Various factors of special pedogenic significance can be estimated from climatic data. Among these is an estimate of the amount of water entering the soil and percolating to various depths. Differences in climate related to this factor, from north to south in this area, do not appear to be great; they may be greater than casual observation of the data suggest when the interactions of rainfall and temperature are considered. The difference in transpiration loss from central Iowa to northwest Missouri is about one inch per year, according to figures presented by Visher (69). The difference in annual precipitation for stations in the two areas (Table 2) is about 8 inches per year. However, transpiration

Table 2. Selected climatic data from southeastern Iowa and northeastern Missouri (67) (68)

Station and County	Climatic element[a]	Month												Yearly mean	Frost free season days
		J	F	M	A	M	J	J	A	S	O	N	D		
Grundy Center	T	17.5	21.6	33.9	47.6	59.2	68.1	73.5	72.0	62.9	52.1	37.1	22.5	47.3	
Grundy Co., Iowa	P	1.14	1.00	1.88	2.64	4.28	4.76	3.65	3.80	4.43	2.58	1.89	1.15	33.20	
Toledo	T	20.6	23.0	36.1	49.1	60.4	69.2	74.6	72.2	64.5	53.1	38.3	24.7	48.8	153
Tama Co., Iowa	P	1.11	1.10	1.87	2.70	4.26	4.76	3.96	3.54	4.65	2.45	1.96	1.20	33.56	
Stockport	T	23.3	26.1	38.2	50.0	61.1	70.6	75.6	73.5	66.1	53.8	39.9	27.8	50.5	
Van Buren Co., Iowa	P	1.30	1.35	2.14	3.04	3.90	4.84	3.98	3.70	4.12	2.59	2.05	1.40	34.41	
Kirksville	T	24.8	27.1	39.7	51.9	62.3	71.7	76.0	74.0	66.3	54.7	4.06	29.6	51.6	172
Adair Co., Missouri	P	1.52	1.53	2.93	4.10	5.33	5.06	4.30	4.12	5.18	3.16	2.12	1.76	41.12	

[a] T = mean temperature (^{o}F)
P = mean precipitation (inches)

and precipitation fluctuate seasonally. A study of evapotranspiration data suggests that during the mid-summer months, evapotranspiration losses exceed the sum of precipitation increments. It can be assumed that water entering the soil is largely withdrawn by plant use from the relatively shallow depths to which it penetrates, and that little water moves into the deeper soil horizons or through the solum during this period. In early fall, average daily temperatures decline and vegetative use of soil moisture decreases with the result that precipitation begins to exceed evapotranspiration losses. During the winter, the amount of precipitation is low, but exceeds the very low rate of loss by evapotranspiration. The soil may be frozen to some depth for an appreciable period in the winter and water infiltration probably is quite limited during that period. For a period in the spring, precipitation continues to exceed evapotranspiration. Late fall and spring and early summer are the two major deep percolation periods. The frozen soil period is, no doubt, appreciably longer in the northern than in the southern part of the study area. The effect of a shorter frozen soil season would be to increase the duration of the deep percolation period and consequently the quantity of water moving to depth and through the soil. This fact combined with higher precipitation in the southeastern area during the excess water period suggest a probability of appreciably greater amounts of deep percolating water in that area. From a study of precipitation data, estimated duration of frozen soil conditions and potential evapotranspiration data, Johnsgard[1] has proposed that the average quantity of water penetrating to a depth of two feet or more during the excess water periods (fall and spring) at the southeast end of the traverse may be as much as 1 1/2 to 2 times the quantity penetrating to that depth on the northwest end of this traverse. This difference may be significant in explaining, in part at least, differences in certain characteristics among soils from the northern to the southern end of the traverse. The probable significance of this matter will be dealt with in more detail in sections that follow.

White (74) has summarized evidence suggesting that the climate of the study may not always have been similar to the present. Ruhe and Scholtes (49) suggest that climate has been similar to present conditions for the past 5000 years, with the exception of a warmer period about 1000 years ago. The effect of this warm period on the direction of soil development and properties of present soils is not known. It is possible that certain features of the morphology of present soils are a result of a combination of both past and present climatic influences. This study must of necessity deal with present soil morphology and present conditions of climate. The modern climate will be assumed to provide at least a

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[1]Johnsgard, G. A., Ames, Iowa. Information on percolating water. Private communication. 1958.

partial basis for explaining the present morphology of the soils. It is beyond the scope of this study to determine which soil characteristics may have been due to this earlier warm period, or to other possible historical climatic changes.

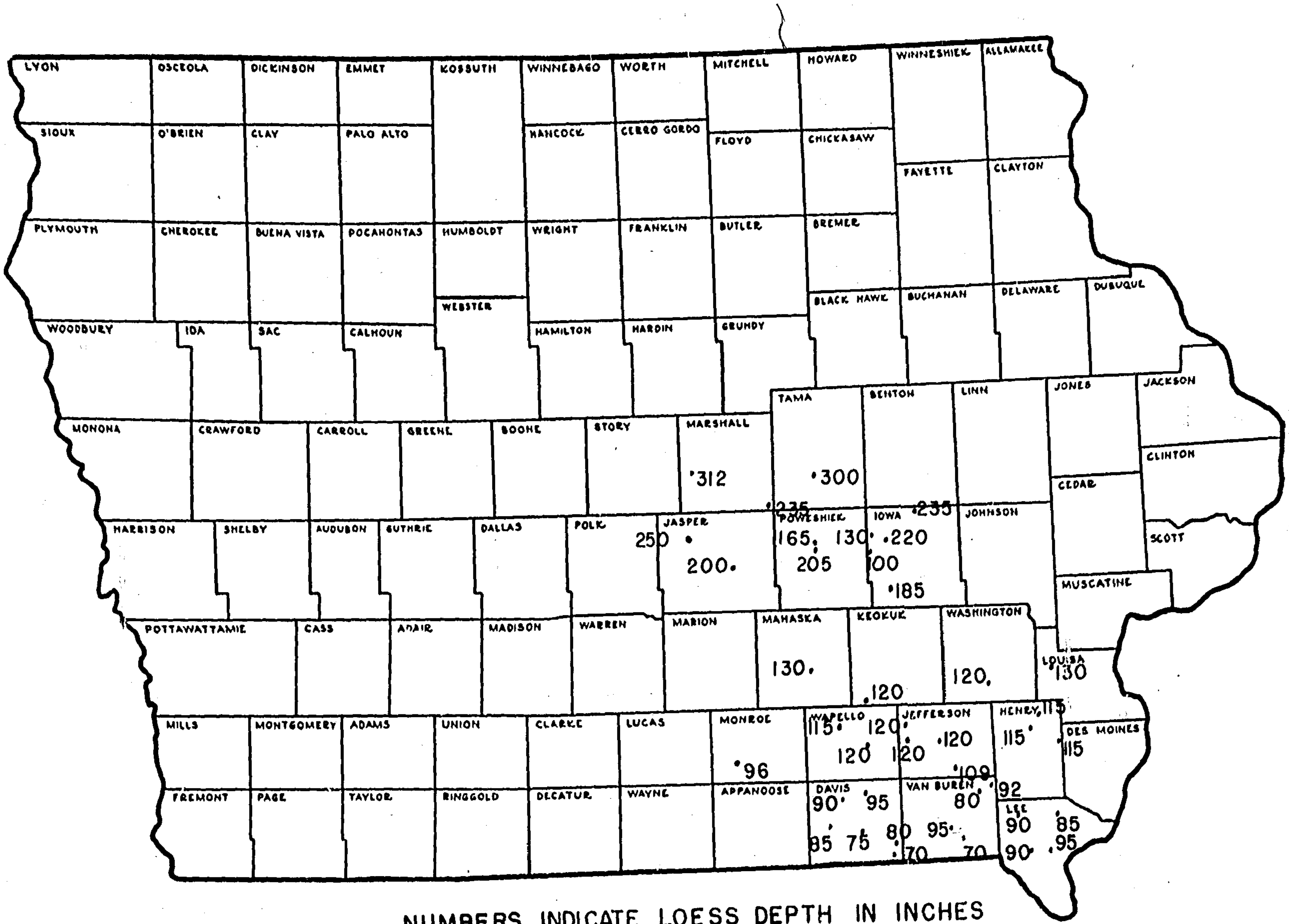
Parent Material

The soils of this study have been formed in calcareous Wisconsin loess. The nature of Wisconsin loess has been discussed by Ruhe and Scholtes (49), and by Schafer (50). The source area of Wisconsin loess is thought to have been the Iowan drift plain as well as the Missouri River Valley. Kaye and Graham (30) favor Iowan drift as the source area for much of the loess in southeastern Iowa. Leighton and Willman (38) stress the unique border relationships of Iowan till to loess deposits. They also suggest that the distribution of loess in other areas of the Mississippi Valley appears to be related to valleys of local streams. Figure 2 shows loess depths at many points in and adjacent to the study area. It will be noted that the loess thins in a southeasterly direction from the Iowan loess-till border. The probability that loess source may be multiple in local areas in southeast Iowa near the broad floodplains of the Skunk and Des Moines Rivers is suggested by Hunter, et al (23). This will be discussed in more detail later.

Numerous studies (24) (21) (57) have suggested progressive texture change with distance from loess source in the

Figure 2. Loess depth in southeast Iowa[1]

[1] Riecken, F. F., Ames, Iowa. Information on loess depth in southeast Iowa. Private communication. 1957.



NUMBERS INDICATE LOESS DEPTH IN INCHES

midwestern United States. The possibility of particle size fractionation of loess with increasing distance from the source area has been considered in the present study. Table 3 gives the clay content at 50 inches depth and the mean and range of clay content of loess parent materials for various segments of the study area. These data do not suggest great differences in clay content from north to south. It will be assumed that the clay content of the loess was relatively uniform throughout the traverse.

Handy, et al (20) found (a) the loess of southwestern and southeastern Iowa contained a mixture of montmorillonite and illite with montmorillonite predominating, (b) that the cation exchange capacity of loess of southeastern Iowa was lower than for loess of southwestern Iowa (the lower cation exchange capacity may indicate that illite is more common in the clay fraction of southeastern Iowa loess) and, (c) loess of southwestern Iowa contained volcanic glass which was not present in loess of southeastern Iowa. These findings suggest several possible kinds of variability in loess composition in the vast loess area of western and southern Iowa. Information regarding these kinds of variability are not available for the various segments of the area of study.

Table 3. Mean and range of per cent clay in loess parent materials of all soils in each of the three segments of the study area

Segment of study area	Mean per cent clay at 50 inch depth	Range in per cent clay at 50 inch depth[a]
Northern	29.1	3.1
Central	29.9	6.3
Southern	30.9	3.0

[a]Difference between maximum and minimum per cent clay among all samples.

Topography

The slopes of soils in this study vary from level to moderately sloping. The total range of slopes for all soils is from 0 to 7 per cent. Slope ranges for soils representing individual great soil groups and intergrades have been limited to segments of this total range as defined in Table 1. The topography of various kinds of soils, defined in terms of the great soil group or intergrade, is a controlled variable.

The broad relief features of various segments of the study area are as follows: The uplands in the northwestern area, nearest the loess source, are characterized by undulating to rolling topography and moderate relief; there are very few broad, flat ridges. The inextensive, nearly flat areas (commonly slightly convex) are at some distance from major drainageways. Very few areas are sufficiently concave to collect runoff water from adjacent slopes; closed depressions are uncommon (1). A thick loess mantle covers the uplands and lower areas, except for alluvial areas. The Tama-Muscatine (grassland soils) and Fayette (forest soils) soil associations are in this area.

The relief in the uplands in the central area is not so great as to the northwest. Broad flat divides, generally extending to within very short distances of the major drainageways are common. The broad high divides are often flat over extensive areas; widely scattered, very slight depressions occur on the flat ridges. The loess mantle is moderately thick in this area. The Mahaska-Taintor (grassland soils) and Clinton-Lindley (forest soils) soil associations are in this area.

In the southeastern area, divides are flat but not quite so wide as those in the central area. The loess mantle is not so thick as to the northwest and soils developed from loess occupy a smaller proportion of the total landscape than to the northwest. Loess derived soils are limited to nearly level divides. Older geologic materials have been exposed by erosion and paleosols occur on the slopes along drainageways.

In general, it is assumed that on materials of similar permeability the quantity of water entering soils decreases as the surface slope gradient increases, other conditions being similar. Conversely, runoff and geologic erosion rates would be expected to be greater on more sloping areas.

Surface slope and relief usually provide a clue to soil water and aeration conditions and consequently to morphological evidence of natural drainage conditions of soils. In some areas, the depth to water tables or to the capillary fringe zone is controlled almost entirely by elevations and surface slope. In other areas, restrictive subsurface layers may cause perching of a water table. In general, the depth to the water table is greatest on high points and where the surface slope is irregular. Smith (57) has shown relations of depth to water table and of surface slope to certain morphologic features of soils, including clay and organic matter depth distribution.

The natural drainage classes of the soils in this study correlate closely with definite landscape sites and slope conditions. The different natural drainage classes will, therefore, be considered as variables correlated with topography. Sequences of soils in different drainage classes in which topography is the variable will be referred to as hydrosequences. Differentials in the rates of geologic erosion will be considered as another possible variable related to topography.

Morphologic characteristics of the soils on moderate slopes suggest good natural drainage; on gentle slopes, imperfect natural drainage; and on flat areas, poor natural drainage. The well drained soils are rarely if ever waterlogged in any part of the solum. The imperfectly drained soils are waterlogged for short periods during the year or the capillary fringe zone extends into the solum for significant periods. Poorly drained soils are often waterlogged or the capillary fringe zone extends into the solum for extended periods.

Soil characteristics related to natural drainage are basic criteria in genetic grouping of soils into catenas or hydrosequences in this study.

Time

The length of time during which soil forming factors have been active in any given area will vary with the age of the parent material, unless there is evidence of exposure of older materials as a consequence of erosion. Many investigators (24) (64) (57) in the midwestern United States have attributed differences in soil profile characteristics to the time factor, where loess of decreasing thickness has been the parent material. It is notable, however, that in recent works (13) (17), on the basis of radio-carbon dating by Ruhe and Scholtes (49), the time factor has been de-emphasized as a variable soil forming factor in the study of soils derived from loess in Iowa.

In the case of local loess, the time factor can be discounted as a variable if one assumes that loess from local sources was deposited concurrently with that loess from more distant source areas.

In this study, the time factor in soil development will be assumed to correspond to the length of time since loess deposition. The time factor will not be considered as a variable of any great magnitude because it is questionable whether the period of loess deposition was sufficiently long to permit significant soil characteristic changes beyond possible partial leaching of carbonates from the loess concurrent with deposition.

Vegetation

The native vegetation of the area prior to settlement by the white men was prairie and deciduous forests in an intricate, orderly pattern controlled in large part by slope (58).

The prairie consisted chiefly of big bluestem (*Andropogon furcatus*) with a mixture of other grasses, legumes and forbs. These formed a tough, thick sod on level areas and very gentle slopes. The grass probably competed quite effectively with tree seedlings for light and moisture.

The forests occupied belts of strongly sloping land adjacent to the streams and were apparently spreading slowly onto the more gentle slopes of the uplands (39). Three definite communities of woody plants have been described on the uplands bordering the Des Moines River (3). They are in order of decreasing mesophytism: the maple-linden association, the oak-hickory association, and the shrub associes. Vegetation may have changed historically with changing climate. As stated previously, the climate of the northern part of the United States has fluctuated during the Pleistocene. Sears (52) has concluded that forests bordered the glacial front both during advance and retreat. On the basis of pollen studies in peat deposits, Lane (37) proposes that forests receded and grass was the dominant vegetation during part of the Aftonian interglacial period. Voss (70) and Lane (37) have presented pollen count evidence indicating that Iowa probably was in a tension zone between coniferous vegetation to the east and grass vegetation to the west during the Sangamon interglacial period. Following the recession of the Mankato glacier, pollen of coniferous vegetation was deposited in a peat bog in Hancock County, Iowa (36). This coniferous vegetation was followed by forest that was dominantly deciduous. The pollen in the upper layer of peat was dominantly from grassland species. (Forest vegetation could conceivably have invaded these peat bed sites during post-Mankato warm, dry periods.) It is not known whether vegetational changes have occurred on present grassland sites in the Wisconsin loess area of southeastern Iowa. White (74) found no apparent morphological indications that the Tama or Grundy (P-3) soils of southeastern Iowa had been influenced by forest vegetation. Possible effects of short periods of forestation on profile characteristics of Brunizem soils cannot be established by this study. White (74) assumed that the present Brunizem soils of the biosequences of his study were developed primarily under the influence of grass vegetation. That assumption will be accepted in this study.

Present forests are primarily on areas of well drained, steep topography adjacent to major streams (56). Shrader (53) found this same slope-vegetation relationship within limited areas in Missouri. He found that this relationship was related to a limited range of climatic conditions.

Factors other than the historical periods of dry climate may have retarded the advance of forest into grassland areas in recent times. McComb and Loomis (39) suggest prairie fires, buffalo grazing, drought periods of short duration, the competitive ability of the tall grasses and soil and climatic conditions as reasons for the presence of grasslands; climate and soil differences were proposed as most important. The following soil factors were proposed most important in retarding forest accession: (a) soil reaction of immature soils derived from calcareous materials, (b) high fertility of grassland soils, which favors dense grass and sod growth, and (c) poor soil aeration under grass. Wilde, et al (76) reported higher water tables under grass than under forest vegetation, and proposed that forest species are more adversely affected by excess moisture than are grasses. The effects of vegetation on the soil characteristics, as found in biosequences of this study, will be discussed later.

METHODS OF INVESTIGATION

The basic structure of this bio-topo (hydro)sequence study has been established by other investigators (13) (74) (14) (50). The forest-grass transition soils and certain other soils representing discrete segments of these sequences were not included in previous studies (see Table 5). The present study involved selection, field characterization and analysis of soils representing segments of sequences not previously studied and assembling of data from other studies to allow treatment of a more complete population.

Field studies of the soils, their relationships to one another, patterns of occurrence and of ranges in morphological characteristics represented the first phase of the investigation. Part of this phase of the study was in conjunction with work as a soil surveyor in Van Buren County. Field observations during the soil survey provided an excellent picture of the occurrence, inter-relationships and range of observable soil properties for the segment of the population in the southern end of the study area. Field studies were also made in other parts of the study area. Those studies were concentrated in areas in which a review of county soil survey reports (1) (43) (7) indicated that transition forest-grass soils may be present. These preliminary field studies provided knowledge required for selection of sampling sites to represent, with a reasonable degree of assurance, the morphological characteristics that reflected the desired conditions of slope (natural drainage) and vegetation.

Laboratory determinations were selected (a) to obtain data that would help define quantitatively some of the characteristics observed in the soils, (b) to help identify evidences of trends in soil formation, (c) to provide a basis for postulating trends in soil development, and (d) to compare and contrast degrees of profile development of soils in terms of many characteristics.

Organic carbon and total organic nitrogen analyses were selected to characterize organic matter profiles and to identify possible differences related to native vegetation, natural drainage conditions and geographical location. Percentages of clay $< 2\ \mu$ were determined (a) to quantitatively define clay distribution in individual profiles, (b) to provide evidence of clay formation in place and/or of clay eluviation and illuviation and (c) to contrast soils developed under (aa) forest, forest-grass transition and forest vegetation, (bb) good and poor drainage, and (cc) at different locations, north to south, in the study area. "Free" iron was determined to ascertain if natural drainage conditions, vegetation and/or location influence iron distribution in soils. Relationships or "free" iron content to soil drainage, to soil matrix colors and to ferric oxide mottles and concretions were also of interest. Soil reaction (pH), exchangeable calcium, exchangeable magnesium and exchangeable hydrogen data were considered essential for characterizing the base status of soils and determining the relative degrees of base depletion in soils developed under defined conditions of natural drainage, native vegetation and geographical location.

The present "state of knowledge" of each of the 24 soils of this study, from the standpoint of laboratory studies, may be described by one of these three categories: (a) soils on which laboratory analytical data have been reported in the literature, (b) soils that have been sampled but never analyzed or on which very few types of laboratory data have been assembled, and (c) soils that have not been sampled and analyzed.

Field Studies

All of the soils included in this study have been recognized and defined as specific series and types for soil survey purposes. From field observations, there is considerable existing knowledge of their occurrence, their interrelationships and their properties.

Field descriptions of soils of category (a) above have been presented in other studies (13) (74) (50) (22) (41). Only soils in categories (b) and (c) will be dealt with in detail in this section. Categories (b) and (c) include, for the most part, soils of intermediate drainage and of transitional character in respect to morphologic indications of vegetation influences.

Possible areas for sampling soils were located by examining soil maps to identify areas where grassland soils (or forest-grass or forest soils as the case may be) occur on gentle or level slopes. Soils of these areas were field checked and suitable sites with soils of fairly uniform characteristics were chosen. The native vegetation had been destroyed in most areas. Soil morphologic criteria known to reflect influences of specific kinds of vegetation were used to identify prior types of native vegetation on individual sites.

The Walford, Atterberry and Stronghurst soils were sampled in Tama and Poweshelk Counties. These soils are members of the Tama-Muscatine or Fayette soil association (see Table 4). The topography of the Tama-Muscatine soil association area is predominantly undulating to gently rolling. The area has a dendritic system of drainageways that reach into all parts of the uplands; the uplands on which these soils occur, consist of rounded ridges and shallow valleys. Very few poorly drained upland flats and depressions are present and well drained soils dominate the landscape. The topographic and drainage pattern probably is relict from that existing on the pre-loess Kansan or Iowan (?) drift plain. Kansan till outcrops on lower slopes in only a few steep valley slopes in the Tama-Muscatine soil association area; in the Fayette soil association area (dominantly forest soils) till or the

Table 4. Array of 24 soils by biosequence, hydrosequence, by soil association and by relative location in the traverse

		Hydrosequence			Soil association	Relative location in area
		Well drained	Imperfectly drained	Poorly drained		
Biosequence	Grass	Tama	Muscatine	Garwin	Tama-Muscatine	
	F-G	Downs	Atterberry	Walford	or	North
	Forest	Fayette	Stronghurst	Traer	Fayette	
Biosequence	Grass	Otley	Mahaska	Taintor	Mahaska-Taintor	
	F-G	Ladoga	Givin	Rubio	or	Central
	Forest	Clinton	Keomah	Berwick	Clinton-Lindley	
Biosequence	Grass	Grundy		Haig	Grundy-Haig	
	F-G	Pershing		Belinda	or	South
	Forest	Weller		Beckwith	Weller-Lindley	

underlying limestone or sandstone may be exposed in places on the steep valley slopes. The ridges of the uplands are usually mantled with loess; the uplands are undulating.

The Muscatine profile used in this study was sampled and described in the Tama-Muscatine soil association area (in 1943). The samples were air dried and stored.

Sites for sampling the Rubio, Givin, Ladoga and Keomah soils were selected in the Mahaska-Taintor and Clinton-Lindley soil association areas in the central portion of the traverse. The loess source in this area is more distant than in the Tama-Muscatine area and the loess is not so thick. The general topography is gently undulating. Level to undulating moderately wide divides form the highest portion of the upland (56). An association of forest soils (the Clinton-Lindley soil association) occurs near the major drainageways. The topography in the Clinton-Lindley area is hilly to rolling with narrow, loess mantled ridges.

The Mahaska soil was sampled in 1952 in the Mahaska-Taintor soil association area. The samples were air dried, and sent to the Soil Conservation Service Soil Survey Laboratories at Beltsville, Maryland, for certain analyses. The samples were returned to Iowa State College for use in this study.

The Grundy-Haig and Weller-Lindley soil associations occur in the southern portion of the traverse at the greatest distance from loess source and on the thinnest loess. The topography is much like that of the Mahaska-Taintor association; divides are narrow and undulating topography borders the high level uplands. On moderate slopes, geologic erosion has cut through the thin loess mantle exposing other material beneath; slopes that would be mantled with loess in areas of thicker loess have soils developed in Kansan till with or without a thin ($<$ 12 inches) mantle of loess. Soils on slopes greater than six or seven percent are generally on till and many soils on slopes of four percent have till within a 36 inch depth. To avoid multiple parent materials, only two slope separations were made in this area; the moderately sloping soils were not sampled.

Forested and forest-grass transition soils in the southern area occur on slopes of the major drainageways and along tributaries which extend into the upland grassland areas. The Pershing and Weller soils were sampled in such areas on slopes of less than three per cent. The Belinda was sampled on a nearly level upland position near a large area of grassland soils. Sites were chosen on the broad divides, wherever possible, or on the flat-topped or very slightly rounded narrow divides. The latter condition was most common in the case of forested soils. By limiting the site selection to the relatively flat, high ridges, the effects of differential erosion were minimized. In all cases, depressional sites were avoided, and except possibly for the Atterberry site, none of the profiles have soil accretions due to the accumulation of local slope wash. Sites southeast of and adjacent to wide stream valleys were avoided because of the possibility of local loess deposition.

In the remainder of this paper, soil sites will be located by reference to segments of the traverse rather than to the soil association name.

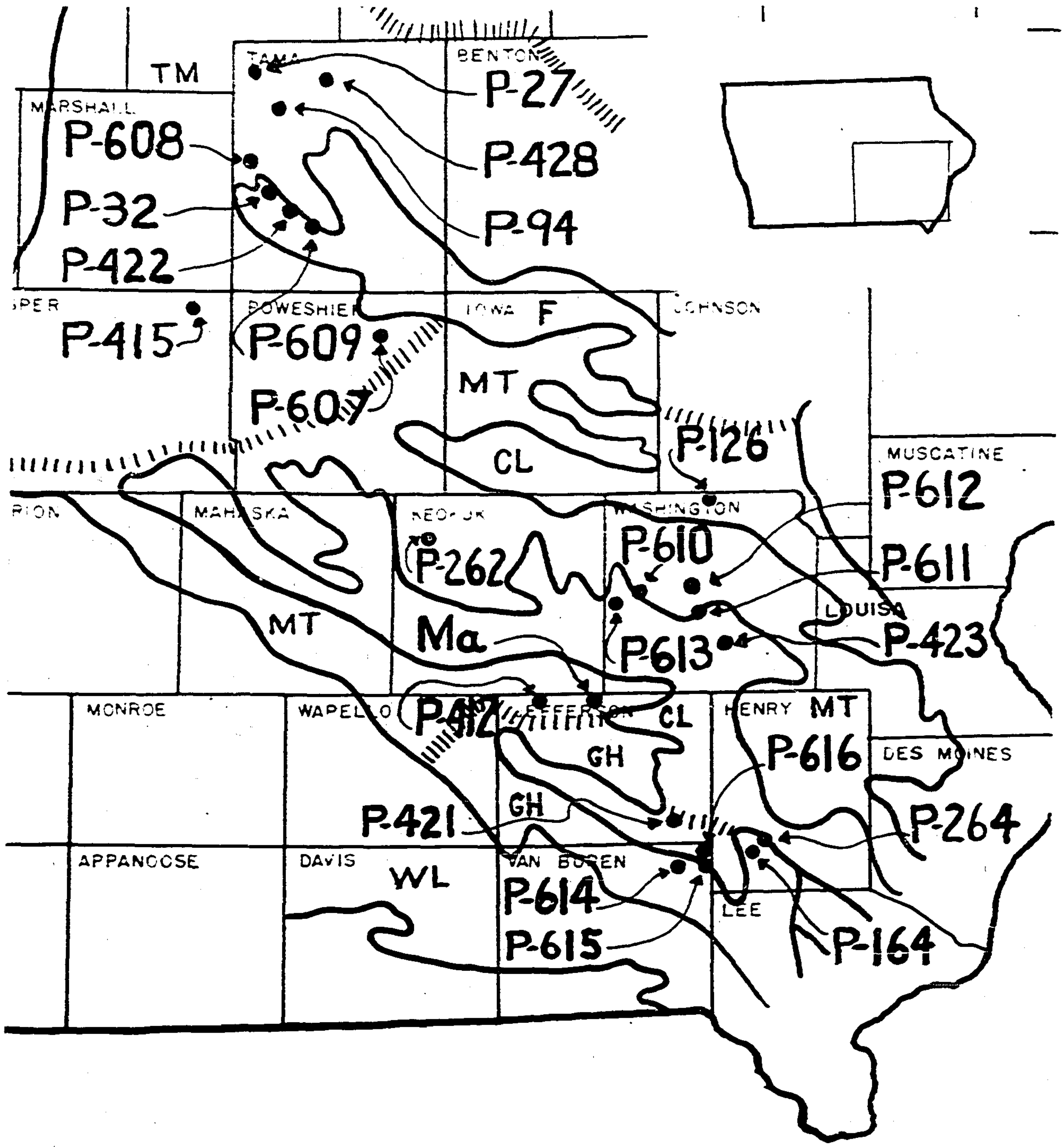
Native vegetation had been removed from the forest-grass transition soil sites. The profiles were selected to represent characteristics intermediate between the modal forest and grassland soils. It is assumed that these soils supported forest vegetation prior to cultivation and represent a situation in which former grasslands had been invaded by forest. Profiles which displayed possible effects of past grassland vegetation, that is, a dark A_1 and dark B_2 horizon were selected. White (74) has listed the order and types of changes in profile properties which occur as forest vegetation encroaches on grassland soils; those criteria provided a basis for identifying various segments of the forest-grass transition.

The locations of the sites of the ten soils sampled are given in the individual soil descriptions in Appendix A. The locations of sampling sites for all 24 soils are shown as points on the map of southeast Iowa, Figure 3.

Soil sampling

A pit was dug at each of the selected sites. After

Figure 3. Locations of sample site with respect to soil association areas in southeastern Iowa



PRINCIPAL SOIL ASSOCIATIONS

CL CLINTON & LINDLEY	MT MAHASKA & TAINTOR
F FAYETTE	TM TAMA & MUSCATINE
GH GRUNDY & HAIG	WL WELLER & LINDLEY
—— ABRUPT BOUNDARY	IIIII GRADATIONAL BOUNDARY

careful study of the morphology of the soils, horizon markings were placed and profile descriptions were prepared. Site characteristics were also recorded. Bulk samples were taken from each horizon for laboratory studies.

Morphological descriptions

Detailed profile descriptions (Appendix A) were prepared for forest-grass transition and other soils not heretofore described in the literature. The descriptive terminology is from the Soil Survey Manual of the U. S. Department of Agriculture (66). Munsell notations are used for designating colors.

Laboratory Methods

Bulk samples were air dried at room temperature. A one quart sample was quartered from each bag to serve as a reference sample; another quart was ground in a Braun Sample Grinder to pass a two millimeter round hole sieve. No gravel, particles in excess of two millimeters diameter, was present in any of the samples. Roots that did not pass through the sieve were discarded. A one pint sample of the sieved soil was quartered, thoroughly mixed and used as a working sample. All data, except those for particle size analysis, are reported on an air dry basis. All analysis were in duplicate.

Physical properties

Less than 2 μ clay. Less than 2 μ clay data were obtained using a procedure (34) which is essentially the same as that outlined by Kilmer and Alexander (33). Sodium hexametaphosphate was used as a dispersing agent.

Chemical properties

Soil reaction. Soil reaction or pH was determined for all horizons sampled, and in addition some horizons of the Muscatine profile were checked. A glass electrode, battery powered, Model G Beckman pH meter was used. Twenty five grams (± 2 grams) of soil was measured with a calibrated scoop and 25 milliliters of distilled water was added, giving a 1:1 soil-water paste. The samples were stirred, allowed to stand 30 minutes, restirred, and pH was measured as quickly as possible.

Exchangeable cations. Exchangeable calcium and exchangeable magnesium were extracted as outlined by Peach, et al, (44). A suction filter flask was equipped with a Buchner funnel fitted with two Whatman number 42 filter papers of 5.5 centimeter diameter. Neutral normal ammonium acetate was leached through the sample until a volume of 250 milliliters had been collected (leaching time: about 45 minutes). The filtrate was evaporated to dryness in a 600 milliliter beaker. Subsequently, the beaker was heated strongly and evenly over a Meeker burner until all traces of the ammonium acetate film had disappeared from the uppermost rim of the beaker.

After cooling, the white residue of metal oxides was dissolved in 10 milliliters of dilute (1 + 1) hydrochloric acid and the solution was diluted with 250 milliliters of distilled water. Iron was removed and calcium and magnesium were determined by disodium, dihydrogen ethylenediaminetetraacetate (EDTA) titration as outlined by Black (8). A 10 milliliter aliquot, instead of the recommended 25 milliliters, was used to avoid burette refill during the EDTA titration.

The volumes of buffer and eriochrome black T were reduced in proportion to the aliquot. The volume of sodium tungstate solution, for calcium precipitation in the magnesium determination, was decreased in proportion to the smaller aliquot of iron-free solution.

The procedure gave results that agreed closely with those by permanganate titration of the calcium oxalate precipitate, and by ammonium phosphate precipitation of magnesium followed by a standard base titration of the excess standard acid used to dissolve the magnesium ammonium phosphate precipitate.

Exchangeable hydrogen was determined on 20 gram samples by the standard barium acetate method of Black (8). Hydrogen was displaced by vacuum filtration using a Buchner funnel fitted with a double thickness of Whatman number 42 filter paper.

"Free" iron. Subsamples, from the two millimeter material, were ground so that all material, including the concretions, would pass a 40 mesh sieve. One gram subsamples of the 40 mesh material were subjected to Jeffries' method (27) as modified by Swenson (62). Iron was measured colorimetrically by the o-phenanthroline method as described by Swenson (62) using an Evelyn photoelectric colorimeter with a 515 millimicron filter. Swenson (62) has recommended a water bath to raise the temperature of the oxalic acid-potassium oxalate buffered solution to 90° to 95° C. This temperature was unattainable in a simple water bath with beakers in actively boiling water in an open pan. A modified procedure, as follows, was developed to achieve the temperature recommended by Swenson (62): (a) a shallow, thick-walled pan was partially filled with mineral oil and a thin-walled aluminum-painted sheet metal pan one-half filled with a 2.0 N sodium chloride solution was placed in the mineral oil, (b) the inner pan was covered with a sheet of 1/4 inch plywood into which spaced holes were bored by means of a drill press equipped with a Robertson and Ruth Model 400 Dial Saw. This cover prevented splashing, supported the beakers, reduced vapor loss and facilitated frequent stirring of the solution in the beakers as recommended by Swenson (62). The purpose of the oil bath was to diffuse the heat from the Meeker burners; the 2.0 N sodium chloride solution raised the boiling point of the water to about 110° C. The procedure resulted in temperatures averaging 90° to 94° C. in the beakers during iron reduction; no beaker varied more than

$\pm$ 2^{o} C. from the average. The conditions of increased temperature and slight temperature variation from center to edge of pan could not be attained without using the oil bath, salt water bath and pan cover described above.

Total organic carbon. A gravimetric dry combustion procedure (8) was used for the determination of total carbon. The soil pH and field tests for free carbonates suggested that all carbon was in the organic form, except for certain layers in the Traer profile (13).

Total nitrogen. Total nitrogen was determined by the Gunning modification of the Kjeldahl procedure as outlined by Black (8). A one inch segment of copper wire was used as a catalyst in the sulfuric acid-potassium sulfate digestion instead of mercuric oxide. Salicylic acid was not used because the nitrate content of these samples was considered to be negligible. The ammonia was distilled into 30 milliliters of a 4 percent boric acid solution to which a mixture of brom cresol green-methyl red indicator had been added. The end point of the indicator was a clear, golden yellow.

Data from previous studies

Certain data for 14 soils in this study are from the work of other investigators. All types of desired data were not available for some of those soils. The kinds of data available and their source are indicated in Table 5.

Data for all kinds of desired analyses were available for the Garwin, Taintor, Haig, Tama, Downs and Fayette soils. Data were incomplete, as shown in Table 5, for Traer, Berwick, Beckwith, Otley, Grundy, Clinton, Muscatine and Mahaska soils. The objectives of this study necessitated completion of those analyses for which data were not available.

The laboratory methods described earlier were used for the analyses of the soils for which data were incomplete. These methods of analysis, except for exchangeable calcium and exchangeable magnesium, are identical to those used by other investigators (13) (50) (74) (22) whose data are presented in this report. The methods for exchangeable calcium and exchangeable magnesium are not the same as those of Cain (13), Schafer (50) and White (74). Values by the two methods, compared on the same soil samples, differed by less than 1.0 milliequivalent per 100 grams of soil in the case of exchangeable calcium and less than 0.5 milliequivalent per 100 grams of soil in the case of exchangeable magnesium. Data for the Clinton soil were by laboratory methods (41) similar to those of Cain (13) and are considered comparable to data by methods used in this study.

Table 5. Kind and source of data for 14 soils studied by other investigators (the "x" denotes data were available, "O" denotes data were not available)

Soil	Particle size	Exch. Ca	Exch. Mg	Exch. H	Organic C	Total N	Free Fe	pH
Traer (13)[a]	x	x	x	x	O	x	x	x
Mahaska[b]	x	x	x	O	x	O	O	x
Muscatine[b]	O	O	O	O	O	O	O	O
Berwick	x	x	x	x	O	x	x	x
Otley (22)	x	x	x	x	O	O	O	x
Clinton (41)	x	x	x	x	O	O	O	x
Beckwith (13)	x	x	x	x	O	x	x	x
Grundy (22)	x	x	x	x	O	x	O	x
Garwin (50)	x	x	x	x	x	x	x(55)	x
Taintor (50)	x	x	x	x	x	x	x(55)	x
Haig (50)	x	x	x	x	x	x	x(55)	x
Tama (74)	x	x	x	x	x	x	x	x
Downs (74)	x	x	x	x	x	x	x	x
Fayette (74)	x	x	x	x	x	x	x	x

[a]Numbers in parenthesis indicate literature citations.

[b]Riecken, F. F., Ames, Iowa. Laboratory data for some Iowa soils. Private communication. 1957.

Chemical and physical data from all methods of analysis for the 24 soils are presented in tabular form in Appendix B.

Profile descriptions prepared by other investigators were consulted for all soils not described by the author. One profile description was found for each of the following soils: Tama, Muscatine, Downs, Traer, Garwin, Mahaska, Berwick and Beckwith. In some cases, profile descriptions and laboratory data were available for several profiles of the same soil series. The author chose one profile from those for which descriptions and data were presented. The choice was based on: (a) location of the sample site in the general area covered by this study, (b) availability of soil samples for the profiles, (c) completeness of laboratory data and morphological descriptions for the profile, (d) the author's best judgement of the "modality" of the profile in representing different classes of drainage and kinds of vegetation, and (e) the suggestions of Dr. F. F. Riecken,[1] who has seen and sampled many of the soils in the field.

The soils for which there was a choice of profile descriptions and data are: Fayette, Clinton, Taintor, Otley, Grundy, Weller, Pershing and Haig.

The Fayette profile (P-32) was from a site in Tama County near the sampling sites of other soils in the northern segment of the study area. Nearly complete data were available for this profile.

The Clinton profile (P-126) was chosen because the site location was near the sites of other soils of the central segment of the study area. Also, the slope of the site was in the range desired in this study. Pulverized soil samples

[1]Riecken, F. F., Ames, Iowa. Information on sample sites. Private communication. 1957.

of this profile were available from storage.

The Taintor profile (P-412) was in the central area, near the location of other soils, and intermediate in most soil properties among the several profiles of this soil studied by Schafer (50).

The Otley profile (P-262[1]) is located in the central portion of the study area near the sites of other soils representing that segment. Hunter (22) found that P-262, of the three profiles studied by him, showed maximal horizon differentiation in respect to clay content. (This suggests that an extreme was selected.)

The Grundy profile (P-264) was chosen because the site was within the study area. A soil from another Grundy site was used by White (74), but this site was in Lucas County, where there was a possibility of multiple loess sources. There were no sample sites for Weller and Pershing soils in the study area, so these two soils were sampled in northeast Van Buren County.

The Haig profile (P-164) was chosen from the Haig profiles studied by Schafer (50)because this particular profile showed maximum differences in clay content between the A and B horizons. This profile has the lowest clay content in the surface and highest clay content in the B horizon of the four

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[1]Called Mahaska by Hunter (22), but Otley more recently (23).

Haig profiles for which data were presented. (This suggests that an extreme was selected.)

DISCUSSION OF RESULTS OF INVESTIGATIONS

Characteristics of the Soils
(Grouped by Sequences)

Morphological characteristics

The color, structure, texture and thickness of the A_1, A_2 (if present) and B_2 horizons, and the depth in inches to mottling, and/or iron-manganese concretions for the 24 soils are presented in Table 6. The 24 soils have been grouped by topo-hydrosequence, biosequence and by geographic location in the study area. Trends from left to right indicate morphologic changes in relation to changing native biotic condition from the characteristic profile of grassland soils toward forested soils. Trends from the top to the bottom of the table indicate changes from moderately sloping (well drained) to level (poorly drained) soils of each native biotic condition.

For convenience, the various biosequence segments will be referred to as grassland soils, forest-grass transition soils and forest soils. Trends of changes will be discussed in that order.

Biosequences of well drained soils (Tama to Downs to Fayette and Otley to Ladoga to Clinton) show progressive trends as follows from grass to forest: The A_1 horizon becomes progressively lighter colored and thinner, an A_2 horizon appears in forest-grass transition soils and becomes more

Table 6. Brief summary of selected morphological characteristics of the 24 soils

Slope and natural drainage class	Grass	Forest on former grassland (forest-grass transition)	Forest
Moderately sloping (well drained)	<u>Tama</u> A_1-Very dark brown silt loam, granular structure, 9 to 11 inches thick. B_2-Dark grayish brown to brown silty clay loam, moderate fine subangular blocky structure, 11 to 14 inches thick, mottling at 34 inches.	<u>Downs</u> A_1-Very dark gray brown silt loam, granular structure, 3 to 6 inches thick. A_2-Dark brown silt loam, platy structure, 8 to 10 inches thick. B_2-Dark brown to dark yellowish brown silty clay loam, moderate fine subangular blocky structure, 13 to 17 inches thick, mottling at 40 inches.	<u>Fayette</u> A_1-Very dark gray silt loam, platy structure, 3 to 5 inches thick. A_2-Dark gray brown silt loam, platy structure, 2 to 4 inches thick. B_2-Dark brown silty clay loam, moderate to strong fine subangular blocky structure, 14 to 18 inches thick, mottling at 40 inches.
Gently sloping (imperfectly drained)	<u>Muscatine</u> A_1-Very dark brown silt loam, granular structure, 12 to 15 inches thick. B_2-Very dark brown to dark brown mixed with dark yellowish brown,	<u>Atterberry</u> A_1-Very dark gray silt loam, granular structure, 6 to 8 inches thick. A_2-Gray brown and dark gray silt loam, platy structure, 7 to 9 inches thick.	<u>Stronghurst</u> A_1-Dark gray silt loam, granular, 4 to 6 inches thick. A_2-Dark gray and dark brown, silt loam, platy structure, 7 to 9 inches thick. B_2-Dark gray brown with dark brown

	mottling at 34 inches.	fine subangular blocky structure, 13 to 17 inches thick, mottling at 40 inches.	18 inches thick, mottling at 40 inches.
Gently sloping (imperfectly drained)	<u>Muscatine</u> A_1-Very dark brown silt loam, granular structure, 12 to 15 inches thick. B_2-Very dark brown to dark brown mixed with dark yellowish brown, silty clay loam, weak medium subangular blocky structure, mottling at 24 inches.	<u>Atterberry</u> A_1-Very dark gray silt loam, granular structure, 6 to 8 inches thick. A_2-Gray brown and dark gray silt loam, platy structure, 7 to 9 inches thick. B_2-Gray brown and dark gray brown with strong brown mottles, silty clay, moderate fine subangular blocky structure, 10 to 12 inches thick, mottling at 4 inches.	<u>Stronghurst</u> A_1-Dark gray silt loam, granular, 4 to 6 inches thick. A_2-Dark gray and dark brown, silt loam, platy structure, 7 to 9 inches thick. B_2-Dark gray brown with dark brown and very dark brown mottles, silty clay loam, moderate fine subangular blocky structure, 10 to 14 inches thick, mottling at 11 inches.
Level (poorly drained)	<u>Garwin</u> A_1-Black, granular structure, silty clay loam, 14 to 16 inches thick. B_2-Dark gray silty clay with light olive brown and yellowish brown mottles, strong fine subangular blocky structure, 18 to 24 inches thick, mottling at 34 inches.	<u>Walford</u> A_1-Very dark gray silt loam, granular structure, 3 to 6 inches thick, mottling. A_2-Gray brown silt loam, platy structure, 4 to 6 inches thick. B_2-Dark gray brown and gray brown silty clay, strong medium subangular blocky structure, 12 to 17 inches thick,	<u>Traer</u> A_1-Dark gray brown silt loam, granular structure, 5 to 7 inches thick, mottled. A_2-Gray brown silt loam, platy structure, 3 to 5 inches thick. B_2-Dark gray brown and very dark gray brown silty clay, strong medium subangular blocky structure, 9 to 13 inches thick.

Table 6. (continued)

Slope and natural drainage class	Grass	Forest on former grassland (forest-grass transition)	Forest
Moderately sloping (well drained)	<u>Otley</u> A_1-Dark grayish brown, granular structure, silt loam, 10 to 14 inches thick. B_2-Dark yellowish brown silty clay loam, moderate medium subangular blocky structure, 6 to 8 inches thick, mottling at 17 inches.	<u>Ladoga</u> A_1-Very dark gray silt loam, granular structure, 5 to 7 inches thick. A_2-Dark gray brown and gray brown silt loam, platy structure, 3 to 5 inches thick. B_2-Dark gray brown, gray brown and brown silt loam, platy structure, 3 to 5 inches thick, mottling at 25 inches.	<u>Clinton</u> A_1-Dark gray silt loam, granular structure, 2 to 4 inches thick. A_2-Brown silt loam, platy structure, 10 to 14 inches thick. B_2-Brown to dark yellowish brown silty clay loam, moderate medium blocky structure, 9 to 12 inches thick, mottling at 40 inches.
Gently sloping (imperfectly drained)	<u>Mahaska</u> A_1-Very dark brown, granular structure, silt loam, 10 to 12 inches thick. B_2-Dark gray brown to olive gray with light olive brown mottles, strong medium subangular blocky structure, 10 to 14 inches thick, mottling at 14 inches.	<u>Givin</u> A_1-Very dark gray silt loam, granular structure, 8 to 10 inches thick. A_2-Dark gray and dark gray brown with yellowish brown mottles, silt loam, platy structure, 7 to 11 inches thick. B_2-Olive gray and light olive brown with yellowish	<u>Keomah</u> A_1-Dark gray silt loam, platy structure, 6 to 8 inches thick, mottled. A_2-Dark gray and dark gray brown to brown silt loam, platy structure, 4 to 6 inches thick. B_2-Dark gray brown and gray brown, silty clay, moderate fine subangular blocky structure, 12 to 16 inches thick.

(imperfectly drained)	granular structure, silt loam, 10 to 12 inches thick. B_2-Dark gray brown to olive gray with light olive brown mottles, strong medium subangular blocky structure, 10 to 14 inches thick, mottling at 14 inches.	silt loam, granular structure, 8 to 10 inches thick. A_2-Dark gray and dark gray brown with yellowish brown mottles, silt loam, platy structure, 7 to 11 inches thick. B_2-Olive gray and light olive brown with yellowish brown mottles, silty clay, moderate fine subangular blocky structure, 8 to 11 inches thick, mottling at 15 inches.	platy structure, 6 to 8 inches thick, mottled. A_2-Dark gray and dark gray brown to brown silt loam, platy structure, 4 to 6 inches thick. B_2-Dark gray brown and gray brown, silty clay, moderate fine subangular blocky structure, 12 to 16 inches thick.
Level (poorly drained)	<u>Taintor</u> A_1-Black silty clay loam, granular structure, 10 to 14 inches thick. B_2-Very dark gray with some very dark grayish brown or olive brown mottles, silty clay, strong medium subangular blocky structure, 10 to 14 inches thick, mottling at 15 inches.	<u>Rubio</u> A_1-Very dark gray silt loam, granular structure, 5 to 7 inches thick, mottled. A_2-Very dark gray and gray silt loam, platy structure, 6 to 8 inches thick. B_2-Very dark gray and dark gray brown with yellowish brown mottles, silty clay, moderate fine subangular blocky structure, 14 to 18 inches thick.	<u>Berwick</u> A_1-Dark gray brown silt loam, granular structure, 6 to 8 inches thick, mottled. A_2-Gray silt loam, platy structure, 4 to 7 inches thick. B_2-Gray brown with yellowish brown and strong brown mottles, silty clay, strong fine blocky structure, 13 to 16 inches thick.

Table 6. (continued)

Slope and natural drainage class	Grass	Forest on former grassland (forest-grass transition)	Forest
Gently sloping (imperfectly drained)	<u>Grundy</u> A_1-Very dark brown to very dark grayish brown, silt loam, granular structure, 12 to 14 inches thick. B_2-Dark gray with brownish yellow mottles, silty clay, moderate fine subangular blocky structure, 6 to 12 inches thick, mottling at 13 inches.	<u>Pershing</u> A_1-Very dark gray granular structure, silt loam, 6 to 9 inches thick, mottling. A_2-Dark gray to dark gray brown, platy structure, silt loam, 4 to 7 inches thick. B_2-Dark gray brown to brown with yellowish brown mottles, silty clay, moderate medium subangular blocky structure, 11 to 15 inches thick.	<u>Weller</u> A_1-Very dark gray silt loam, platy structure, 2 to 4 inches thick, mottling. A_2-Gray and gray brown silt loam, platy structure, 6 to 10 inches thick. B_2-Gray brown and brown silty clay with yellowish brown mottles, strong very fine subangular blocky structure, 6 to 11 inches thick.
Level (poorly drained)	<u>Haig</u> A_1-Very dark gray silt loam to silty clay loam, granular structure, 12 to 15 inches thick. B_2-Very dark gray to dark gray to	<u>Belinda</u> A_1-Very dark gray silt loam, platy structure, 6 to 8 inches thick, mottling. A_2-Dark gray and gray silt loam, platy structure,	<u>Beckwith</u> A_1-Dark gray silt loam, platy structure, 3 to 5 inches thick. mottling. A_2-Gray brown to light brownish gray, silt loam,

	ture, 6 to 12 inches thick, mottling at 13 inches.	mottles, silty clay, moderate medium subangular blocky structure, 11 to 15 inches thick.	brown mottles, strong very fine subangular blocky structure, 6 to 11 inches thick.
Level (poorly drained)	<u>Haig</u> A_1-Very dark gray silt loam to silty clay loam, granular structure, 12 to 15 inches thick. B_2-Very dark gray to dark gray to olive gray, strong brown mottles, silty clay, strong fine subangular blocky structure, 12 to 18 inches thick, mottling at 14 inches.	<u>Belinda</u> A_1-Very dark gray silt loam, platy structure, 6 to 8 inches thick, mottling. A_2-Dark gray and gray silt loam, platy structure, 9 to 11 inches thick. B_2-Black to very dark gray and dark gray brown with yellowish brown mottles, silty clay, moderate to strong fine subangular blocky structure, 9 to 13 inches thick.	<u>Beckwith</u> A_1-Dark gray silt loam, platy structure, 3 to 5 inches thick. mottling. A_2-Gray brown to light brownish gray, silt loam, platy structure, 7 to 9 inches thick. B_2-Dark gray brown to gray brown with dark brown to yellowish brown mottles, silty clay, moderate to strong fine subangular blocky structure, 13 to 17 inches thick.

strongly expressed in forest soils, the B_2 horizons become progressively thicker, and depth to mottling increases slightly in soils of equivalent slope and natural drainage class.

Imperfectly drained biosequences (Muscatine to Atterberry to Stronghurst, Mahaska to Givin to Keomah and Grundy to Pershing to Weller) show the following progressive trends from grass to forest: The A_2 horizon becomes progressively lighter colored and thinner; an A_2 horizon appears in forest-grass transition soils and becomes more conspicuous in forest soils; the A_2 horizon becomes more brown in forest soils than in forest-grass transition soils; the B_2 horizons become progressively lighter colored from grass to forest soils. Mottlings occur at shallower depth in forest soils than in grassland soils under equivalent drainage conditions.

Poorly drained biosequences (Garwin to Walford to Traer, Taintor to Rubio to Berwick and Haig to Belinda to Beckwith) show these progressive trends form grass to forest: The A_1 horizon becomes progressively lighter colored, lower in clay content and thinner. A weak platy structure develops in the A_1 horizon and an A_1 horizon appears in the forest-grass transition soils; the A_2 horizon becomes progressively more conspicous and is more brown and thinner in forest soils than in forest-grass transition soils; the B_2 horizon becomes progressively thinner and less dark, with fewer olive mottles, and mottles or concretions are at progressively greater depths from grass to forest soils. /This trend of increasing depth to mottles and concretions in soils of equivalent slope (natural drainage conditions) from grassland to forest soils may be significant. It may suggest a change in subsurface aeration relations as a function of kind of vegetation./

Changes in morphology in relation to slope and natural drainage class (a topo-hydrosequence) will be described in this order: Well drained (moderately sloping), imperfectly drained (gently sloping) to poorly drained (level) soils. Trends indicate kinds of changes from the characteristic profile of the well drained soil.

Topo-hydrosequences of grassland soils (Tama to Muscatine to Garwin, Otley to Mahaska to Taintor and Grundy to Haig) show these progressive trends: The A_1 horizon becomes progressively darker, higher in clay, and thicker; the B_2 horizon becomes progressively thicker and darker, and mottles (especially gray and olive colors) become more common as natural drainage becomes poorer. Mottlings and concretions are found nearer the surface as drainage becomes poorer, especially in the soils of the northern segment of the study area.

Topo-hydrosequences of forest-grass transition soils (Downs to Atterberry to Walford, Ladoga to Garwin to Rubio and Pershing to Belinda show these trends; color, structure, texture and thickness of the A_1 horizon do not show consistent trends: the A_2 horizon color becomes progressively darker, and mottling becomes more common and of higher contrast as natural drainage becomes poorer. Mottling is at progressively shallower depths as drainage becomes poorer.

Topo-hydrosequences of forest soils (Fayette to Stronghurst to Traer, Clinton to Keomah to Berwick and Weller to Beckwith) show trends as follows: The A_1 horizon becomes progressively more brown and thicker, (all members of the southernmost hydrosequences have platy A_1 horizons); the A_2 horizons become progressively more brown (less gray); the B_2 horizons become more gray brown (less brown) and mottling becomes more common as natural drainage becomes poorer. Mottling and concretions are found at progressively shallower depth as drainage becomes poorer.

The changes of morphology among members of geographical location sequences (segments of the study area) of well drained, imperfectly drained and poorly drained grassland, forest-grass transition and forest soils will be discussed in this order: North to central to south within the study area. Trends indicate changes from the members in the northern segment of the traverse.

A well drained grassland sequence (Tama to Otley) shows these trends: The A_1 horizon becomes grayer and thicker, the B_2 horizon becomes thinner, browner and higher in clay from northern to central area. Mottlings and concretions occur at shallower depth in the central area.

A well drained forest-grass sequence (Downs to Ladoga) shows these trends: The A_1 horizon becomes darker and

and thicker, the A_2 horizon becomes grayer and thinner, the B_2 horizon becomes grayer from northern to central area. Mottlings and concretions occur at shallower depths in the central area.

A well drained forest sequence (Fayette to Clinton) shows these trends: The A_1 horizon becomes grayer, the A_2 horizon becomes thicker and browner (less gray), the B_2 horizon becomes brighter in color and thinner from northern to central areas.

The imperfectly drained grassland sequence (Muscatine to Mahaska to Grundy) shows these progressive trends: The A_1 horizon becomes slightly grayer (less black); the B_2 horizon becomes thinner and more gray (less brown), mottling becomes more common and clay content increases from north to south. Mottlings and concretions occur at shallower depths in the southern area.

The imperfectly drained forest-grass sequence (Atterberry to Givin to Pershing) shows these trends: Characteristics of morphology of A_1 and A_2 horizons are similar from the northern to central to southern portion of the traverse, colors of the B horizon of the Pershing soil indicate that it is more nearly moderately well drained than imperfectly drained. Depths to mottling and concretions do not follow a definite locational trend in this sequence.

The geographical location sequence of imperfectly drained forest soils (Stronghurst to Keomah to Weller) shows these trends: The A_1 horizons of soils of the central and southern segments of the study area have platy structure; the A_2 horizons become more gray (less brown); the B_2 horizons become thinner, lighter colored, and finer textured from north to south. Mottling and concretions are at shallower depth in the southern area.

The geographical location sequence of poorly drained grassland soils (Garwin to Taintor to Haig) shows these progressive trends: The A_1 horizons become grayer (not so black) and lower in clay, the B_2 horizons become finer textured and darker from north to south. Depth to mottling is nearly constant but mottles become more contrasting in the B_2 horizons from north to south.

The locational sequences of poorly drained forest-grass transition soils (Walford to Rubio to Belinda) shows these trends: Platiness is absent in the A_1 horizons of soils of the northern and central areas, but is present in A_1 horizons of soils of the southern area. The A_2 horizons become progressively darker and thicker, the B_2 horizons become progressively darker and thinner, and mottles are of higher contrast from north to south. Mottles and concretions are present in the surface horizons and subhorizons of soils in all three segments of the study area.

The geographic location sequence of poorly drained forest soils (Traer to Berwick to Beckwith) show these trends: The A_1 horizon becomes progressively darker gray and platy structure appears; the A_2 horizon becomes slightly thicker; the B_2 horizon becomes lighter colored, thinner and contains more clay, and mottles have higher contrast from north to south. Mottling and concretions are present in the surface horizons and subhorizons of soils in all three segments of the traverse.

Laboratory data

Total nitrogen and organic carbon. Total nitrogen and organic carbon data and ratios of organic carbon to total nitrogen (C/N ratios) for all soils are presented in Appendix B. Total nitrogen is plotted against depth in Figure 4 and the depth distribution of organic carbon is shown in Figure 5.

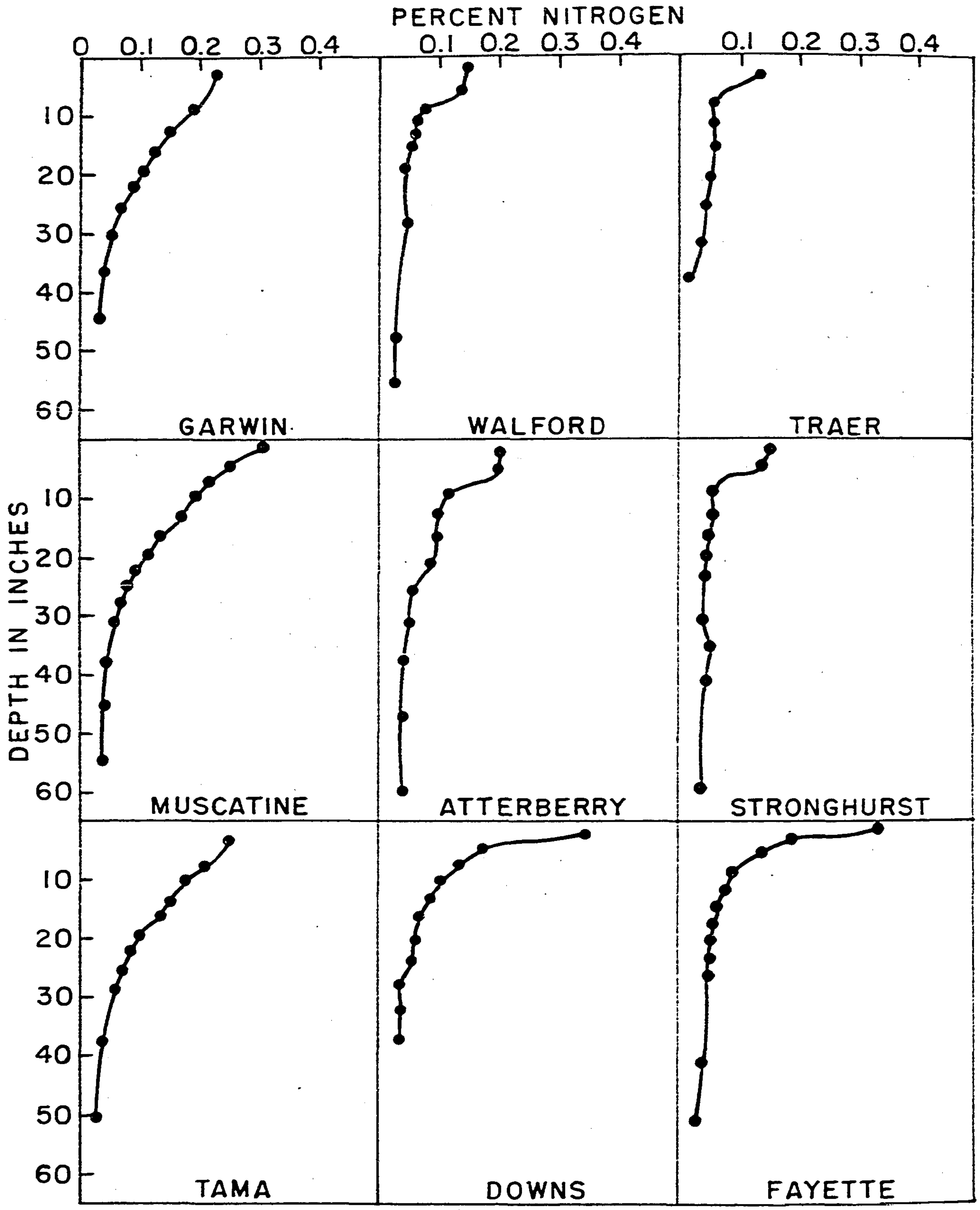
The nitrogen and carbon data and graphic presentations show contrasts and trends among grassland, forest-grass transition and forest soils similar to those already adequately described by other investigators (74). Those general relationships will not be discussed in this report.

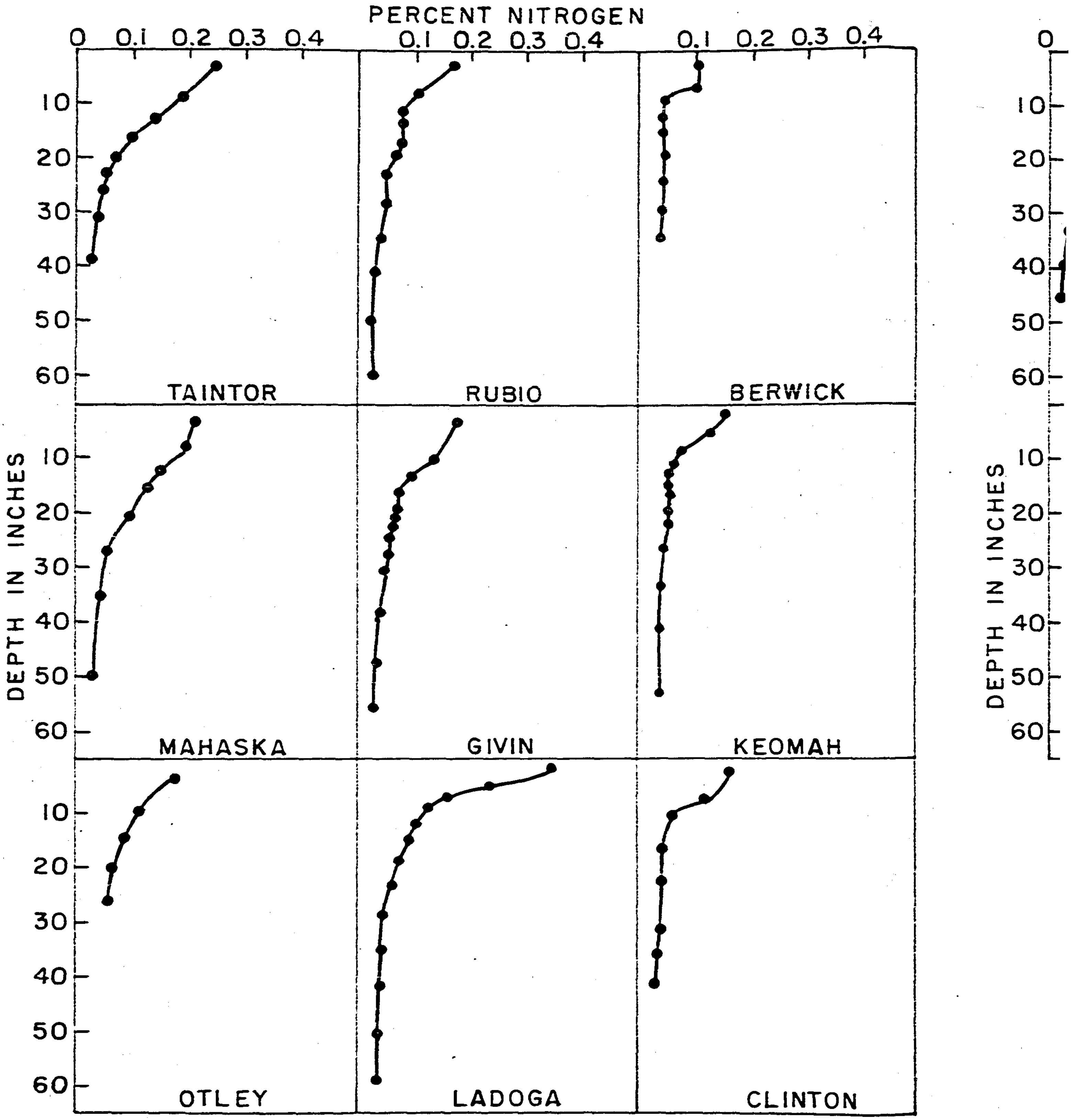
The relative areas between individual total nitrogen curves and the zero nitrogen axis, in Figure 4, were measured by counting the squares of a grid overlay to provide an index of relative total nitrogen content of soils. The relative areas between depths of 5 and 40 inches, are presented in Table 7. The segment of the curves above the 5 inch depth was not included because of possible differential influences related to past management practices; some soils are virgin and some have been cultivated. All curves in Figure 5 show a nearly constant amount of total nitrogen and rate of decrease in total nitrogen below the 40 inch depth; differences below that depth are very small. Inclusion of the area above the five inch depth would increase the size of the numbers slightly but would not cause reversals or important changes in magnitude of the trends of relative total nitrogen content among the various soils. Averages of the relative total nitrogen data will be used to compare soils developed under varying conditions of the soil forming factors.

Trends of carbon/nitrogen ratios for two depth segments of soil profiles of special interest are summarized in Table 8. The "lower A" horizon in grassland soils refers to depths equivalent to those of the A_2 horizons in forest soils. Carbon to nitrogen ratios decrease with depth in all soils. The mean values for C/N ratios suggest that there is no differential for soils of equivalent vegetation and natural drainage class on the basis of geographic location. For this reason, C/N ratios of the "lower A" horizon and the B_2 horizon of soils of equivalent vegetation and natural drainage for all geographic locations were grouped. Differences among the mean C/N ratios will be used to compare soils developed under varying conditions of the soil forming factors.

Cursory examination of the C/N data shows that grassland soils have consistently wider ratios than forest soils in both the "lower A" and the B_2 horizons. The C/N ratios are

Figure 4. Depth distribution of total nitrogen in the 24 soils


PERCENT NITROGEN
0 0.1 0.2 0.3 0.4
0.1 0.2 0.3 0.4
0.1 0.2 0.3 0.4
DEPTH IN INCHES
10 20 30 40 50 60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE


PERCENT NITROGEN
0 0.1 0.2 0.3 0.4
DEPTH IN INCHES
10 20 30 40 50 60
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON

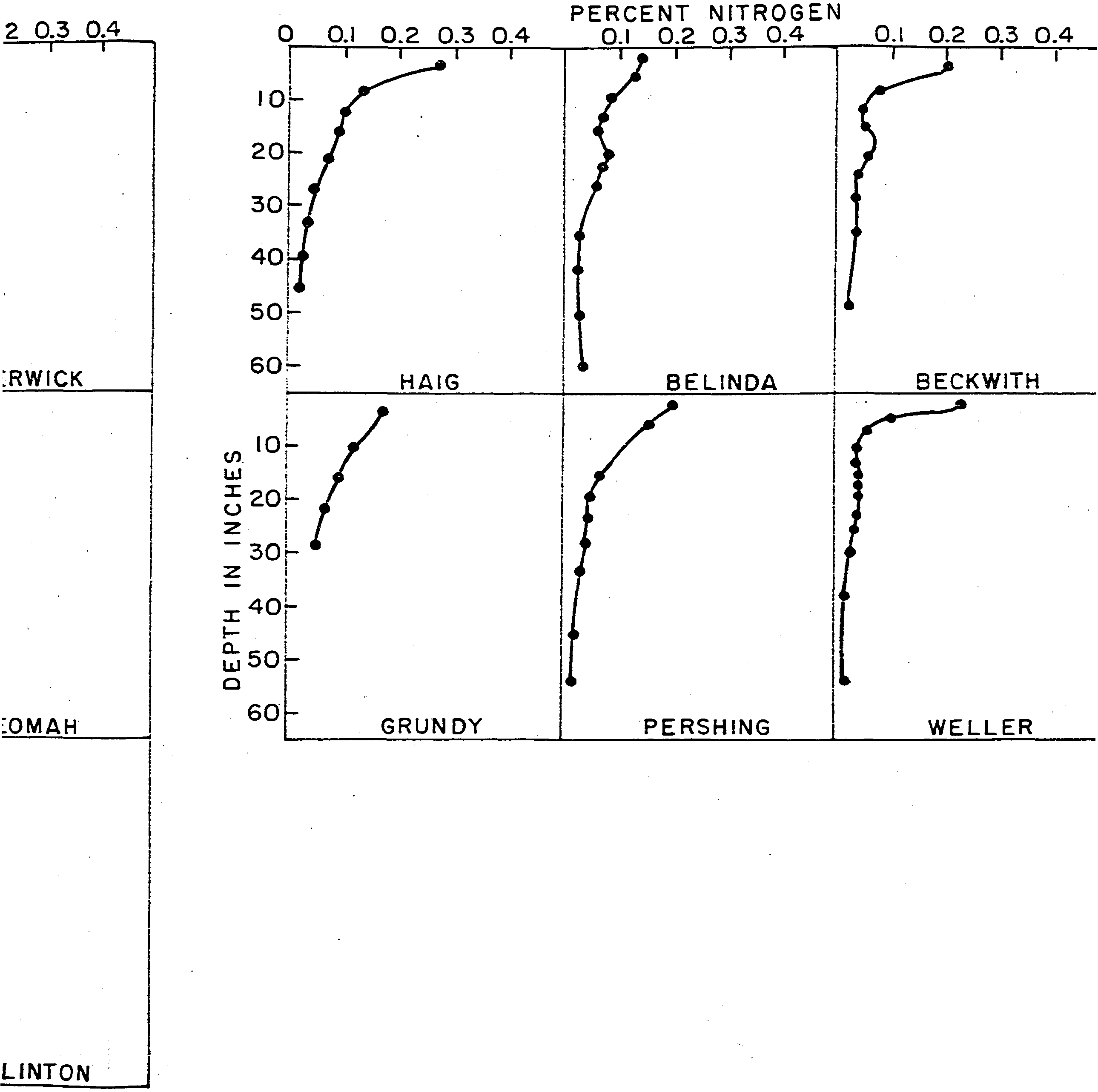
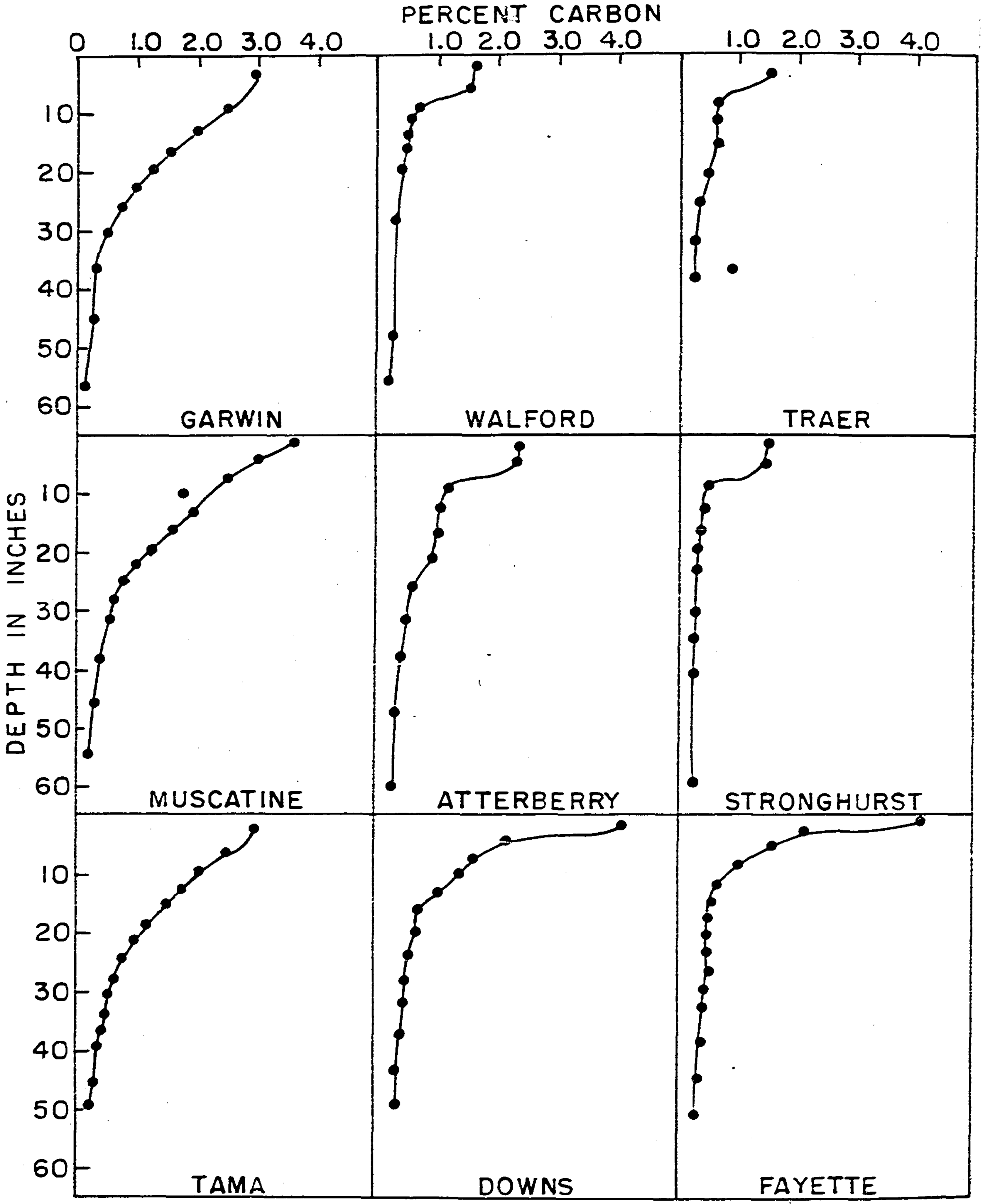
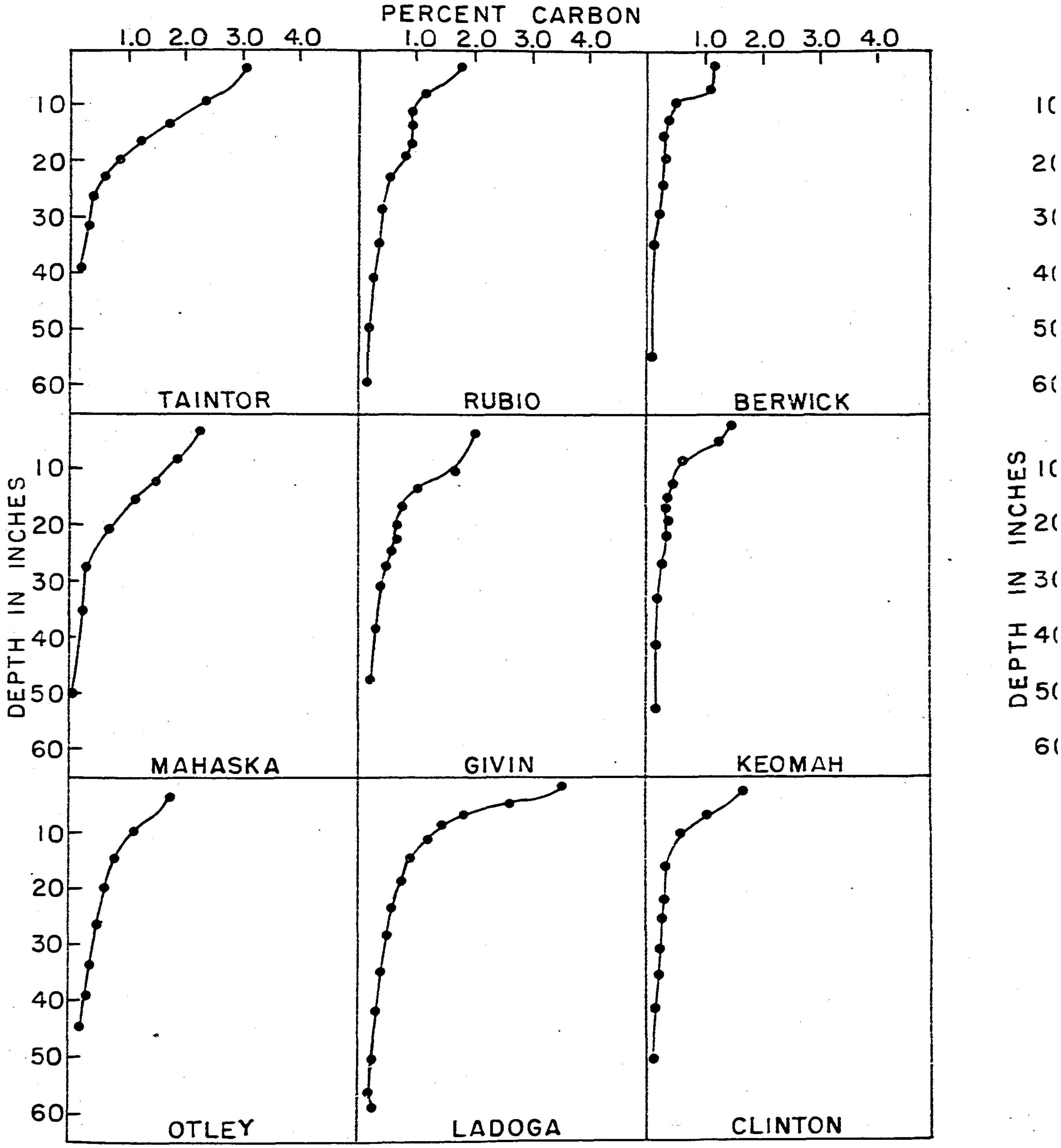
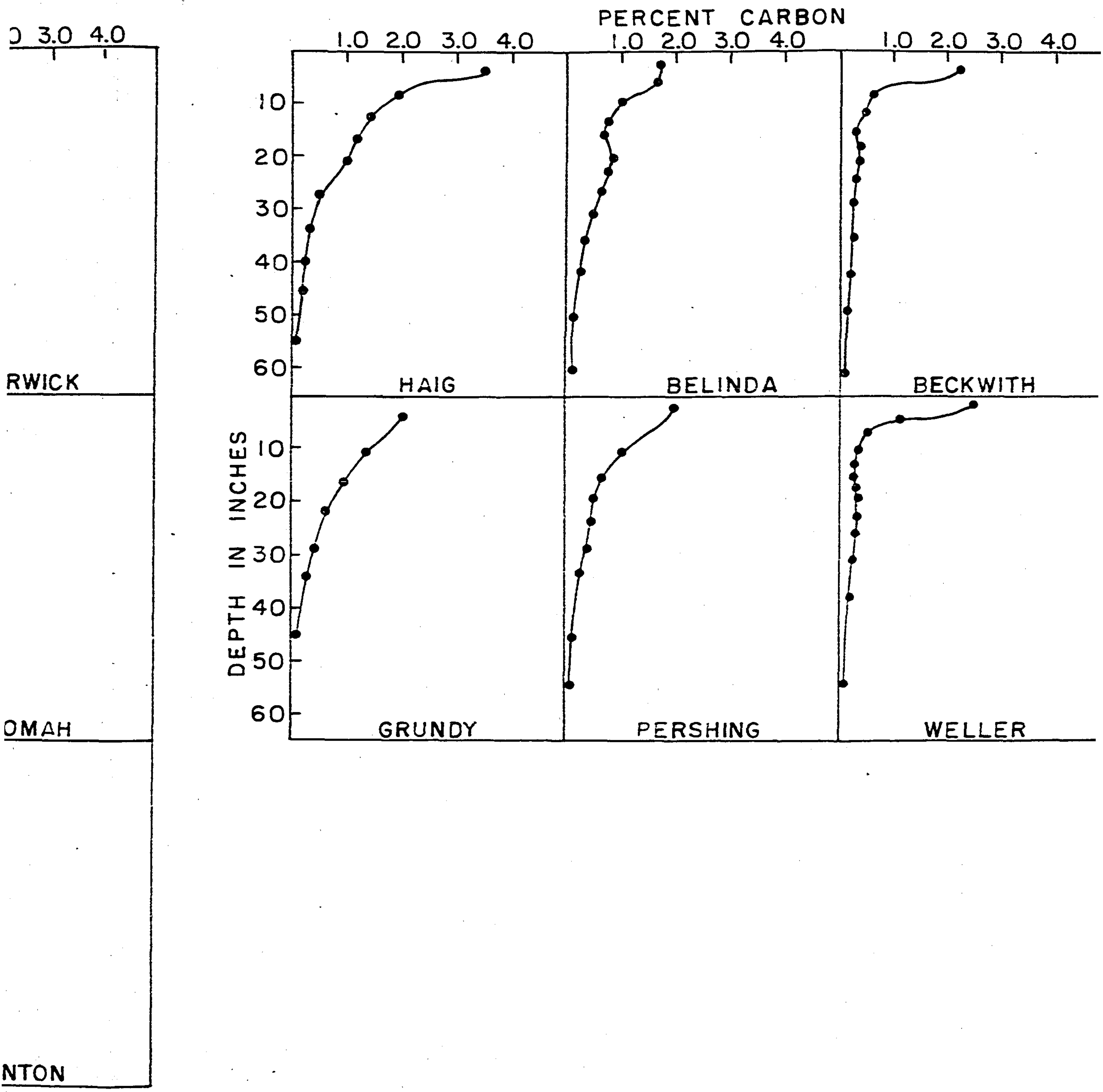

PERCENT NITROGEN
DEPTH IN INCHES
0 0.1 0.2 0.3 0.4
10
20
30
40
50
60
RWICK
EOMAH
LINTON
HAIG
BELINDA
BECKWITH
GRUNDY
PERSHING
WELLER

Figure 5. Depth distribution of organic carbon in the 24 soils


PERCENT CARBON
0 1.0 2.0 3.0 4.0
DEPTH IN INCHES
10 20 30 40 50 60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE


PERCENT CARBON
1.0 2.0 3.0 4.0
DEPTH IN INCHES
10
20
30
40
50
60
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON



PERCENT CARBON
1.0 2.0 3.0 4.0
DEPTH IN INCHES
10
20
30
40
50
60
RWICK
HAIG
BELINDA
BECKWITH
OMAH
GRUNDY
PERSHING
WELLER
NTON

Table 7. Relative total nitrogen between depths of 5 and 40 inches in the 24 soils

Segment of study area	Grass				Forest-grass transition				Forest				
	WD[a]	ID[b]	PD[c]		WD	ID	PD		WD	ID	PD		
8	15				9				8				10.7[d]
Northern		16		15[e]		13		10		8		7.3	12.3
			14				8				6		9.3
	10				11				7				9.3
Central		13		11.7		10		10		8		7.3	10.3
			12				9				7		9.3
	--				--				--				--
Southern		11		11		10		9.5		6		6.5	9.0
			11				9				7		9.0
	12.5[f]	13.3	12.3		10	11	8.7		7.5	7.3	6.7		

[a]Well drained soils.

[b]Imperfectly drained soils.

[c]Poorly drained soils.

[d]Average relative total nitrogen if natural drainage (slope) and geographical location are held constant and members of biosequences are grouped. (Averages are underlined.)

[e]Average relative total nitrogen if vegetation and geographical location are held constant but members of hydrosequences are grouped.

[f]Average relative total nitrogen if vegetation and natural drainage (slope) are held constant but members of geographical location sequences are grouped.

Table 8. Summary of the mean carbon/nitrogen ratios for the "lower A" (or A_2) horizons and B_2 horizons of groups of soils (Soils from all geographic locations segments make up a group)

Soil horizon	Grass			Forest			
	WD[a]	ID[b]	PD[c]	WD	ID	PD	
"lower A" (or A_2)	9.9			9.7			-0.2[d]
		10.3			8.4		-1.9
			13.4			9.8	-3.6
			+ 3.5[e]			+0.1	
B_2	9.1			8.2			-0.9
		8.8			7.2		-1.6
			11.9			7.7	-4.2
			+ 2.8			-0.5	

[a]Well drained soils from northern and central segments of the traverse.

[b]Imperfectly drained soils from northern, central and southern segments of the traverse.

[c]Poorly drained soils from northern, central and southern segments of the traverse.

[d]Difference between values for grassland and forest soils. (Differences are underlined.)

[e]Difference between values for well drained and poorly drained soils.

narrower in the B_2 than in the "lower A" horizon in any single group of soils of equivalent drainage and vegetation.

Trends and relationships of organic carbon and total nitrogen data suggest that either could be used as an index of total organic matter. Organic matter content of the soils will be inferred from the total nitrogen data. It is assumed that high total nitrogen content is indicative of high soil organic matter content. The trends of organic matter and C/N ratio will be discussed for the soils grouped by biosequences, hydrosequences and geographic location sequences.

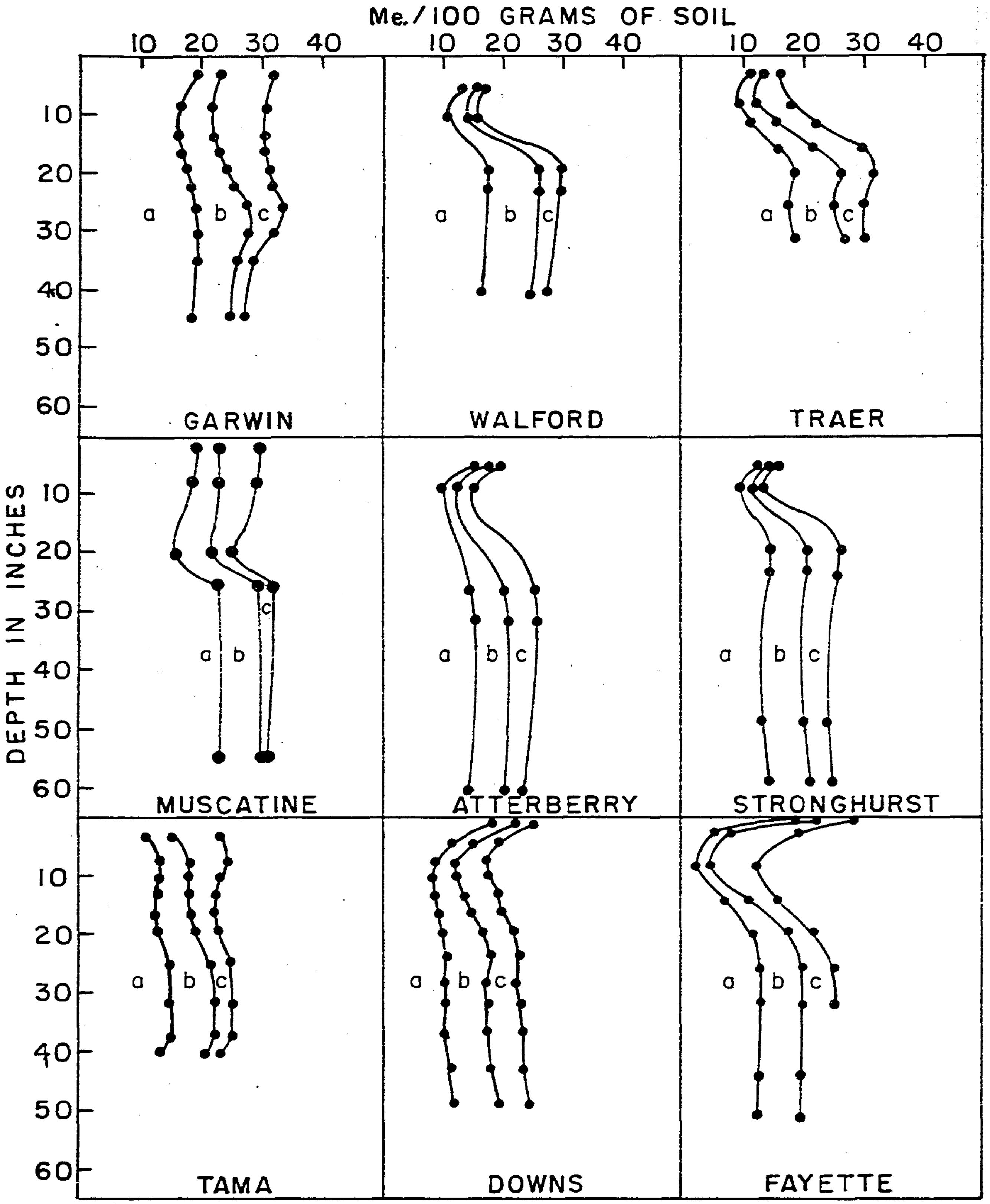
Among biosequences of well drained, imperfectly drained and poorly drained soils, (a) the progressively decreasing averages of relative total nitrogen suggest more frequent or higher rates of addition of fresh organic matter or a greater dominance of effects of organic matter additions over processes of organic matter destruction in grassland than in forest soils, and (b) wider C/N ratios in the "lower A" horizon and the B_2 horizon in grassland soils than in forest soils, under equivalent conditions of natural drainage, suggest that decomposition of organic materials is more advanced in forest than in grassland soils.

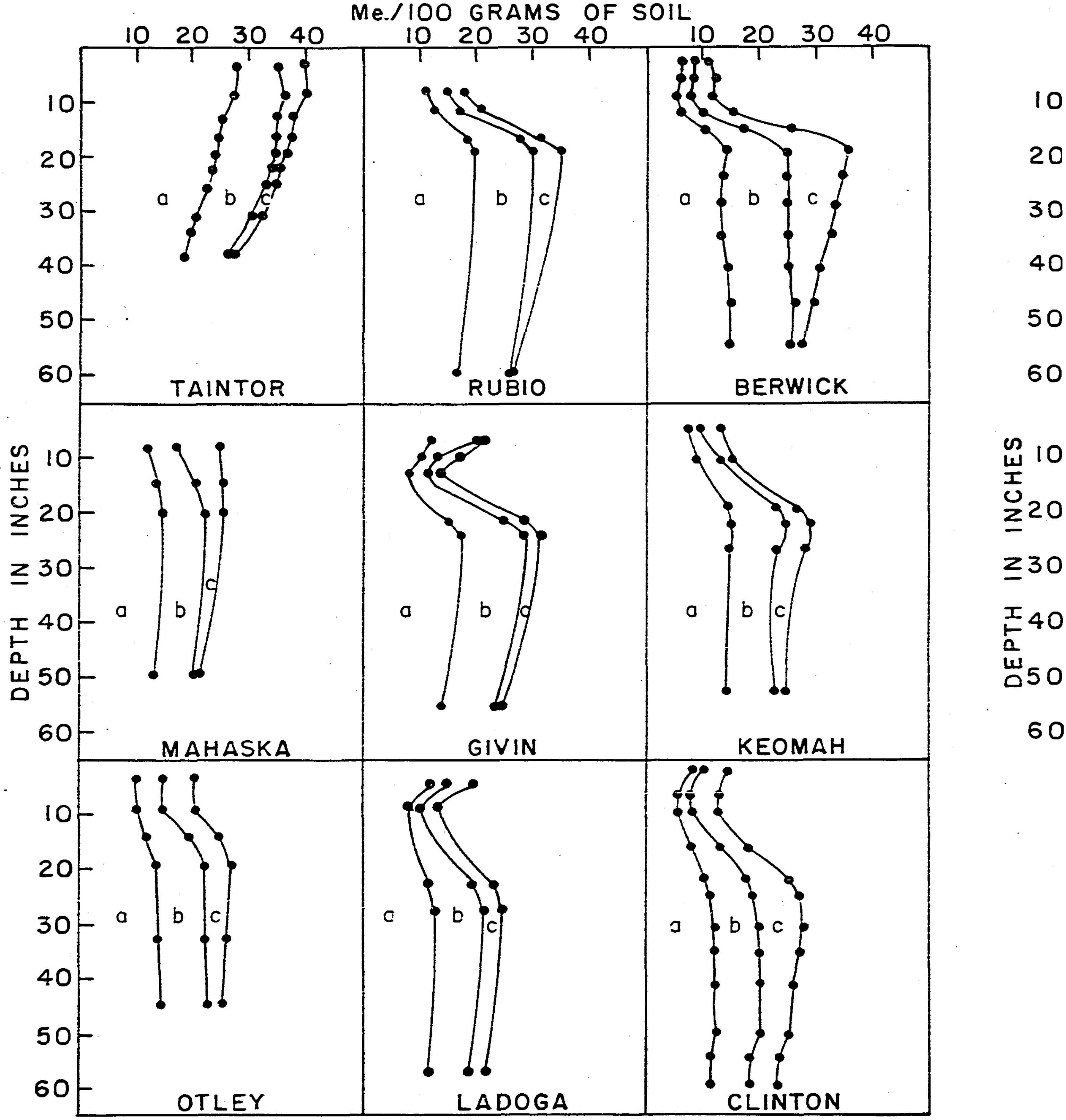
Among hydrosequences (toposequences), the relative total nitrogen data suggest slightly more frequent or slightly higher rates of addition of fresh organic matter or a slightly higher greater dominance of effects of organic matter additions over processes of organic matter destruction in imperfectly drained soils (gently sloping) than in well drained (moderately sloping) or poorly drained (level) soils under all types of vegetation. The differences in organic matter content are so small between well drained and poorly drained soils that analyses from many more profiles would be necessary to establish differences and the presence of a trend, and (b) the C/N ratios in the "lower A" horizon and the B_2 horizon in poorly drained soils and well drained soils, under equivalent kinds of vegetation, suggest a similar stage of decomposition of organic materials under forest and under grassland vegetation on well drained sites, but a more advanced stage of decomposition of organic matter in poorly drained soils under forest than under grass. The Beckwith and Belinda soils have slight organic carbon and nitrogen bulges in the B horizon.

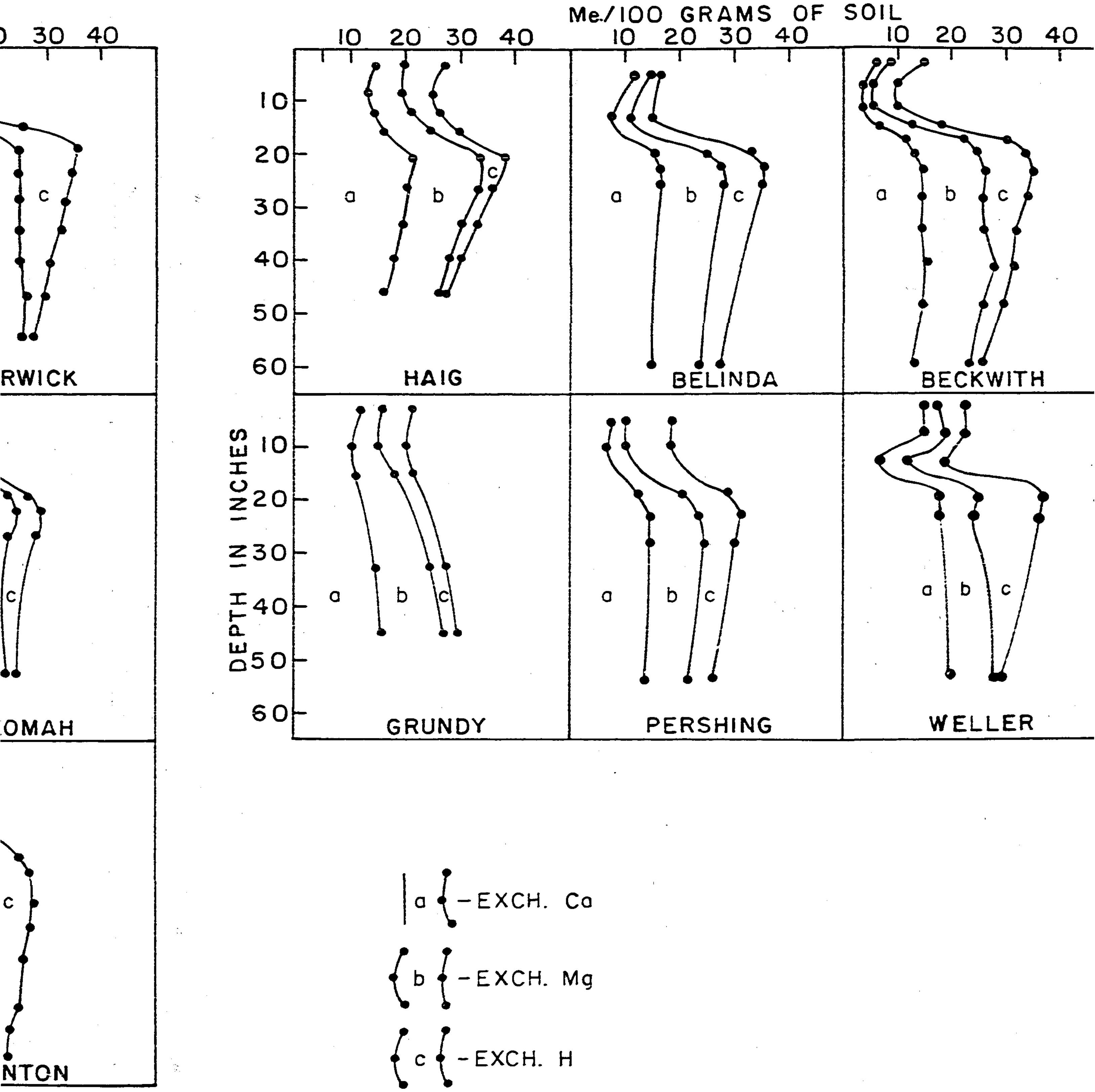
Among members of geographical location sequences, the progressively decreasing averages of relative total nitrogen suggest that the dominance of processes of organic matter additions over processes of organic matter decomposition are greater for northern soils than for southern soils for all drainage classes under all types of vegetation.

Exchangeable cation status. Exchangeable cation data (calcium, magnesium and hydrogen) for the 24 soils are in Appendix B and are plotted against depth in Figure 6. The curve to the extreme right in each diagram represents the sum of exchangeable calcium, magnesium and hydrogen and will be

Figure 6. Exchangeable cation distribution with depth for the 24 soils

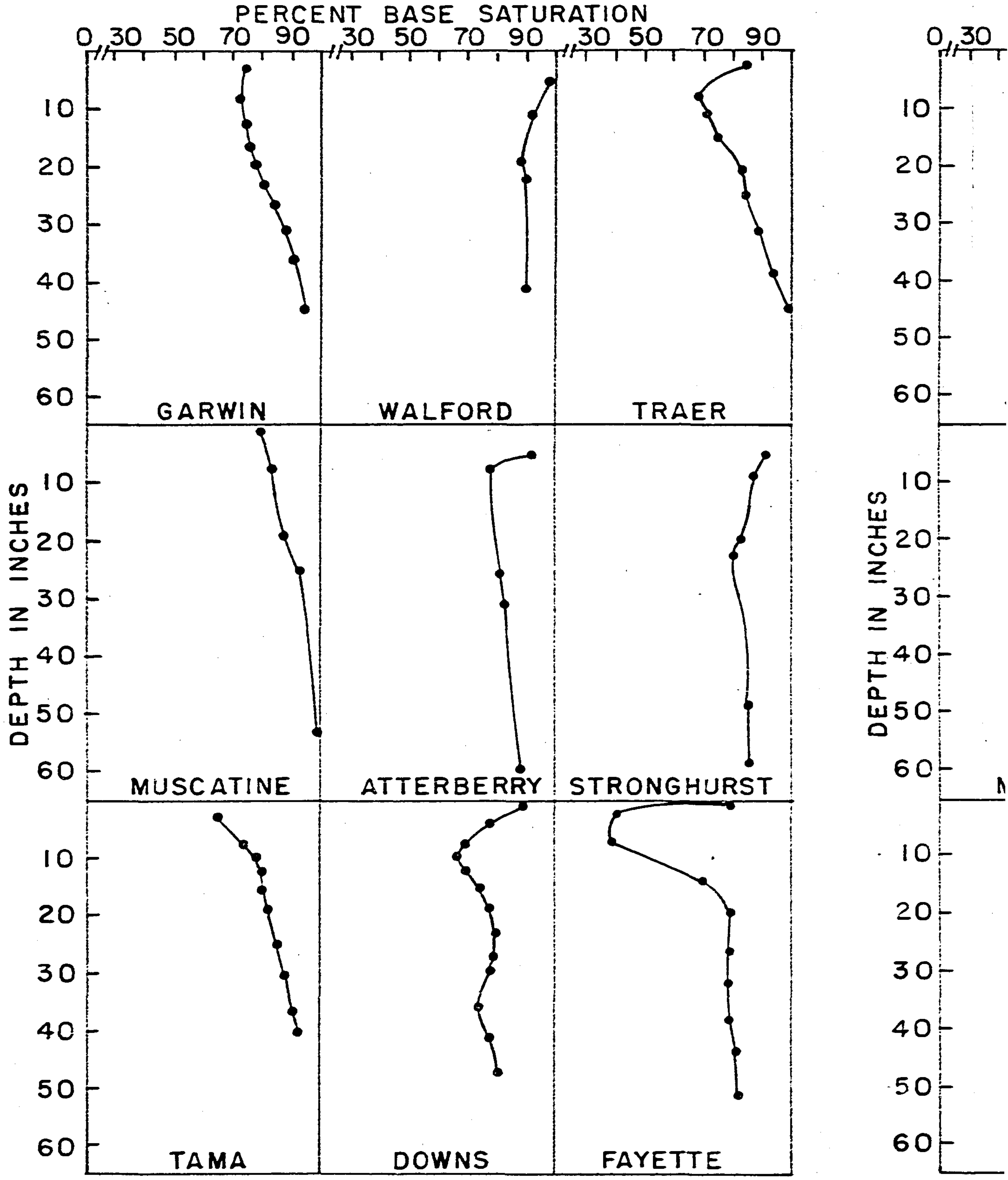

Me./100 GRAMS OF SOIL
10 20 30 40
DEPTH IN INCHES
10 20 30 40 50 60
a b c
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE

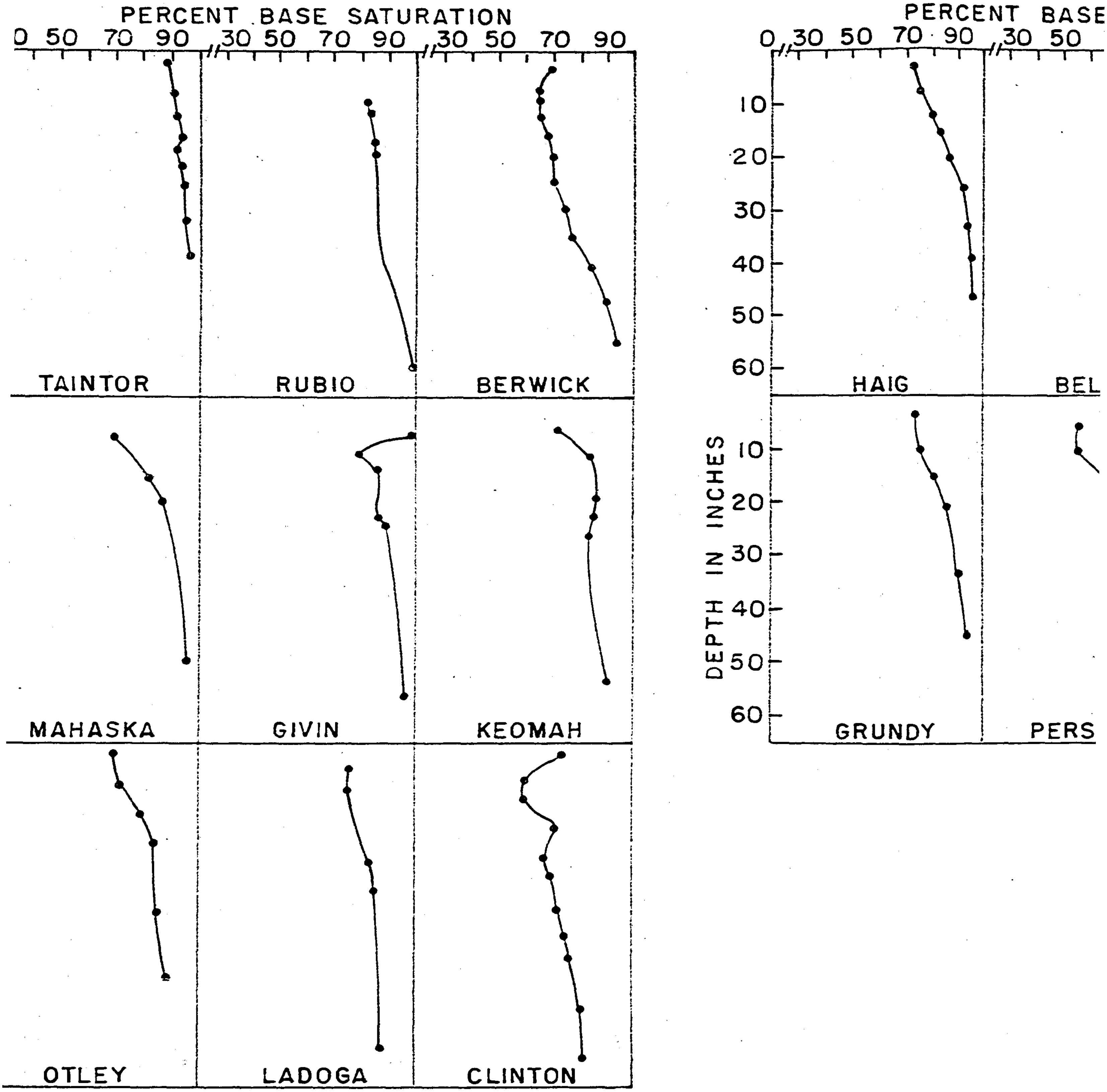

Me./100 GRAMS OF SOIL
10 20 30 40
DEPTH IN INCHES
10 20 30 40 50 60
a b c
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON



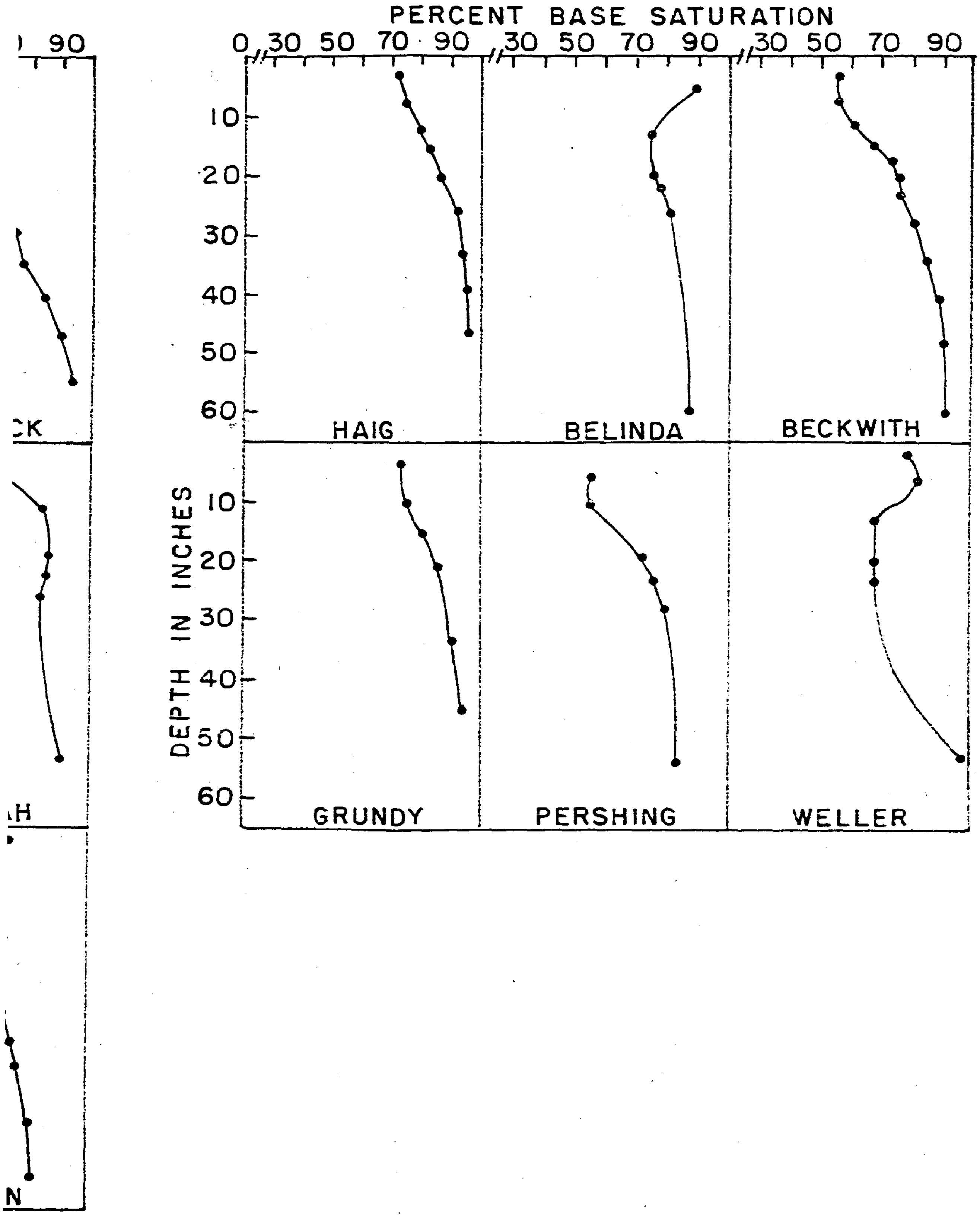
Me./100 GRAMS OF SOIL
10 20 30 40
DEPTH IN INCHES
RWICK
HAIG
BELINDA
BECKWITH
OMAH
GRUNDY
PERSHING
WELLER
NTON
a
b
c
a - EXCH. Ca
b - EXCH. Mg
c - EXCH. H

Figure 7. Per cent base saturation with depth for the 24 soils


PERCENT BASE SATURATION
0 30 50 70 90
30 50 70 90
30 50 70 90
DEPTH IN INCHES
10
20
30
40
50
60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE

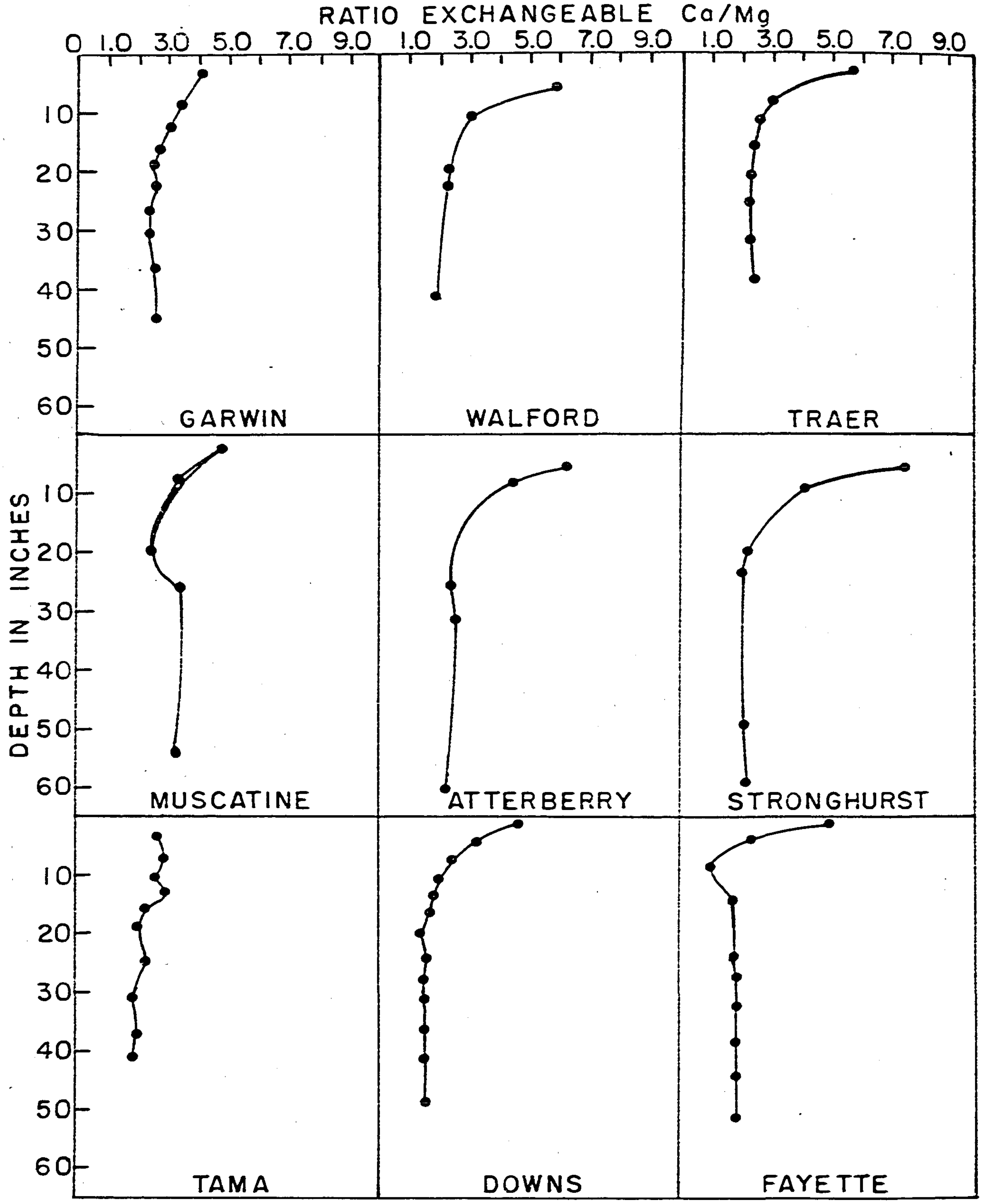


PERCENT BASE SATURATION
0 50 70 90 30 50 70 90 30 50 70 90
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON
PERCENT BASE
0 30 50 70 90 30 50
10
20
30
40
50
60
DEPTH IN INCHES
HAIG
BEL
GRUNDY
PERS

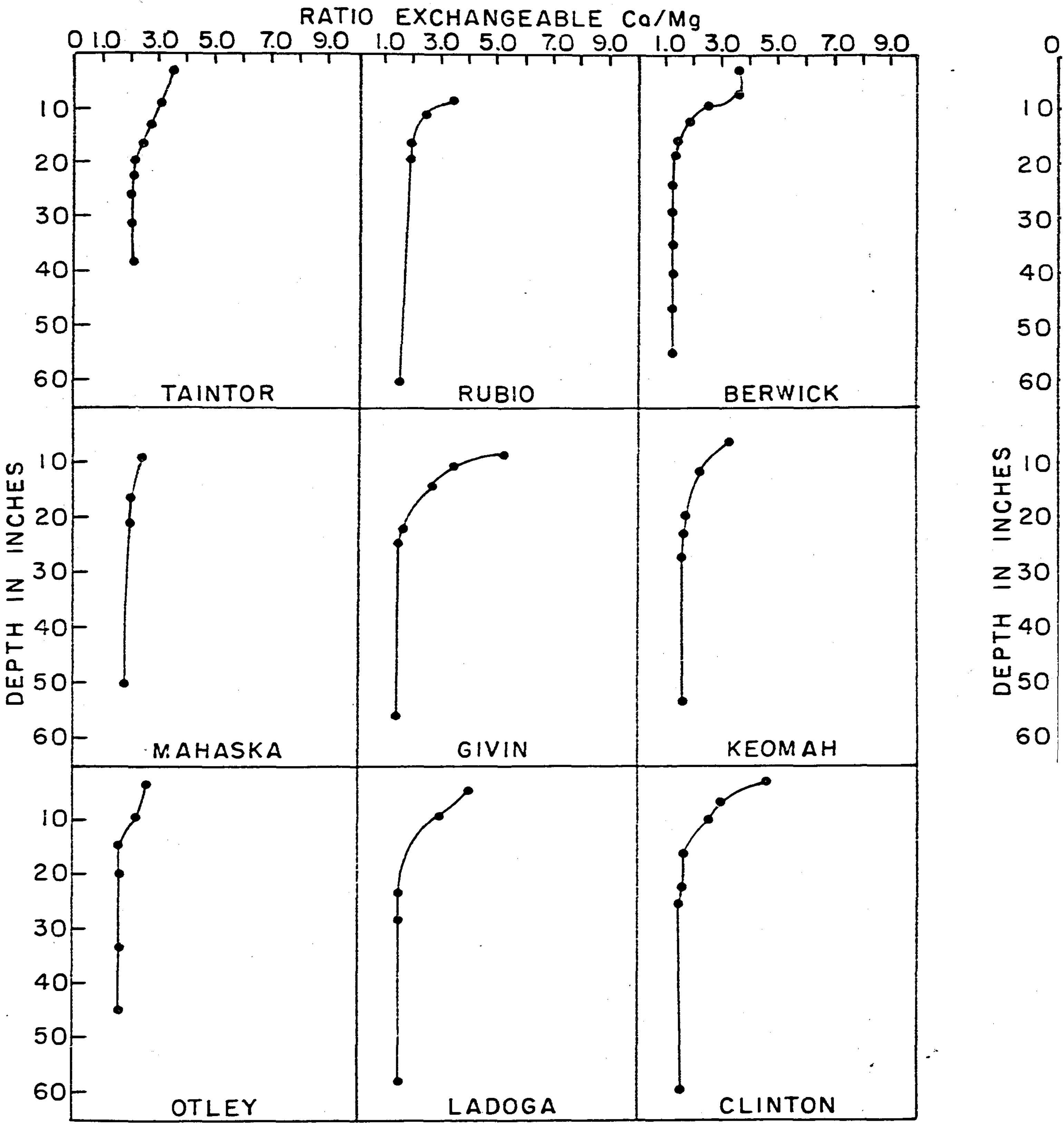


PERCENT BASE SATURATION
0 30 50 70 90 30 50 70 90 30 50 70 90
DEPTH IN INCHES
10
20
30
40
50
60
HAIG
BELINDA
BECKWITH
GRUNDY
PERSHING
WELLER
CK
H
N

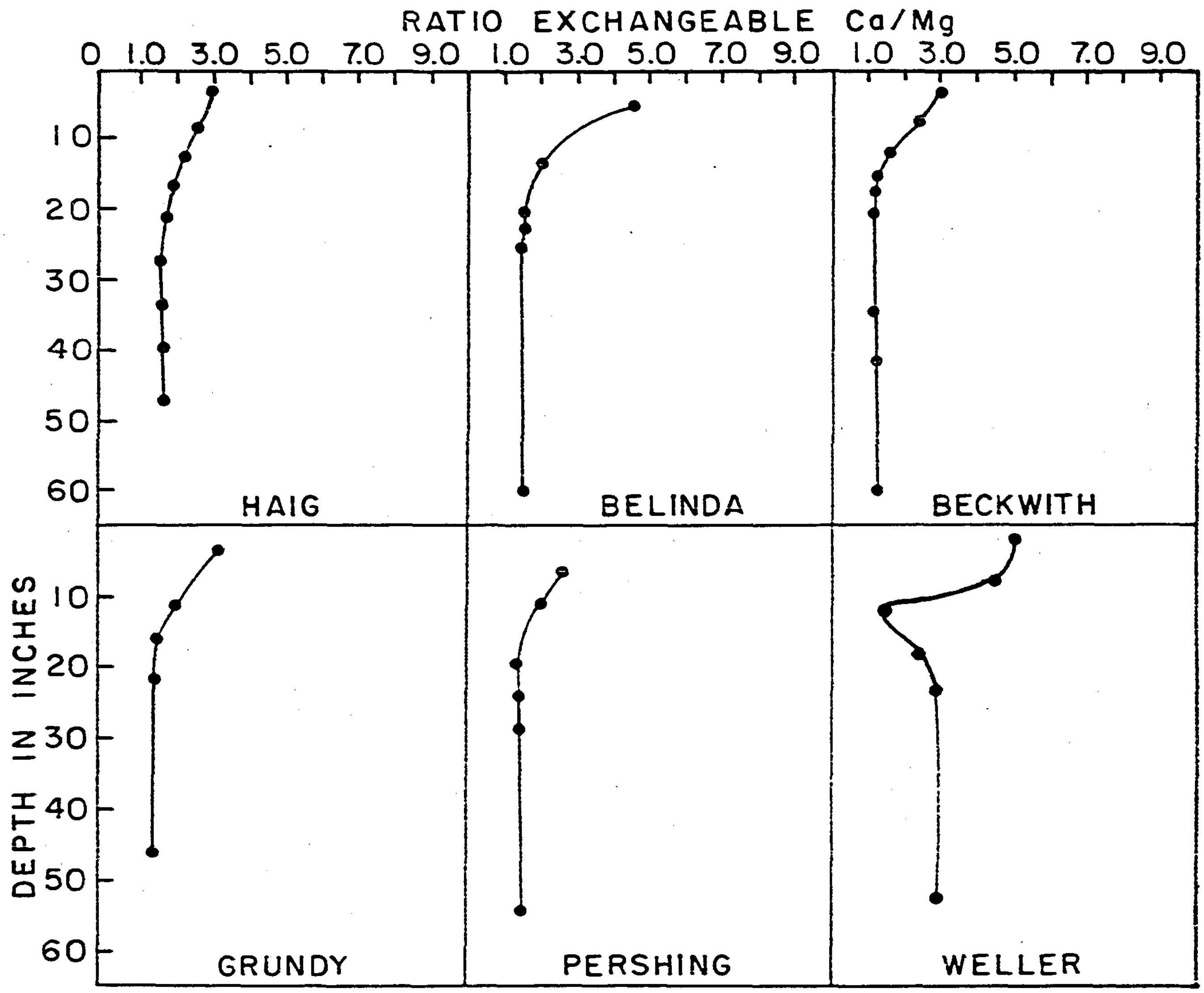
Figure 8. Ratio of exchangeable calcium to exchangeable magnesium with depth for the 24 soils



RATIO EXCHANGEABLE Ca/Mg
0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0
DEPTH IN INCHES
10 20 30 40 50 60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE



RATIO EXCHANGEABLE Ca/Mg
0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0
DEPTH IN INCHES
10
20
30
40
50
60
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON


RATIO EXCHANGEABLE Ca/Mg
0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0 1.0 3.0 5.0 7.0 9.0
DEPTH IN INCHES
10
20
30
40
50
60
HAIG
BELINDA
BECKWITH
GRUNDY
PERSHING
WELLER

assumed to represent the approximate total cation exchange capacity. The "sum of cations" (Ca, Mg, H) will be referred to as "exchange capacity" throughout the remainder of this report.

Per cent base saturation data for the 24 soils are in Appendix B and are plotted against depth in Figure 7. The ratios of exchangeable calcium to exchangeable magnesium (Ca/Mg) for the 24 soils are in Appendix B and are plotted against depth in Figure 8. The pH data for the 24 soils (in Appendix B) followed trends similar to trends in per cent base saturation; pH data are not presented graphically.

It is assumed that the loess parent material of all soils was calcareous and the initial condition was 100 per cent base saturation of the exchange complex plus an excess of free carbonates. Liming may have influences the per cent base saturation of some soils. No quantitative or qualitative measures of liming practices are available for the individual sites from which the soil samples were collected.

The relative intensity of base depletion, as a function of dominance of effects of removal by leaching over renewal by weathering and biological cycling, is suggested by comparing per cent base saturation of the soils.

The ratio of exchangeable calcium to exchangeable magnesium has been used by other investigators (13) (14) (64) as an indicator of stage of soil development. That the ratio may also be influenced by differential rates of renewal of calcium and magnesium in various parts of the soil by different kinds of vegetation is suggested by White (74).

The area in Figure 7 between the per cent base saturation curve and the 100 per cent base saturation axis (the right borderline of each box) was determined by means of a grid overlay. The relative areas and averages of those areas for soils developed under varying conditions of the soil forming factors specified are presented in Table 9. As the total base depletion of the profile increases, the "area" becomes greater. Trends of the averages will be used as an index of the relative degree of solum base depletion among soils. These values will be referred to as "indices of solum base unsaturation".

A measure of the relative base unsaturation at a depth of 40 inches has also been made. All soils are less than 100 per cent base saturated at a depth of 40 inches. Since the per cent base saturation is that proportion of the "cation exchange capacity" which is composed of basic cations, the remaining percentage (100 - per cent base saturation) may be called the per cent hydrogen saturation. The percentages of hydrogen saturation at the 40 inch depth and averages for groups of soils are presented in Table 10. As the numbers become larger, the degree of hydrogen saturation (base unsaturation) increases.

The trends of averages of "indices of solum base unsaturation" and hydrogen saturation at the 40 inch depth, from Tables 9 and 10, and trends of ratios of exchangeable calcium

Table 9. Indices of solum base unsaturation for the 24 soils

Segment of study area	Grass				Forest-grass transition				Forest				
	WD[a]	ID[b]	PD[c]		WD	ID	PD		WD	ID	PD		
North	16.0	10.5	16.5	14.3[e]	23.0	16.5	8.0	15.8	30.0	14.5	15.0	19.8	23.0[d] 13.8 9.8
Central	16.5	14.5	5.5	12.2	16.5	8.5	14.5	13.2	29.0	17.5	25.5	24.0	30.6 13.5 15.2
South	--	14.5	14.0	14.3	--	26.5	18.0	22.3	--	25.5	24.0	24.7	-- 22.2 18.6
	16.3[f]	13.2	12.0		19.7	17.2	13.5		29.5	19.2	21.5		

[a]Well drained soils.

[b]Imperfectly drained soils.

[c]Poorly drained soils.

[d]Average relative area of base unsaturation if natural drainage (slope and geographical location are held constant and members of biosequences are grouped. (Averages are underlined)

[e]Average relative area of base unsaturation if vegetation and geographical location are held constant and members of hydrosequences are grouped.

[f]Average relative area of base unsaturation if vegetation and natural drainage class (slope) are held constant, but members of geographical location sequences are grouped.

Table 10. Per cent hydrogen saturation at 40 inch depth for the 24 soils

Segment of study area	Grass				Forest-grass transition				Forest				
	WD[a]	ID[b]	PD[c]		WD	ID	PD		WD	ID	PD		
North	9				23				20				17[d]
		5		7[e]		17		17		14		13	12
			7				10				5		7
Central	13				13				23				16
		6		7		8		11		14		19	9
			3				12				18		11
South	--				--				--				--
		8		7		18		17		23		17	16
			5				16				11		11
	11[f]	6	5		18	14	13		22	17	11		

[a]Well drained soils.

[b]Imperfectly drained soils.

[c]Poorly drained soils.

[d]Average percent hydrogen saturation; drainage class (slope) and geographical location held constant and members of biosequences grouped. (Averages are underlined)

[e]Average percent hydrogen saturation; vegetation and geographical location held constant but members of hydrosequences grouped.

[f]Average percent hydrogen saturation; vegetation and natural drainage class held constant but members of geographical location sequences grouped.

to exchangeable magnesium (Ca/Mg) will be summarized within the framework of biosequences, hydrosequences (toposequences) and geographic location sequences.

Among biosequences of well drained, imperfectly drained and poorly drained soils, (a) progressively increasing indices of base unsaturation suggest greater dominance of processes of base depletion over processes of base renewal in forest soils than in grassland soils (forest-grass transition soils are intermediate), (b) progressively increasing hydrogen saturation at a depth of 40 inches suggests that processes of base depletion operate with greater intensity at this depth and probably to greater depths in forest soils than in grassland soils, and (c) the ratios of exchangeable Ca/Mg suggest that there is a differential in removal and/or cycling of calcium and magnesium among soils developed under forest and those developed under grass vegetation. The exchangeable Ca/Mg ratios are higher in the surface horizons of forest soils than in grassland soils, but exchangeable Ca/Mg ratios are generally lower in subhorizons of forested soils than grassland soils. The per cent base saturation of the surface horizon generally increases from grassland to forested soil, for soils of equivalent natural drainage class. Base depletion is generally greater in the A_2 horizon in forest soils than in the "lower A" of grassland soils.

Among hydrosequences (toposequences) of grassland, forest-grass transition and forest soils, (a) progressively decreasing "indices of solum base unsaturation" suggest lower dominance of processes of base depletion over processes of base renewal under poor drainage than under good drainage (the soils with imperfect drainage are intermediate except for imperfectly drained forest soils and the sequence soils of the central area), (b) relative hydrogen saturation at 40 inches suggests that base depletion is greater at this depth and possibly at greater depths in well drained than in poorly drained soils (imperfectly drained soils are intermediate), and (c) the exchangeable calcium to exchangeable magnesium ratios become greater as drainage becomes poorer (except for Haig which has lower ratios for corresponding horizons than does Grundy).

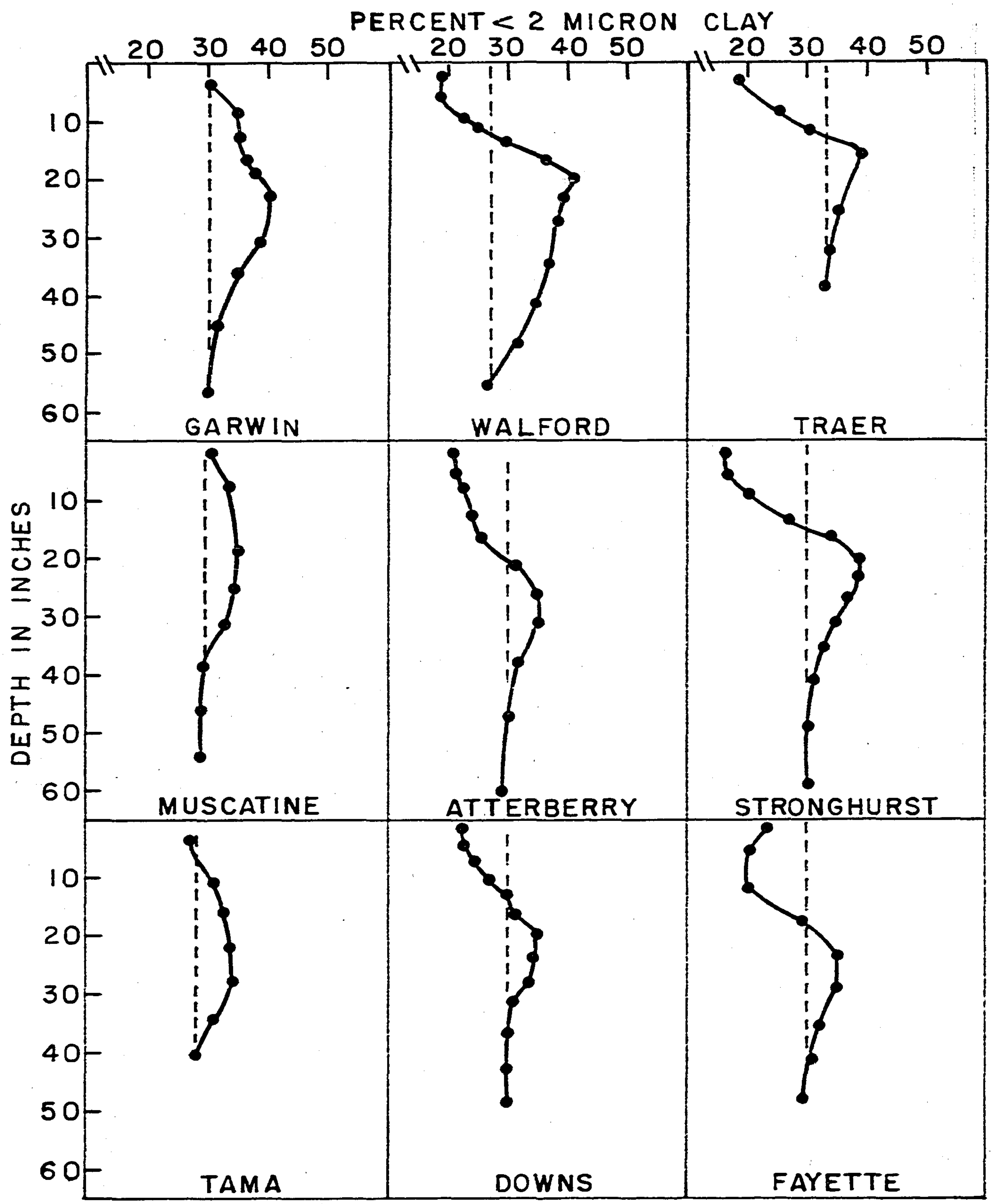
The trends associated with changing geographic location (from north to south) for soils of similar natural drainage (developed on comparable slopes) and under similar vegetation are as follows: (a) a general progressive increase in indices of base unsaturation from north to south suggests greater dominance of processes of base depletion over base renewal in southern than in northern areas (soils of the central area are intermediate except for location sequences of grassland and forest-grass transition soils), (b) no trend in depth of base depletion related to location is apparent, and (c) the ratio of exchangeable Ca/Mg for corresponding horizons generally decreases from north to south, but this trend is not consistent.

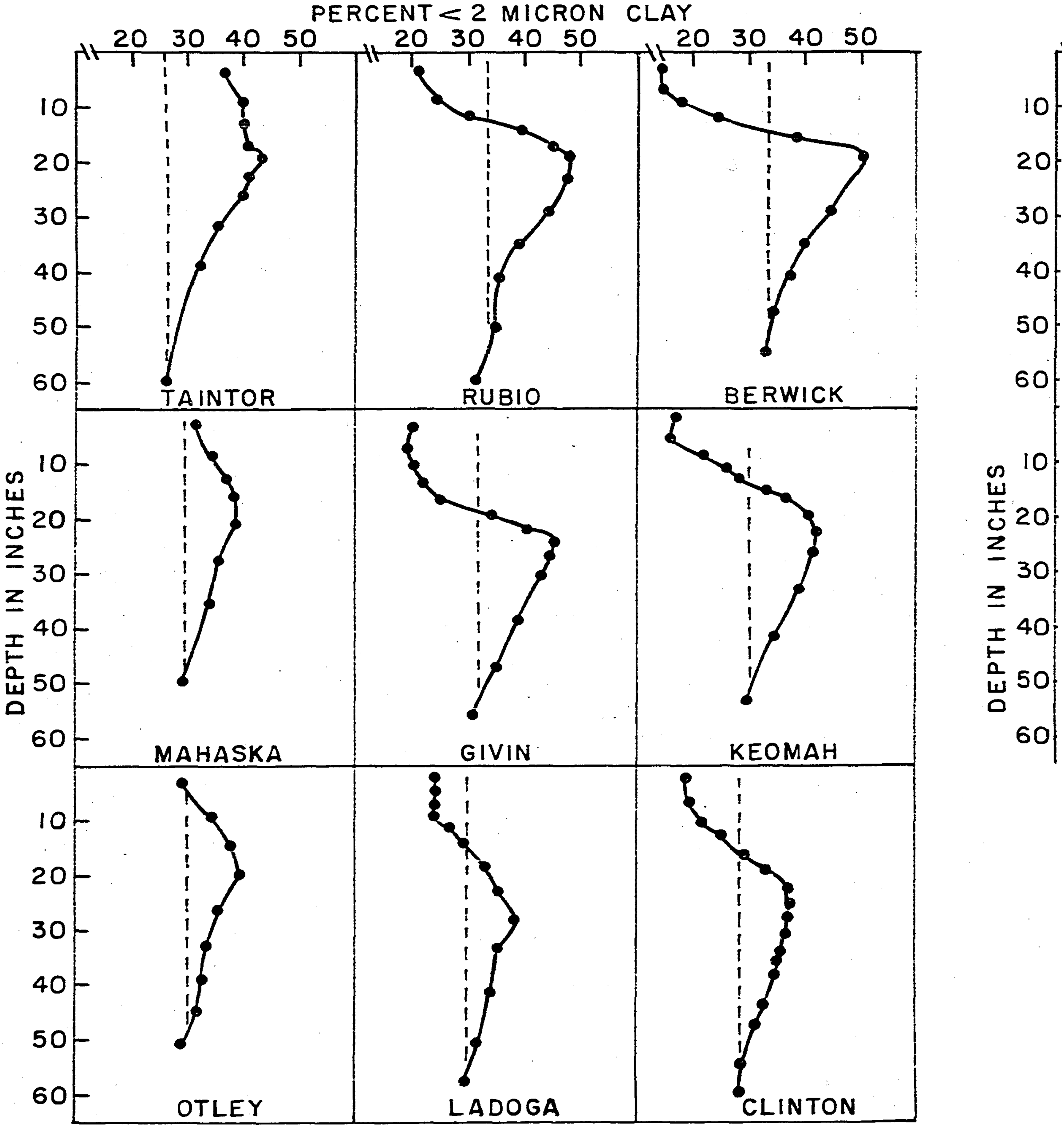
<u>Less than 2 μ clay.</u> The < 2 μ clay data are presented in detail for all soils in Appendix B and are plotted against depth in Figure 9.

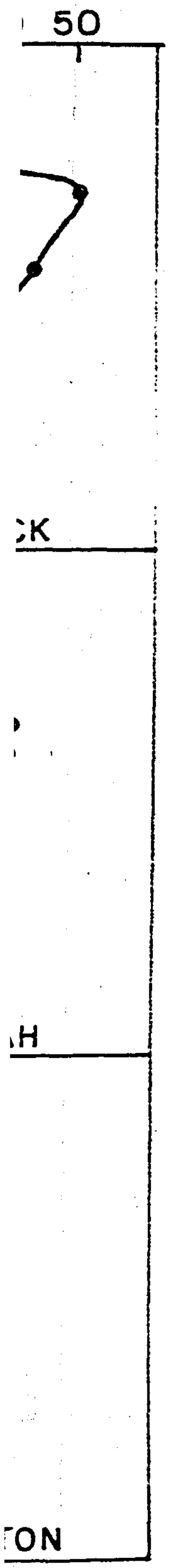
For purposes of estimating the change in clay distribution in the solum as a result of soil development influences, the clay content of the parent material has been assumed to be uniform with depth. Minimum clay at the greatest depth of sampling, in the C horizon, was assumed to represent the initial clay content of the parent material of the entire solum. In Figure 9, a vertical line was extended from the C horizon to the surface to represent the assumed clay content of the soil material throughout the solum at soil formation time "zero". The minimum clay content of the C horizon may not be a valid reference because of differences in sampling depths, trends in the clay content in the C horizon and, in at least one case (the Traer soil), the presence of carbonates. Trends in clay content among soils, rather than absolute values, will be considered in relation to varying conditions of the soil forming factors.

The area between the clay curve and the vertical line in Figure 9 was determined for each soil by counting squares in a grid overlay. Areas to the left of the vertical line were assigned a negative sign in Table 11 because this area represents that part of the profile which contains less clay than the C horizon. Areas to the right of the vertical line were assigned a positive sign because the clay content is higher

Figure 9. Depth distribution of less than 2 micron clay in the 24 soils


PERCENT < 2 MICRON CLAY
20 30 40 50
DEPTH IN INCHES
10
20
30
40
50
60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE


PERCENT < 2 MICRON CLAY
20 30 40 50
20 30 40 50
20 30 40 50
DEPTH IN INCHES
10
20
30
40
50
60
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON


50

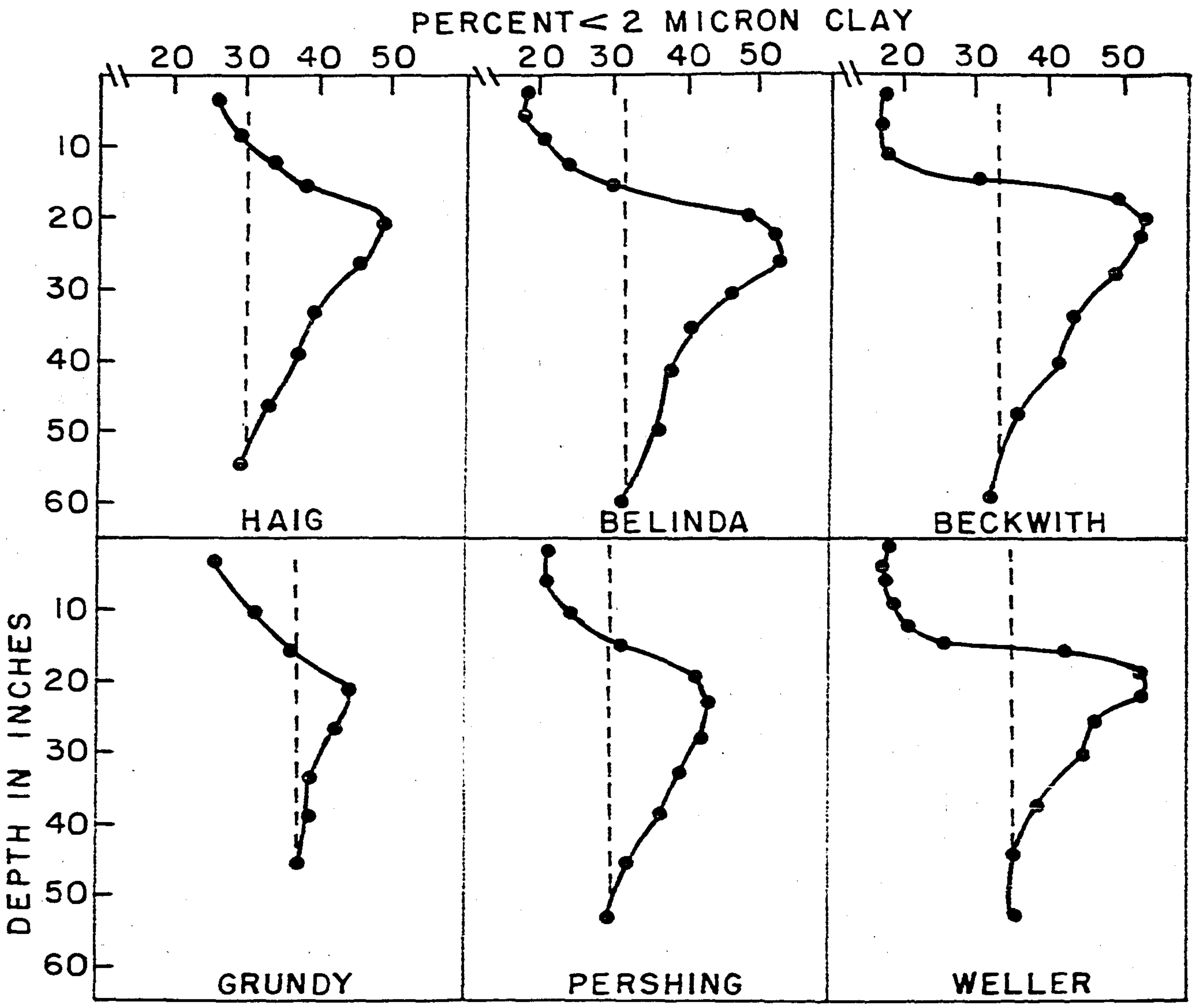

PERCENT < 2 MICRON CLAY
20 30 40 50
10
20
30
40
50
60
DEPTH IN INCHES
HAIG
BELINDA
BECKWITH
GRUNDY
PERSHING
WELLER

Table 11. Some ratios and relative clay contents of the A, B and C horizons for the 24 soils

Soil name	Relative areas in Figure 9 with clay content: Less than that of C horizon	Greater than that of C horizon	Relative net clay increase (+) or loss (-) in the total solum	Ratios[a] A/B	A/C	B/C
			Well drained soils			
Tama	-0.5	5.0	4.5	.80	.99	1.23
Otley	-0.2	8.8	8.6	.74	1.00	1.34
---[b]	---	---	---	---	----	---
	-0.3[c]	6.9	+6.6	.77	1.00	1.29
Downs	-2.3	2.3	0	.65	.76	1.17
Ladoga	-2.5	6.7	4.2	.62	.80	1.27
---[b]	---	---	---	---	---	---
	-2.4	4.5	+2.1	.64	.78	1.22

[a]Ratios: A/B $\frac{\text{minimum per cent clay in A horizon}}{\text{maximum per cent clay in B horizon}}$

A/C $\frac{\text{minimum per cent clay in A horizon}}{\text{per cent clay in C horizon}}$

B/C $\frac{\text{maximum per cent clay in B horizon}}{\text{per cent clay in C horizon}}$

[b]No well drained soils were samples in the southern area.

[c]Averages are underlined.

Table 11. (continued)

Soil name	Relative areas in Figure 9 with clay content: Less than that of C horizon	Greater than that of C horizon	Relative net clay increase (+) or loss (-) in the total solum	Ratios[a] A/B	A/C	B/C
			Well drained soils			
Fayette	-5.4	3.2	-2.2	.58	.70	1.21
Clinton	-4.7	8.0	3.3	.50	.67	1.34
	-5.0	5.6	+0.6	.54	.69	1.28
			Imperfectly drained soils			
Muscatine	0	6.5	6.5	.88	1.10	1.24
Mahaska	0	12.4	12.4	.83	1.10	1.32
Grundy[d]	-4.7	4.0	-0.7	.60	.71	1.18
	-1.6	7.6	+6.1	.77	.97	1.25
Atterberry	-5.0	2.8	2.2	.60	.73	1.22
Givin	-7.3	10.7	3.4	.43	.62	1.45
Pershing	-4.0	11.3	7.3	.49	.71	1.45
	-5.4	8.3	+2.8	.51	.69	1.37

[d]The form of the clay depth distribution curve suggests that greatest sample depth probably was not well into the C horizon.

Table 11. (continued)

Soil name	Relative areas in Figure 9 with clay content: Less than that of C horizon	Greater than that of C horizon	Relative net clay increase (+) or loss (-) in the total solum	Ratios[a] A/B	A/C	B/C
			Imperfectly drained soils			
Stronghurst	-5.7	5.3	-0.4	.44	.54	1.23
Keomah	-5.2	10.5	5.3	.39	.54	1.41
Weller	-9.4	10.2	0.8	.33	.69	2.12
	-6.8	8.7	+1.9	.39	.59	1.59
			Poorly drained soils			
Garwin	0	12.5	12.5	.75	.96	1.28
Taintor	0	26.3	26.3	.85	1.13	1.33
Haig	-1.1	15.4	14.3	.55	.91	1.66
	-0.4	18.1	+17.7	.72	1.00	1.42
Walford	-2.6	14.5	11.9	.45	.68	1.50
Rubio	-4.2	14.0	9.8	.44	.67	1.53
Belinda	-7.0	15.0	8.0	.35	.57	1.65
	-4.6	14.5	+9.9	.41	.64	1.56
Traer[d]	-3.0	5.5	2.5	.47	.62	1.36
Berwick	-8.8	12.7	3.9	.28	.43	1.53
Beckwith	-8.5	17.0	8.5	.33	.60	1.84
	-6.8	11.7	+5.0	.36	.55	1.58

than in the C horizon. The sum of these areas suggests the relative dominance of clay formation processes over clay destruction processes in the complete solum of soils under various conditions of the soil forming factors. The area measurements also provide an estimate of the total magnitude of change in the clay content of the solum by incorporating another dimension, namely depth. The trends of the average of groups of soils in the column "Relative net clay increase in solum" in Table 11 will be used in interpreting the trends of net clay increase or loss in the sola of biosequences and hydrosequences, but the data for individual soils rather than the averages will be used to point out trends among the members of location sequences.

The relative clay data and ratios in Table 11 are of somewhat limited value because bulk density data were not available for all soils to allow adjustment for bulk density differences. In spite of this limitation, the values are useful in suggesting trends of various processes, namely, clay formation, destruction, eluviation and illuviation, which affect the clay distribution profile. The A/C or B/C ratios in Table 11 will provide a clue to gains or losses of clay relative to C; a horizon which has lost clay, with respect to the C horizon, will have a ratio less than one; a horizon which has gained clay with respect to the C horizon will have a ratio greater than one.

The clay content of a soil layer may increase as a result of clay formation, by weathering of minerals in place, or as a consequence of movement of clay or materials essential for clay synthesis into the layer from other parts of the soil. Clay formation in place may be accomplished by (a) decementation of aggregated materials as a consequence of destruction of the cementing materials, (b) reduction in size of particles larger than clay, or (c) synthesis from molecular materials formed by weathering. Movement may be either as clay particles or as simple molecular materials formed by weathering. Synthesis of clays may occur in the layer in which weathering takes place or in layers to which the molecular materials have been eluviated.

The clay content of a layer may decrease as a consequence of movement (eluviation) and/or decomposition of the clay. The simple decomposition products may again recombine in processes of clay synthesis. It is impossible to determine from these ratios whether reductions in clay content are because of decomposition or eluviation.

The A/C ratio provides an estimate of the trend in clay content at a point in the upper solum since time "zero", whereas the B/C ratio provides a similar estimate of the trend of clay content in the lower solum. The A/B ratio is used as an index of the degree of clay stratification in the solum. (Illuviation of clay in the B horizons of some soils observed by the author was suggested by the presence of "clay skins" on ped surfaces and in root channels. Other investigators did not consistently record this feature in profile descriptions so data are not sufficiently complete to allow use of this criterion as an index of clay illuviation among the various soils.)

Brief inspection of the averages in Table 11 can be summarized as follows: (a) all groups of soils show a net increase in clay in the total solum except for Fayette, Grundy and Stronghurst, (b) A/B ratios are less than 1.0 for all groups of soils, (c) A/C ratios are less than 1.0 except for Otley, Muscatine, Mahaska and Taintor profiles, and (d) the B/C ratios are greater than 1.0 for all groups of soils.

The nature of changes in the clay content of members of biosequences, hydrosequences and geographic location sequences are summarized in the following paragraphs.

The implications of changes in the clay content within biosequences have been interpreted from the relative areas and ratios presented in Table 9. The trends among members of biosequences are considered in the order: grass to forest-grass transition to forest soils.

Among biosequences of well drained, imperfectly drained and poorly drained soils, (a) the progressively decreasing "relative net clay increase" values suggest that the degree of dominance of processes of clay formation over clay destruction is greater in grassland soils than in forest soils, (b) the progressively decreasing A/B ratios indicate there is less stratification of clay in grassland than in forest soils, (c) the progressively decreasing A/C ratios suggest that the amount of clay lost from the upper solum of grassland soils is less than that lost from forested soils, and (d) the trend for progressively increasing B/C ratios suggests that there is somewhat greater clay translocation in forested than in grassland soils, except that in the biosequence of well drained soils, the difference in clay translocation between grassland and forest soil is probably negligible.

Trends of clay data among members of hydrosequences (toposequences) will be presented in this order: well drained to imperfectly drained to poorly drained soils. The trends among hydrosequences of grassland, forest-grass transition and forest soils follow: (a) the "relative net clay increase" data suggest that dominance of processes of clay formation over those of clay destruction becomes greater from good to poor drainage or from moderately sloping to level topography (the imperfectly drained soils are intermediate except for the hydrosequence of imperfectly drained soils which includes the Grundy profile; this soil may not have been sampled to sufficient depth to obtain C horizon material), (b) the progressively decreasing A/B ratios indicate less clay stratification in well drained (moderately sloping) than in poorly drained (nearly level) soils, (c) the decreasing A/C ratios suggest a smaller loss of clay from A horizons of well drained (moderately sloping) soils than from poorly drained (nearly level) soils except for the poorly drained grassland soils (the Taintor profile contains an unusually high amount of clay in the surface horizon), and (d) the trend for increasing B/C ratios suggests that there is somewhat greater clay translocation in poorly drained (nearly level) than in well drained (moderately sloping) soils. (The two profiles which do not conform to this trend are Traer and Grundy; these soils may not have been sampled deeply enough to obtain C horizon material).

Trends of clay data among members of location sequences will be presented in this order: north to central to south. The trends among soils developed on comparable slopes and under similar vegetation from north to central to south are: (a) the decreasing "relative net clay increase" values suggest the dominance of processes of clay formation over clay destruction in well drained soils is greater in the central area than in the northern area (this trend is not consistent for imperfectly and poorly drained soils except in a few cases), (b) the trend in most members of the location sequences (north to central to south) is for decreasing A/B ratios, suggesting greater stratification of the clay in soils of the southern area than in the soils of the northern area, (c) there is no distinct trend of A/C ratios, and (d) a strong progressive increase in B/C ratios suggests that there is greater clay translocation in southern than in northern soils.

The trends described above are summarized in the following paragraphs. Dominance of processes of clay formation over clay destruction is generally greater (a) in grassland than in forest soils for all drainage classes, (b) in poorly drained (nearly level) soils than in well drained (moderately sloping) soils under all types of vegetation, and (c) in southern than in northern soils for all drainage classes and under all types of vegetation.

Clay stratification in the solum generally is greater (a) in forest than in grassland soils for all classes of natural drainage, (b) in poorly drained (nearly level) than in well drained (moderately sloping) soils under all types of vegetation, and (c) in southern than in northern soils for all drainage classes and under all types of vegetation.

The amount of clay lost from the A horizon increases (a) from grassland to forest soils for all classes of natural drainage, (b) from well drained (moderately sloping) to poorly drained (nearly level) soils under all types of vegetation.

Clay translocation increases (a) from grassland to forest soils for all drainage classes, (b) from well drained (moderately sloping) to poorly drained (nearly level) soils under all types of vegetation, and (c) from northern to southern soils under all types of vegetation and for all drainage classes.

<u>"Free" iron.</u> "Free" iron data for all soils are in Appendix B and are plotted against depth in Figure 10. Clay

percentage has also been plotted against depth in Figure 10 to allow visual evaluation of the correlation between clay and "free" iron.

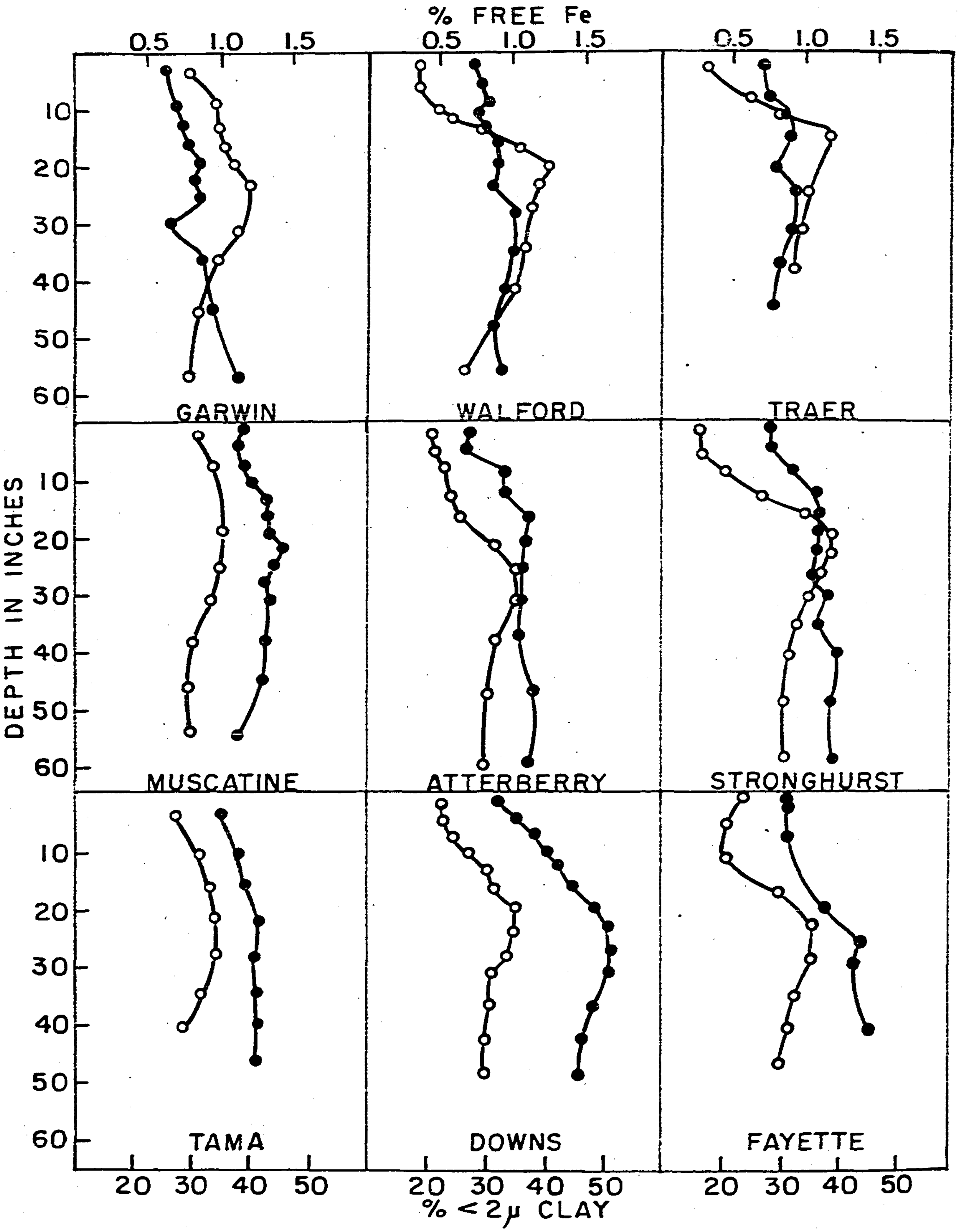
In all hydrosequences, regardless of vegetation or location, there is a weak trend for the amount of "free" iron to decrease in corresponding horizons as the natural drainage conditions become poorer. The depth distribution of "free" iron and clay are approximately parallel in individual well drained soils regardless of vegetation and location; there is little or no parallelism between the two in poorly drained soils, regardless of location and vegetation.

The trends in "free" iron for biosequences will be described in this order: grass to forest-grass transition to forest.

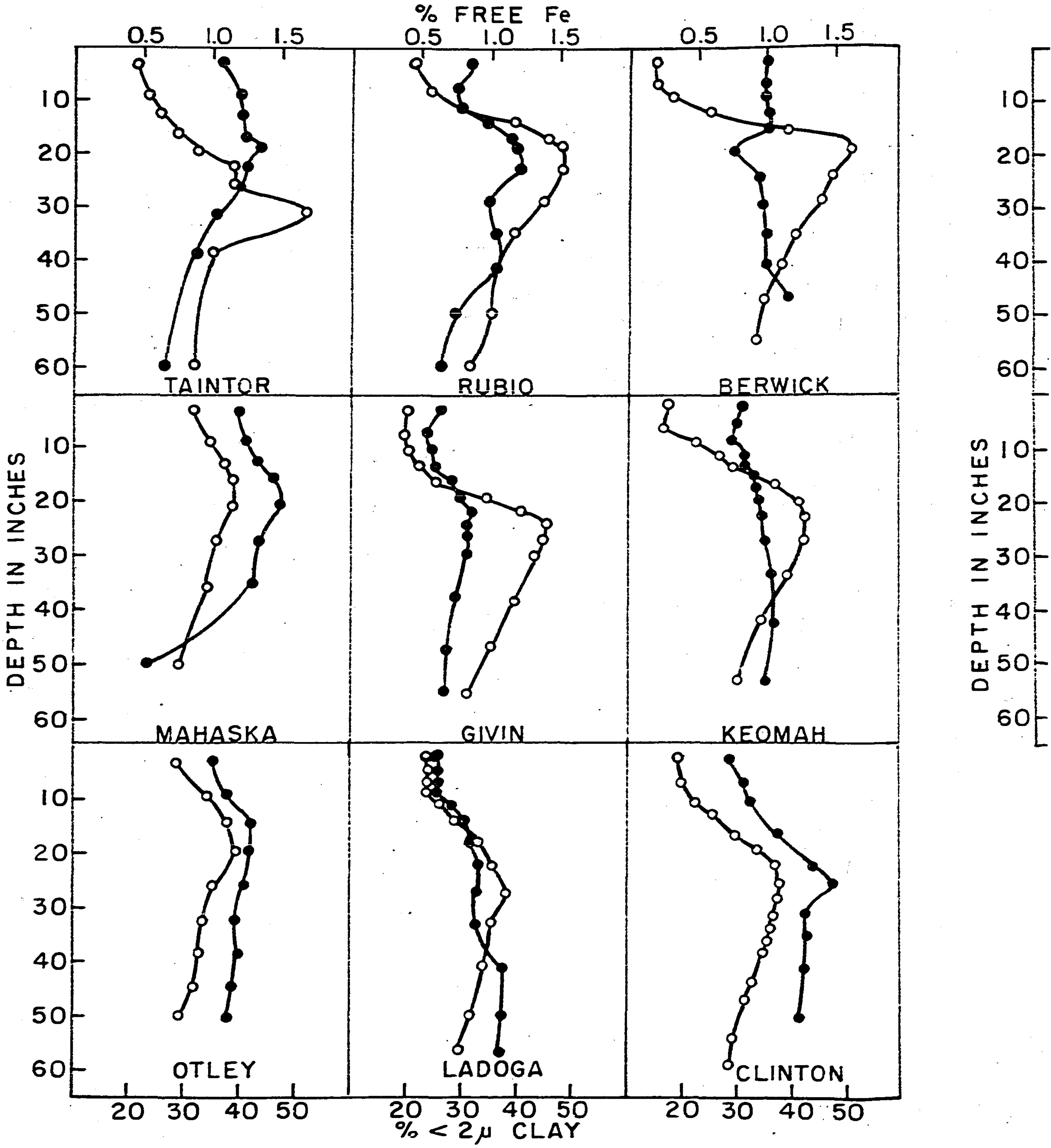
Biosequences of well drained soils (Tama to Downs to Fayette and Otley to Ladoga to Clinton) show these trends: The "free" iron curves are similar in form to the clay curves. "Free" iron content of the surface layers decreases from grassland to forest soils, but the "free" iron content of the upper B horizon increases from grassland to forest soils. The Ladoga forest-grass transition profile does not conform to this general trend in that it has less "free" iron in the surface layers and in the B horizon than either Clinton (forest) or Otley (grassland) profiles.

Biosequences of imperfectly drained soils (Muscatine to Atterberry to Stronghurst, Mahaska to Givin to Keomah and

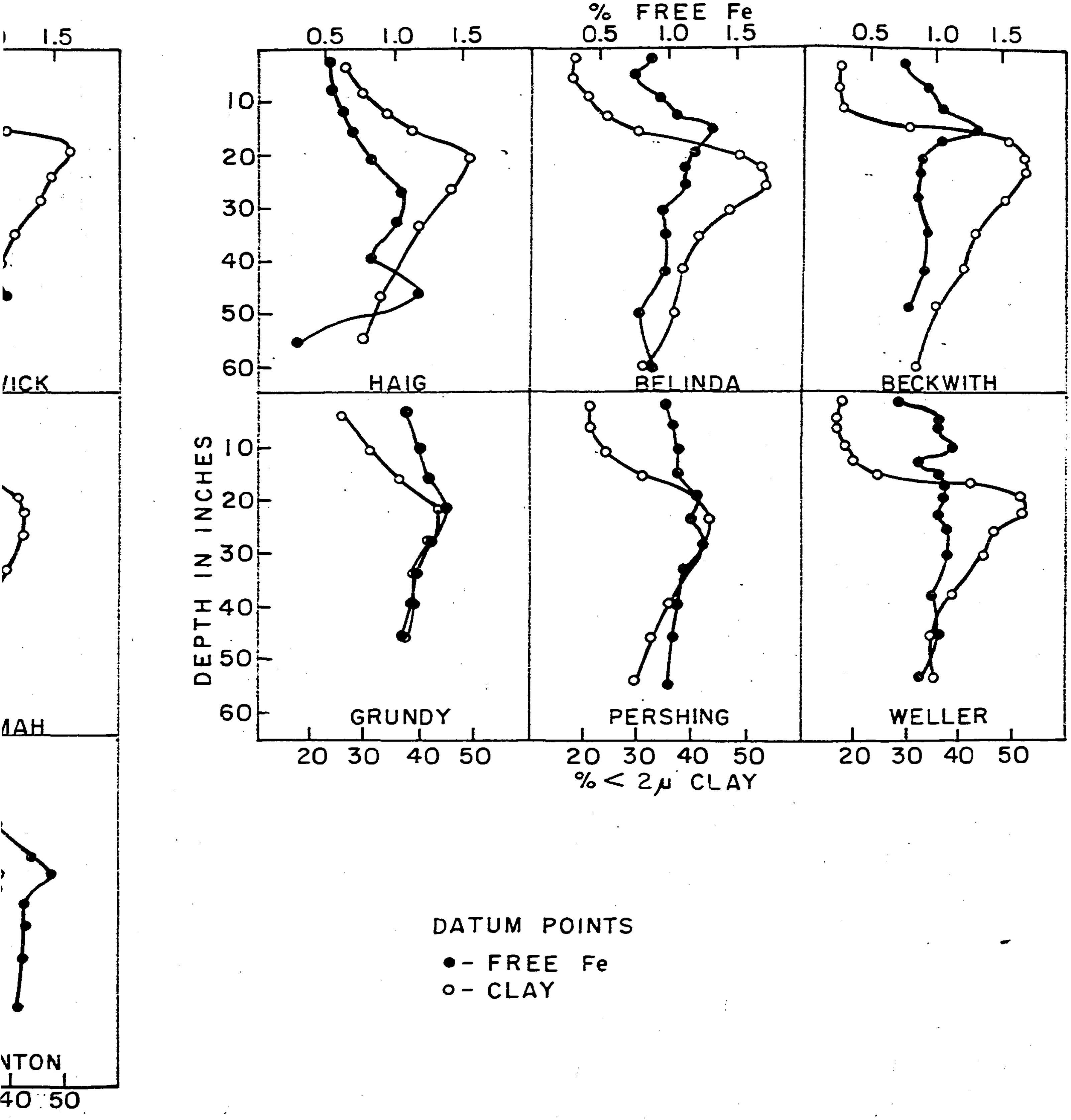
Figure 10. Depth distribution of "free" iron and less than 2 micron clay in the 24 soils



% FREE Fe
0.5
1.0
1.5
DEPTH IN INCHES
10
20
30
40
50
60
GARWIN
WALFORD
TRAER
MUSCATINE
ATTERBERRY
STRONGHURST
TAMA
DOWNS
FAYETTE
20
30
40
50
% < 2μ CLAY



% FREE Fe
0.5
1.0
1.5
DEPTH IN INCHES
10
20
30
40
50
60
TAINTOR
RUBIO
BERWICK
MAHASKA
GIVIN
KEOMAH
OTLEY
LADOGA
CLINTON
20
30
40
50
% < 2μ CLAY


% FREE Fe
0.5 1.0 1.5
DEPTH IN INCHES
10 20 30 40 50 60
HAIG
BELINDA
BECKWITH
GRUNDY
PERSHING
WELLER
20 30 40 50
%< 2µ CLAY
DATUM POINTS
● - FREE Fe
○ - CLAY

Grundy to Pershing to Weller) show these trends: The grassland members of the biosequences have more or less parallel depth distribution curves for "free" iron and clay. "Free" iron content of surface horizons and subhorizons decreases from grassland to forest soils.

The biosequences of poorly drained soils (Garwin to Walford to Traer, Taintor to Rubio to Berwick) and Haig to Belinda to Beckwith) show these trends: The content of "free" iron in the surface layers increases slightly from grassland to forest soils. The "free" iron content of the upper B horizon does not follow a trend within the biosequences. There is a zone of lower "free" iron in B horizons in poorly drained soils, usually slightly below the zone of maximum clay content.

The "free" iron data for the various soils do not show consistent trends related to location from north to south.

DISCUSSION

Trends in macroscopic morphology and various individual soil characteristics, in relation to the principal sequence variables have been considered in the preceding section. In this discussion, contrasts and similarities in field morphology between end members of the various sequences will be considered.

The trends of soil properties and proposed explanations, in terms of processes and reactions related to conditions of the soil forming factors, will be within the framework of bio- and topo-hydrosequences as set forth earlier in this report. Proposed explanations in many cases will be speculative.

Trends in soil morphology and soil development as suggested by field observations and laboratory data will be considered for (a) biosequences of well drained and poorly drained soils, (b) topo-hydrosequences of grassland and forest soils, and (c) geographic location sequences.

Biosequences

Time (or age of parent material), physical and chemical properties of parent material and topography will be assumed to be relatively constant within a biosequence for which natural drainage class (slope) is specified. Differences in ages of parent materials and in the length of time that soil forming processes have been active are probably minor, in terms of the length of the total period since deposition of the loess parent material. The type of parent material (loess) is uniform but there may be slight differences in texture from north to south and within individual segments of the traverse. Topography, in terms of surface slope, ranges from 3 to 7 per cent for well drained soils and from 0 to 1 per cent for poorly drained soils. Within biosequences, in which natural drainage class of soils is specified, slope will be considered constant. It will be considered as a variable, with possible significant influences on water relationships and geologic erosion, in contrasting biosequences of well drained and poorly drained soils in the topo-hydrosequence section that follows.

The climate (macroclimate) has been assumed to be constant within a geographical location segment of the area, but microclimate probably varies locally with the principal variable in the biosequence, namely, vegetation. Variations due to greatly contrasting types of vegetation (grass versus forest) probably cause microclimate differences in the external environment as well as within soils.

The principal variable in a biosequence is the native vegetation and directly or indirectly related factors. The vegetative conditions which will be contrasted are grass and forest. Intermediate members of the biosequences (forest-grass transition soils) will be excluded from this discussion unless they deviate greatly from the general trend between end members of the sequence.

The kind and duration of a particular type of vegetation at a given site was interpreted from soil morphology; considerable accumulated evidence on relationships of vegetation to soil morphology suggests that this is a valid approach.

In the following paragraphs are generalized trends of soil characteristic changes among members of biosequences within individual geographic location segments of the study area. The trends of soil properties between types of vegetation are generally specified; the general order is grass to forest.

Trends in properties, from grassland to forest soils, among biosequences of soils of equivalent natural drainage class (slope) within individual geographical location segments are as follows: (a) an A_2 horizon, absent in grassland soils, appears in the forest-grass transition soils and becomes more strongly differentiated in forest soils (the characteristic horizon sequence in grassland soils is A_1, A_3, B_1, B_2, B_3, C. In forest-grass transition and forest soils, the sequence is A_1, A_2, A_3, B_1, B_2, B_3, C. In imperfectly and poorly drained soils, effects of gleying are apparent in the B and C horizons), (b) the B_2 horizons become thinner and lighter colored in proceeding from grassland to forest soils, (c) in biosequences of poorly drained soils, high contrast mottles are at greater depth under forest than under grass, (d) total nitrogen in the solum decreases from grassland to forest soils suggesting more frequent or higher rates of addition of fresh organic matter and/or greater dominance of the effects of organic matter contributions over processes of organic matter destruction in grassland than in forest soils, (e) lower C/N ratios in forest soils than in grassland soils suggest that decomposition of organic materials is more advanced in forest soils than in grassland soils, (f) lower base saturation in the upper A horizons of grassland soils than in the A_1 horizon of forest soils, (g) lower base saturation of subhorizons of forest soils than in grassland soils, below the A_1, suggests greater dominance of processes of base depletion over processes of base renewal in subhorizons of forest soils than in grassland soils, (h) higher per cent hydrogen saturation at the 40 inch depth in forest than in grassland soils suggests that processes of base depletion have operated more intensively to greater depths in forest soils than in grassland soils, (i) lower exchangeable Ca/Mg ratios in the surface horizons of grassland soils than in forest soils suggests that differential cycling of calcium in relation to magnesium is greater in forest soils than in grassland soils, (j) lower Ca/Mg ratios in the A_2 of forest soils than in the "lower A" horizon of grassland soils suggests that base depletion is generally greater in the A_2 of forest soils than in the "lower A" of grassland soils, (k) decreasing relative net clay values for the entire solum from grassland to forest soils suggests the dominance of processes of clay formation over clay destruction is greater in grassland than in forest soils, (l) decreasing A/B clay ratios from grassland to forest soils suggests that clay stratification in the solum is greater in forest than in grassland soils, (m) decreasing A/C clay ratios from grassland to forest soils suggest that the amount of clay lost from the A horizon increases from grassland to forest soils, (n) all clay data collectively suggest that clay translocation increases from grassland to forest soils, and (o) the depth distribution of "free" iron correlates rather closely with clay content in both grassland and forest soils.

White (74) found the following profile changes as well drained Brunizem soils were invaded by forest and ultimately transformed to Gray Brown Podzolic soils: pH, per cent base saturation and exchangeable Ca/Mg ratio increased in the upper A horizon; organic matter content, pH, base saturation and Ca/Mg ratio decreased in the lower A horizon; pH and base saturation decreased and clay content increased in the B horizon. In the advanced stages of this transformation, the upper A horizon had lost much of the dark color of the Brunizem A_1 horizon; the lower A (or A_2) had become strongly platy, and blocky peds in the B horizon became very strong and displayed reddish coatings. These progressive stages were established in studies of two biosequences on Iowan loess in southeast and south central Iowa, and one biosequence on Cary glacial till in central Iowa.

Changes similar to those summarized by White (74) were noted among loess-derived soils of biosequences along the northwest to southeast traverse of this study. The northwest to southeast traverse of this study is nearly parallel to the postulated direction of prevailing winds during the period of loess deposition. White's traverse was nearly north to south.

It is proposed that the contrasts in profile properties between grassland and forest soils may be related to numerous fundamental differences between two greatly contrasting vegetative types and their effects on the external environment and on the soil interior. It seems very probable that differentials between the two types of vegetation relating to moisture effectiveness, organic matter production and placement, and base or other nutrient uptake and cycling would be of considerable magnitude. The nature of some of these differentials and their probable significance in relation to soil properties is proposed in the following paragraphs.

Effects of the vegetation variable on soil morphology may be direct and/or indirect. One example of direct effect, probably related to contrasts in organic matter placement as a function of differences in plant anatomy and growth characteristics, is suggested in the contrasting organic carbon and total nitrogen profiles of grassland and forest soils. Indirect effects would include those influences resulting from differentials in microclimate induced by the presence of grass versus forest vegetation.

Perhaps the most striking direct effect of the contrasting vegetation types on soil morphology is related to differences in organic matter contributions and placement between grass and forest. Forests and grass not only supply different amounts of organic materials to the soil but annual amounts contributed in different depths of the solum also differ between the two types of vegetation.

Forests contribute leaves to the soil surface annually. Stems, trunks and roots are perennial and are supplied or contributed to the soils only at long intervals, primarily upon death of individual trees. Grasses contribute the total top growth and a substantial amount of root material each year. Table 12 gives estimates of organic matter additions by grass and forest from several sources. These data indicate that differences in top growth additions by forest and grass vegetation are not great, but that annual root contributions are much higher for grasses.

Soil macrofauna, including earthworms, are no doubt a factor in incorporation of organic matter in both grassland and forested soils. Differentials in their effects may exist between grassland and forest soils in this area, but no data are available from which conclusions can be drawn. It will be assumed that the effects of macrofauna are secondary to direct effects of the two types of vegetation and that the principal differences in organic matter profiles can be explained on the basis of direct effects of vegetation.

The major differences in annual organic material additions between grass and forest, appears to be in underground (root) additions. Grass roots generally are concentrated in the upper solum; below depths of 6 to 12 inches the root population decreases rapidly (72). On the other hand, large tree roots and feeder roots are common at depths of 4 or 5 feet or more. Tree roots may be quite numerous in a thin surface layer of soil, usually the A_1 horizon, in forest soils in the virgin condition, but these constitute only a small portion of the total root system. It is estimated in Table 12, that grasses might contribute about six times as much dry weight of roots annually as trees. The relatively large annual addition of root organic materials under grass is probably distributed on the basis of relative root concentration at various depths. The small annual organic matter contribution by tree roots is probably sparsely distributed to greater depth and throughout a much larger volume of soil material. Furthermore, root growth in the A_2 horizon (the zone of minimum per cent base saturation and lowest pH) of forest soils is probably sparse.

Table 12. Estimated annual contribution of organic materials by forest and grass vegetation

Type of vegetation	Roots lbs./acre	Tops lbs./acre	Total return lbs./acre
Grass	3000[a]	3000[b]	6000
Forest	500[c]	3800[d]	4300

[a]Calculated from root counts (72) and annual root necrosis data (73).

[b](2).

[c]Average for loblolly pine (51).

[d]Average figure derived from several sources (15) (40).

The average age or organic matter in soils containing 4 to 6 per cent organic matter in Iowa has been estimated at about 350 years by carbon 14 determinations[1]. Under grass, the rate of annual organic matter contribution by root death was probably quite high at depths corresponding to the depths of horizons of strong organic matter coloration. Organic matter content was high partly because of frequent, relatively high contributions by annual root death. It is proposed that as trees invaded the grassland soil, the rate of annual addition in the lower part of this zone was probably materially reduced. It is also proposed that only a

[1]Smith, G. D., Ames, Iowa. Information on carbon 14 determinations. Private communication. 1956.

moderate decline in organic matter decomposition or loss rates occurred in this depth zone after forest invasion with the result that a progressive decline in organic matter began to take place in this zone. Because of repeated annual contributions in the "lower A" horizon in soils under grass, the organic matter was maintained at an equilibrium level of about 3.5 per cent. This high level probably could not be maintained by the lower annual rates of addition by trees. Losses of organic matter in subhorizons after a few generations of trees may be sufficient to change the organic matter profile from that of a grassland soil to that of a forest-grass transition soil.

In summary, the annual organic additions to the soil under the two types of vegetation would appear to be in the order: grasslands--high annual additions of organic matter to both the surface and subsurface horizons; forests--fairly high annual additions to the surface, but low annual additions throughout the remainder of the solum.

Differentials in microclimate may cause possible indirect effects of contrasting types of vegetation. It is proposed that microclimate variations related to or induced by contrasting types of vegetation, superimposed on the general climate of the area, can cause important local differences in several aspects of "effective" climate in terms of pedogenic effects. Many of the probable microclimatic differences between grasslands and forests suggest the probability of greater movement of water through forest soils than through grassland soils.

Grass and forest vegetation may affect the local climate in various ways. Four distinct and striking differences in microclimate from forested to adjacent open area have been summarized by Zon (78) from Michigan studies. Several of the factors would directly influence the evapotranspiration losses from sites under the contrasting vegetation types. Firstly, the maximum temperature during the warmest part of the day in the summer season was about 3° F. cooler on the average in forested than in open areas. Secondly, soil temperatures were cooler by at least 10° F. in midsummer in forested than in open areas. Thirdly, the relative humidity was about 5 per cent higher in forested sites than in open areas. Fourthly, the wind velocity was lower in forest sites than in open areas (the velocity would decrease with increasing distance into the forest). These factors individually and collectively might be expected to cause less rapid transpiration and evaporation of moisture from forested than from grassland areas. The high canopy cover and low wind velocity in forest sites effectively increases the distance through which water vapor must move and thus retards the rate of water loss under forest vegetation. The higher wind velocity and lower canopy in grassland areas facilitates water loss by evaporation.

The length of frozen soil season in a cool temperate climatic area will determine in part at least the proportion of the precipitation that infiltrates the soil. Johnsgard[1] estimates from various data that the frozen soil season in forest soils of the northern segment of the study area may be at least one month shorter than in grassland soils in the same area. Comparisons of the southern area to areas of similar climate in other states where data are available, indicate that differences in the duration of the frozen soil season are probably greater between grassland and forest soils than in the northern area. Forest soils of the southern area may freeze only periodically to shallow depths in most winters and only occasionally to great depths in unusually cold winters when snow cover is thin (46) (6).

Storey (61) has classified types of soil freezing in relation to kinds of vegetation cover and other conditions. He suggests that granular frost, a loose porous frost, easily broken or penetrated, is most often found under forest vegetation. Upon partial melting and reformation of granular frost, the structure grades to honeycomb or stalactite frost, which is most commonly found in meadows and pastures. The latter kinds of frost probably correspond to the frost structure in the frozen virgin grassland soils. He also suggests that any disturbance of vegetation or vegetative litter increased the probability of formation of a

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[1]Johnsgard, G. A., Ames, Iowa. Estimates of excess water for percolation. Private communication. 1958.

very dense, impermeable type of frost. From Storey's suggestion and from work in Connecticut (31), it seems probable that soils with vegetative cover or litter destroyed, would freeze about two weeks earlier in the fall. It is proposed that depth of freezing would probably be greater and frozen conditions might persist several weeks longer in the spring under grass than under forest vegetation.

Snow cover acts as an insulator against deep soil frost penetration. Snow cover of 21 to 24 inches in the northeastern United States (6) has been shown to be effective in preventing penetration of frost. Vegetation that does not allow extensive removal of snow by drifting may aid in protecting the soil against deep frost penetration. Wind velocities in forests are less than in grassland areas because of the barrier action of trunks, limbs and understory. Drifting is at a minimum and snow cover is more or less uniform in forested areas. This probably contrasts with areas of grassland vegetation where winds would probably tend to remove snow from convex slope positions to sheltered drifts or may differentially concentrate snow in the moister soil sites in which the taller species of grasses dominate. The margins of forested sites may receive considerable snow by drifting from grasslands where grassland areas are adjacent to forested areas and especially where the grassland area is to the north of the forest area. These forested sites would receive more water from snow melt than would areas without the additional snow cover.

Snow cover not only protects the soil against deep soil freezing but may permit soil frost to thaw while the snow cover remains (46). New England studies (31) indicate that frost in forested areas may disappear during this snow melt period, whereas soils of open areas may remain frozen during and following this snow melt period.

Contrasts in types of grasses on different sites may be of some significance in influencing the amount of effective water. The grasses of the moist sites are dominantly the very tall species of which big bluestem is a prominent member. On drier sites and more sloping sites, little bluestem and other short grass species which are also less rank, are most common (2). When grasses die, the stems tend to break over to form a loosely knit, open, semi-erect mat. The mat is thicker in the poorly drained than in the well drained sites because of the higher proportion of taller grasses. This difference may be of some importance in relation to total water supplies in the two types of sites. Snow is likely to be drifted by the wind, especially where the mat is thin; it would probably tend to concentrate in larger amounts on the poorly drained areas where the taller grasses and thicker organic mat are most prominent. By this process, differentials in grass species become a factor influencing the amount of water available for plant growth in the succeeding growing season and in the amount of water effective in various pedogenic processes.

In forests, there is small probability of snow movement by wind so this kind of differential probably does not exist.

Excess water periods in the study area are fall and spring. Grass is probably more effective in water use, and removal of excess soil water, in these periods because of earlier beginning of growth in spring and later growth in fall (grass begins to grow before tree leaves emerge in spring and may grow after frosts have killed tree leaves in fall). A differential in water removal between grass and forest, during these excess water periods would have important implications in terms of amount of water effective in eluviation under the two types of vegetation.

The conditions reviewed above may influence the amount of effective percolation water and/or the length of period of active percolation, resulting in a local differential of less percolation water in grassland than in forest soils.

It is proposed that after the water has entered the soil, the type of vegetation may continue to influence its effectiveness in pedogenic processes. The root system of grasses is relatively more shallow and more dense at shallow depths than that of trees (71) (58); more of the percolating water may be intercepted at shallow depths by the root system of grass. Shallow root interception of water may be greater under grass than under trees because tree roots are more sparsely distributed and trees might be expected to draw a higher proportion of their water needs from greater depths than does grass.

Some estimates of the excess water available for deep percolation under grass and under forest are given in Table 13 in the section on geographic location sequences. The data in Table 13 suggest that percolation water is greater under forest vegetation than under grass. It is proposed that the greater amount of percolation water under forest is due to the interaction of the several factors already discussed. It is proposed that the greater quantity of percolating water might result in more intense eluviation of forest soils than grassland soils.

The trends among members of biosequences of well drained soils and poorly drained soils will be discussed in this order: grass to forest.

In the biosequences of soils of all classes of natural drainage, the trend is toward lighter colors in the A_1 horizon from grassland to forest soils. Some of the differences noted may be related to cultivation of some of the soils, but the major differences are probably related to differences in the organic matter profiles of the virgin soils. The zone of greatest organic accumulation under forest vegetation was much thinner than under grass under virgin conditions. Cultivation probably caused mixing of light colored A_2 soil material into the A_p zone of forested soils. Plowing did not extend below the depth of the very dark A horizon in grassland soils. Differences in organic matter additions and the balance of decomposition versus addition of organic materials under forest and under grass has been proposed to account for the high organic matter content of the "lower A" horizon in the grassland soil and the low organic matter content of the A_2 horizon in forested soils. Darker brown B horizons in grassland soils than in forest soils are also probably closely related to the relative annual organic material contribution at this depth under the two types of vegetation. The content of organic matter in the subhorizons of forest soils is not sufficient to mask the colors of the lighter colored mineral materials with the result that colors are not as dark as in grassland soils in which organic matter is sufficient to impart a dark color.

It has been suggested that the decomposition of organic materials is more advanced under forest vegetation than under grassland vegetation. There are several factors which could account for this difference. Firstly, there is a higher annual increment of fresh, wide C/N ratio materials under grass than under forest with the result that the organic matter as a whole is at a less advanced stage of decomposition. Secondly, substantial amounts of the organic matter in the total biotic system under forest vegetation is in the living woody tissues of the trees; (much of the material probably was removed and destroyed as land was cleared). Thirdly, there may be a differential in the rates of decomposition of the organic material contributed because of placement (there is possibly more rapid decomposition of forest leaf litter deposited on the surface than of grass roots contributed at depth in the soil because of differentials in oxygen supply for decomposition). Fourthly, there may be slower rates of decomposition or higher levels of organic matter stabilization in grassland soils for reasons such as less acid soil conditions or higher general nutrient status of the organic material contributed. Fifthly, an appreciable part of the total nitrogen of the total system (forest soil plus forest vegetation) is in the living tissues of the trees; its presence in the soil would make possible the stabilization of the organic matter at a higher level. Sixthly, soil temperatures, as suggested earlier in the discussion of frozen soil conditions, may remain somewhat warmer and more favorable for organic matter decomposition in forest soils during the cold season.

It is proposed that the trend of increasing depth of base depletion and decreasing total base saturation from grassland to forested soils is both directly and indirectly related to the type of vegetation. The direct effect on the former is related to the probability that trees, because of deeper rooting, feed on bases and nutrients throughout greater soil depths. Indirect effects, influencing both total base saturation and depth of depletion may be related to greater quantities of excess water available for percolation in the forested soils.

Total exchangeable bases tend to be lower in the A_2 horizon of forest soils (especially in the uncultivated forest soils) than in the "lower A" of grassland soils. This trend is associated with and related to lower percentages of base saturation and decreasing exchange capacity in this zone as a result of the lower organic matter and/or clay content in forested soils at this depth.

The ratio of exchangeable Ca/Mg is generally wider in the surface horizon of forest soils than in grassland soils. The magnitude of this ratio is probably directly related to the type of vegetation. White (74) has presented data by Metz (40), Fraps and Fudge (18), Kik (32), Stansel, et al (60) indicating that grassland vegetation contains less calcium in relation to magnesium than does forest vegetation. White (74) concludes: "...calcium returned to the surface soil layers by the leaf fall of a representative deciduous forest vegetation might be about double that returned by a representative prairie vegetation. However, the magnesium content of the grass . . . and . . . oak would appear to be about equal."

The higher base status and pH of the surface layers of forest-grass transition and forest soils may be due in part to this differential return of bases to the surface by the two kinds of vegetation. The higher ratio of exchangeable calcium to exchangeable magnesium of the surface layers of forest soils may be a reflection of a differential in nutrient uptake by the two types of vegetation and higher return of calcium than magnesium by leaf fall than by grass residues.

In most soils, several processes that affect the clay distribution profile may be operating; processes of clay formation, destruction and eluviation are probably involved. It is proposed that in forest soils processes of clay destruction and/or conditions which inhibit clay formation are more active than in grassland soils. Perhaps a part of the reason for the lower clay content in forest soils may be inferred from known changes in the types of clay present. The ratio of montmorillonite to kaolinite is lower in the surface horizons of forest soils than in grassland soils (45) (19). This suggests that decomposition of alumino-silicate minerals may be taking place more rapidly in forest soils and may result in a decrease in total clay content. Clay formation rates in the more advanced weathering stages in forest soils may be somewhat lower if an appreciable reduction in amounts of alumino-silicate minerals has taken place.

The differential in organic matter content between grassland and forest soils may be a factor related to clay preservation or destruction. Kroth and Page (35) found that the organic matter content was higher in the shell of structural peds than in the center. The larger amount of organic matter at the surfaces of peds may more effectively coat clay particles and thus slow the processes of clay destruction in grassland soils. The coatings may be thinner on individual mineral grains or peds of forest soils.

Under forest vegetation, the proposed greater amount of percolating water may carry a higher proportion of the decomposition products of clay destruction to great depths. The greater volume of excess water and higher average water content in the solum may reduce the probability of solute concentration favorable for the synthesis of clay.

The strong clay translocation and stratification in forest soils, as suggested by the wide A/B clay ratios, is probably related to the large quantity of percolating water. Depletion of electrolytes, possible peptization by organic materials and other factors may be involved in deflocculation of the clay in the A horizon. The clay eluviated from the A horizon may illuviate in the B horizon as a consequence of water withdrawal by vegetation, flocculation by electrolytes, mechanical sieving from the percolating suspensions or by other means. Bray (11) and Jenny and Smith (29) have suggested that "free" iron oxides may cause flocculation and retard translocation of clay. The lower contents of "free" iron in the A horizon than in the B horizon of forest soils may favor flocculation in the B of clay that was deflocculated in the A horizon. The iron profiles of well drained forest and grassland soils contain a "bulge" in the lower A or upper B horizon; the presence of "free" iron oxides in this zone may be a factor in flocculation of clay in the B horizon.

In summary, clay may be deposited from suspension as a result of: (a) attractive forces of surrounding particles overcoming the hydraulic effect of percolating water, (b) root withdrawal preventing further downward water movement, (c) higher electrolyte concentrations inducing flocculation, (d) destruction of organic peptizating agents, and (e) sieving of the clay from the percolating suspensions by fine pores.

"Free" iron has been shown to follow the depth distribution trends of clay in well drained soils for all vegetation types. The "free" iron may have originally been present as simple oxides or may have been released from more complex minerals by weathering.

The present depth distribution of "free" iron may have resulted from the movement as adsorbed coatings on clays, from sorption of soluble iron from solutions in the B horizon, and/or to the movement of iron as the oxide. White (74) suggests that decomposition of complex iron bearing minerals probably occurs in the incipient A_2 horizon of forest-grass transition soils. By the time the A_1, A_2, B_2 horizon sequence of forested soils has become well defined, much of the iron released by weathering has moved downward and may have been removed from the solum or fixed in secondary alumino-silicate minerals in lower horizons.

The possibility of iron movement as iron-organic compounds and of peptization of iron by some organic compounds has been suggested by Bloomfield (10). The presence of organic matter may affect the fate of "free" iron in the soil. Forest litter may have a higher peptizing capacity or, as suggested by Norman and Moody (42), a higher reducing capacity than grassland organic matter. Iron in horizons of high organic matter content and in the horizons through which the soluble organic matter percolates in forest soils might be subjected to fairly strong reducing conditions. Winters (77) has suggested that iron in the reduced state may be more mobile than oxidized iron and could be removed from the horizon in which reduction takes place by leaching solutions.

If organic materials have been involved in clay or iron movement, they have since been removed from the horizon or have been destroyed by decomposition. There is no clearly defined indication of a horizon of accumulation of organic matter associated with the clay or iron accumulation horizons in well drained or imperfectly drained forested members of the northern and central biosequences. It seems probable that the general chemical conditions in the B horizons of these soils would be favorable for fairly rapid decomposition of the small amounts of organic matter that might be involved in clay and iron movement.

Differences in "free" iron may be in part related to the method of analysis. The oxidized forms of iron, segregated as concretions or mottles or in the unsegregated form, may react differently to the buffered oxalic acid-nascent hydrogen extraction procedure used in this study.

Further work should be conducted to determine the forms of iron that undergo movement and the influences of organic compounds on iron movement in these soils.

Topo-Hydrosequences

The conditions of certain soil forming factors will be assumed to be constant among members of topo-hydrosequences. Time and parent material will be assumed constant within a topo-hydrosequence, on the basis of evidence and arguments presented in the preceding section (biosequences) of this report.

The type of vegetation, interpreted from the soil morphology, will be specified. The manner in which type of vegetation might affect microclimate has been suggested in the section on biosequences.

The climate (macroclimate) will be assumed to be constant within a single geographical location segment of the study area, but contrasting slope (natural drainage class) may result in differences in microclimate among sites.

The principal variable in a topo-hydrosequence is the surface slope and the related factor of natural soil drainage. The natural drainage class of the soil, interpreted from the soil morphology, is one of the major variables in this study. Three classes of surface slope, each identified with a specific condition of soil drainage were recognized. Moderate slopes with well drained soils, gentle slopes with imperfectly drained soils and level slopes with poorly drained soils are the classes. Trends in soil properties will be indicated by contrasting well drained (moderately sloping) soils and poorly drained (level) soils. Intermediate slope and drainage members of the hydrosequences will be considered in evaluating trends of soil properties but will be excluded from the discussion unless they deviate from the general trends between the end members of the sequence.

The general kinds and magnitude of differences in many soil properties in relation to contrasting vegetation were considered in the previous section on biosequences. The trends in soil properties presented below do not group types of vegetation. The trends as specified are common to both topo-hydrosequences of forested soils and topo-hydrosequences of grassland soils unless stated otherwise. Trends of soil characteristics covering the entire range from well drained to poorly drained soils are for the northern and central areas only; no well drained soils from the southern area were included in the study. Trends among imperfectly drained and poorly drained soils are for all areas: northern, central and southern.

Generalized trends of soil characteristics among members of hydrosequences from well drained (moderately sloping) to poorly drained (level) soils with equivalent types of vegetation and within a single geographic location segment are as follows: (a) in grassland soils, the A_1 horizon becomes thicker and darker as drainage becomes poorer (no trend in thickness and color can be definitely stated for forest soils because most of the sites have been cultivated with the result that the thin A_1 horizon has been mixed with A_2 horizon material), (b) the A_2 horizon, present only in forest-grass transition and forest soils, becomes progressively more brown as drainage becomes poorer, (c) in grassland soils, the B_2 horizon becomes progressively more brown as drainage becomes poorer, (d) in grassland soils, the B_2 horizon becomes progressively darker and thicker as drainage becomes poorer, (e) mottling and concretions are found at progressively shallower depth as drainage becomes poorer in both grassland and forested soils, (f) there are suggestions, from total nitrogen data, of more frequent or slightly higher rates of contributions and/or a slightly greater dominance of effects of organic matter destruction in imperfectly drained (gently sloping) than in well drained (moderately sloping) or poorly drained (level) soils under all types of vegetation as drainage becomes poorer (the difference in total nitrogen among soils of the three drainage classes is greater in the case of grassland and forest-grass transition soils than in forest soils), (g) similar carbon/nitrogen ratios suggest that the stage of decomposition of organic materials is similar in forest and grassland soils on well drained sites; narrower carbon/nitrogen ratios suggest that the stage of decomposition of organic matter is more advanced in poorly drained soils under forest than under grass, (h) the solum base saturation data suggest the dominance of processes of base depletion over processes of base renewal is weaker under conditions of poor drainage than under good drainage in both grassland and forest soils, (i) per cent hydrogen saturation data suggest that processes of base depletion have operated to greater depth in well drained than in poorly drained soils under both types of vegetation, (j) progressively increasing ratios of exchangeable Ca/Mg as drainage becomes poorer suggest that there may be greater cycling or renewal of calcium than magnesium in poorly drained than in well drained soils, (k) relative net solum clay content data suggest that processes of clay formation dominate processes of clay destruction more strongly in poorly drained (level) soils than in well drained (moderately sloping) soils, (differences in relative net clay increase in the solum are greater among members of hydrosequences of grassland soils than among forested soils), (l) clay stratification in the solum is weaker in well drained (moderately sloping) than in poorly drained (level) soils, under both types of vegetation (clay stratification is stronger in forested than in grassland soils), (m) less clay is lost from the A horizon in well drained (moderately sloping) than in poorly drained (level) soils, (n) clay illuviation in the B horizon is somewhat greater in poorly drained (level) than in well drained (moderately sloping) soils, (o) "free" iron correlates rather closely with clay content in well drained (moderately sloping) but no correlation is apparent in poorly drained (level) soils.

Differences in kind and intensity of various pedogenic processes possibly related to topographic and drainage differences among members of topo-hydrosequences are proposed in the paragraphs that follow.

The amount of infiltrating water during the excess water periods is probably greater in poorly drained (level) soils than in well drained (moderately sloping) soils because of smoother topography and consequently less runoff. In the case of grassland soils, snow accumulation is also greater on the soils of the moister sites because of the presence of the taller grasses. The water content of the poorly drained soils is near or above field capacity for much longer periods.

Plant growth on well drained soils is probably limited by a lack of adequate moisture in years when precipitation is poorly distributed or below normal quantity. Vegetation on imperfectly and poorly drained sites probably would not be as water deficient as often or for such long periods as vegetation on well drained soils with the result that larger amounts of organic material probably are produced on imperfectly drained and poorly drained sites than on well drained sites.

Percolation in poorly drained soils may be similar to that in well drained soils during dry periods, but the pattern may be very different during the extended periods when poorly drained soils are waterlogged or partially waterlogged. Each increment of fresh water infiltrating a waterlogged soil is added to a large volume of water already present in the filled or partially filled pores with the result that the water table rises or pores become more completely filled with water, unless an equivalent amount of water escapes by percolation. Appreciable amounts of solutes may be present in the water already present. Diffusion of the "fresh" percolating water or solutes may cause some dilution of the solutions already present. Solutes present in the water are not readily flushed downward as in the case of well drained soils, but move slowly downward as the water table recedes. Water loss rates by percolation and lateral movement are slow in poorly drained soils and dissolved materials are not removed as rapidly or perhaps as frequently as in the flushing type of action in well drained soils in which excess water moves downward freely. The solutes carried to the water table during active percolation may move upward to some degree between percolation periods if the capillary fringe extends into the zone from which water is removed by evaporation or plant root uptake. This would result in some recharge of solutes and cations in zones from which removal may have taken place by prior percolation. This type of recharge would be unlikely in well drained soils because of the absence or very short duration of conditions of waterlogging in the solum or subsolum.

The sola of poorly drained soils (on very smooth topography) in the central and southern segments of the study area probably contain a water table or are influenced by water in the capillary fringe for a considerable period during most years because of the presence of slowly permeable Kansan gumbotil at relatively shallow depths. This restrictive layer may cause a perched water table as soon as percolating water reaches this depth, during the excess water periods of most years. Slow percolation through the gumbotil and slow lateral movement may dispose of some of this water, but excess water may persist in this zone for some time after the end of the period of deep percolation. The loess in the northern area is thick; a water table perched on an impermeable unconforming layer would be at considerable depth, excess water probably would not reach and influence the lower part of the solum for as long a period as in soils underlain by gumbotil at a shallow depth.

Differences in amount of runoff between level and moderately sloping areas may not be great, but the trend is for greater runoff and greater geologic erosion as slope increases. Many studies have shown that measureable soil losses may occur on moderate to gentle slopes under forest and grass vegetation; it can probably be assumed that there would not be measureable losses on level areas. If soil losses on the moderate slopes were assumed to have taken place at even a very slow rate since time "zero", it seems probable that a few inches of soil material may have been removed from the surface of soils on those sites by normal geologic erosion. There would have been essentially no losses on the level areas.

Possible effects of variations in conditions of the soil forming factors in response to changing topography and natural drainage, as proposed above, will be considered in attempting to explain the trends in soil properties among hydrosequence members summarized earlier in this section. The trends are discussed in the order: well drained (moderately sloping) soils to poorly drained (level) soils.

Increasing clay content of the B horizon from well drained to poorly drained soils is probably due to greater dominance of processes of clay formation over processes of clay destruction and/or to less effective translocation of clay in poorly drained than in well drained soils. Further discussion of these processes will be reserved for the consideration of clay data later in this section on hydrosequences.

The presence of mottling and concretions and depth of occurrence of these features have been used as an index of the natural drainage class, degree of aeration of soils and possible alternation of "oxidizing" and "reducing" conditions in soils. The absence of mottles has generally been associated with well drained and well aerated conditions.

Mottles and/or concretions in the surface horizon in many poorly drained soils of this study suggest that the entire sola of these soils have been poorly aerated and alternately "oxidized" and "reduced" for considerable periods. Poor aeration and the presence of a large amount of reducing materials, such as raw organic matter, in the poorly drained soils may be largely responsible for the mottling, concretions and gleization. Mottling and concretions are absent from the sola of well drained soils, but are present in subhorizons of imperfectly drained soils.

The higher total organic matter in the solum of imperfectly drained (gently sloping) soils than in the well drained and poorly drained soils is probably related to differentials in the amount of organic material produced and contributed by the vegetation under the three drainage situations. There is strong substantiating evidence (darker colors to greater depths) of higher amounts of organic matter in imperfectly drained than in well drained soils, but colors do not suggest higher amounts of organic matter in imperfectly drained than in poorly drained soils. It is proposed that organic matter production in imperfectly drained soils may be greater than in well drained soils, probably related to more favorable water supplies for a greater part of the growing season in the former than in the latter soils. If this proposed trend for greater production is extrapolated to poorly drained conditions, it is anticipated that the total quantity of organic matter would be greater in poorly drained than in either imperfectly drained or well drained soils. The organic matter content of the near surface horizons of poorly drained soils often is higher than in corresponding horizons of well and imperfectly drained soils, but the content decreases more quickly with depth in poorly drained than in imperfectly drained soils. Extended periods of poor drainage and aeration would probably cause limited root growth of both grass and trees at the 5 to 40 inch depth. Vegetation on imperfectly drained soils would probably be less affected by extremes of precipitation, either high or low, than would vegetation on well drained or poorly drained soils; the imperfectly drained soils may represent the most favorable balance between moisture excess and moisture deficit for maximum plant growth over extended periods. It is proposed that the total organic matter content of imperfectly drained soils is higher than that of well drained or poorly drained soils because of more favorable general moisture conditions for plant growth.

As decomposition of plant materials takes place, considerable amounts of oxygen are immobilized. In well drained soils, in which water content seldom exceeds field capacity, the oxygen supply is probably less limiting to organic matter decomposition than in imperfectly and poorly drained soils. As the length of the period of excess soil water, and consequently poor aeration, increases the rate and

and degree of decomposition of subsurface additions of organic materials probably decreases. Differentials in aeration as a factor influencing organic matter decomposition may be especially significant in organic matter preservation in grassland soils where relatively large contributions of organic matter are made in subsurface horizons by annual root death. This factor may not be as important in poorly drained forest soils where the annual organic contributions are made primarily on or near the surface.

Differences in base depletion between well drained (moderately sloping) and poorly drained (level) soils are probably closely related to differences in the soil moisture conditions and the behavior of water under the two soil drainage conditions. As has already been suggested, percolating water raises the water table or capillary fringe zone in poorly drained soils during seasons when excess water is present. Solutes present in the soil water are probably not flushed downward as readily by successive increments of percolating water as in well drained (moderately sloping) soils in which "free" downward flow is the dominant situation. If the water table or capillary fringe is high in the solum and within the zone of water removal by evaporation or root uptake, the exchange complex may be subject to recharge by exposure to relatively high solute concentrations between percolation periods.

The "free flow" or flushing type of recharge in well drained soils tends to displace bases more rapidly and cause base depletion to greater depths for two reasons. Firstly, the bases are quite effectively removed by the freely percolating water. Secondly, there is little likelihood of recharge of the exchange complex by upward movement of solutes because there is no water table or capillary fringe in these soils.

The relative net clay increase data suggest that there is a relationship between soil drainage and total solum clay content. The processes of clay formation appear to dominate processes of clay destruction more strongly in poorly drained (level) soils than in well drained (moderately sloping) soils. The weathering of minerals in place and synthesis of clays from products of weathering may be somewhat more intense in the poorly drained soils because of higher moisture content for longer periods and slower rates of removal of the products of weathering.

The thick, high clay B horizon of poorly drained soils may be related to several factors, some of which are probably more strongly operative in soils of the southern area than in those of the northern area. Several of those factors and their possible significance will be considered in the following paragraphs. Discussion of geographical trends from north to south will be reserved for the geographical location section that follows.

Differential geologic erosion rates between level and moderately sloping sites probably has been a factor in the degree of development of horizons of clay eluviation and illuviation in these soils. The possible role of erosion in retarding formation of extreme eluvial and illuvial horizons on moderately sloping sites will be considered later.

The presence of a stratum of low permeability at relatively shallow depth below the solum may be a factor in controlling to some extent the soil moisture content of poorly drained soils of the southern and perhaps the central area. The perched water table may be a factor contributing to the high clay content of the soils and to the occurrence of concretionary material in the sola of the soils. The following arguments support the proposed relationship between perched water table, high clay content and the presence of numerous concretions in the poorly drained soils of the southern area: (a) the water perched over the low permeability material contains solutes, including soluble silicon, aluminum and small amounts of soluble organic matter, removed from overlying material by downward percolation of water; the prolonged period of high water content may also favor appreciable further enrichment of these components in solution by weathering of minerals in the perched water table zone, (b) a capillary fringe zone would exist above the perched water table, (c) an oxidation-reduction gradient would exist in the capillary fringe zone; (reducing conditions would be most intense near and below the water table and would be progressively less intense, more favorable for oxidation, with increasing distance upward from the water table) reduced iron could move upward and precipitate in the ferric form in the upper capillary fringe zone, (d) loss of water from the capillary fringe zone by evaporation or root withdrawal could cause concentration of solutes in the zone of withdrawal; replenishment of water and solutes would take place by upward capillary flow. If the foregoing conditions operated over a long period of time (a) upward movement of soluble iron and subsequent precipitation could be a factor in concretion formation, (b) concentration of essentials for clay synthesis and subsequent interaction to form clay could be a mechanism to account in part for the unusually high clay content of the B horizons of imperfectly and poorly drained soils in the southern segment of the study area.

In summary, the clay contents of the illuvial (B) horizons of the imperfectly drained and poorly drained soils in the study area are probably due to a combination of (a) eluviation of clay from overlying horizons, (b) weathering of minerals in place, and (c) synthesis of clay from the essential molecular materials orginating in the zone of weathering in place or entering the zone by eluviation from above or capillary rise from below.

Clay stratification in the solum is less strongly expressed in the moderately sloping (well drained) than in the level (poorly drained) soils. This may be due to: (a) less total percolating water in the moderately sloping (well drained) than in the level (poorly drained) soils as a consequence of greater runoff from the former than from the latter soil, (b) less eluviation of clay from the A to the B horizon in well drained than in poorly drained soils, probably related to the smaller total quantity of water that infiltrates and penetrates deeply in the moderately sloping (well drained) soils. (Clay will probably not move from the A to the B so effectively if water does not infiltrate deeply or infiltrates deeply only at infrequent intervals during the excess water period), and (c) geologic erosion, as mentioned previously in this section, is probably effective in removing some of the surface material from moderately sloping soils whereas little or no erosion occurs on the level sites. In the moderately sloping soils, the upper part of the zone of clay illuviation (B horizon) probably has been progressively invaded by the lower part of the horizon of clay eluviation as small increments of the surface soil have been removed by water erosion. The zone of clay illuviation on the sloping sites is continually migrating downward, the lower B is slowly encroaching into the upper C horizon. The A/B clay ratio will be narrower in the soil subject to erosion than in soils in which one depth zone, the A horizon, has been constantly depleted by eluviation and an underlying horizon (the B horizon) has been constantly enriched with clay by illuviation, as is the case in level soils. Continued illuviation of clay in the same depth zone may cause a reduction in porosity and permeability with the result that mechanical sieving effects, as a factor in clay illuviation, may become intensified. The rather abrupt increase in clay content in the upper B horizon of poorly drained soils, particularly those developed under forest vegetation, suggests that mechanical sieving may have been a factor in clay illuviation. The possible role of erosion in causing invasion of the B horizon by the A horizon suggests that clay translocation and stratification may be somewhat greater in moderately sloping soils than comparisons of A/B clay ratios would indicate. Much of the clay illuviated in the upper B horizon in an earlier stage of soil development may have been eluviated and redeposited at greater depths; the same clay may have been eluviated and illuviated one or more times as a consequence of invasion of the B horizon by the A horizon.

The relation of "free" iron curves to clay distribution in well drained soils suggests that iron may have moved with the clay or may have been intercepted and adsorbed on the clay in the B horizon. Iron may be periodically more soluble in poorly drained soils because of periodic strong reducing conditions in those soils. Reducing conditions may result from poor aeration, as a result of high soil moisture content, and high organic matter content. Well drained soils would be less subject to reducing effects because they are seldom waterlogged for long periods of time.

Concentration of iron in mottles and concretions in poorly drained soils suggests periodic solution and migration. There also may be some loss of reduced iron by leaching as the water slowly percolates through the underlying zone of low permeability or moves laterally to seepage outlets. Either mechanism of iron movement may operate in imperfectly and poorly drained soils, which have periodic waterlogging and good aeration, but neither operates effectively in well drained soils where oxidizing conditions prevail almost continually.

Differences in the amount and frequency of percolating water in the soil have been proposed to explain many of the differences in soil properties among moderately sloping (well drained) and level (poorly drained) soils. Differences in behavior of percolating water in soils supporting grass and forest vegetation were used to explain differences in many of the trends of soil properties in biosequences. Because attempts to explain contrasts in certain soil properties in both biosequences and topo-hydrosequences are closely linked to the same factor, namely percolating water, the discussion of trends in clay, bases and "free" iron in this topo-hydrosequence section was rather brief as compared to the discussion of these same soil properties among biosequence members. The reader should refer to the discussion of biosequences to obtain the full implication of some of the processes dealt with rather briefly in this section on topo-hydrosequences.

Geographic Location Sequences

The effect of varying conditions of vegetation and slope on soil properties have been considered in the two preceding sections; in biosequences, the principal variable was vegetation, in topo-hydrosequences the principal variable was topography and natural drainage. Among end members (north versus south) of geographic location sequences, the contrasts in most soil characteristics are as striking as those among end members of bio- or topo-hydrosequences. However, the conditions of the soil forming factors which probably cause these locational differences are more subtle, in fact, some of the characteristic differences may be due to the effects of seemingly minor trends of several soil forming factors. Some of the more apparent of these factors and their probable pedogenic significance are discussed in the paragraphs that follow.

Time (or age of parent material) was considered as a variable among members of a geographic location sequence of soils by early workers in this general area. Recent work by Ruhe and Scholtes (49) suggests that time can be assumed to be of little importance as a major factor responsible for differences in soil properties from the northern to southern part of the area. The possibility of slightly greater age of parent materials in the southern area still exists and cannot be completely overlooked.

Other investigators (64) (13) (22) have suggested that the texture of the parent loess, as represented in the C horizons of soils, becomes finer in proceeding from northwest to southeast in Iowa. Data assembled in this study suggest that differences in clay content between parent materials of the northern and southern segments of the area are not as great as may have been anticipated from data from other studies but a trend toward higher clay content in the southern area is present. This factor may have some significance in relation to differences in clay content and clay distribution profiles of soils from north to south.

In this study, it has been assumed that time and parent material are relatively uniform and that differences among soils from north to south in the study area are related in a large degree to other factors as stated below.

The topographic and relief features and depth of loess vary from north to south and may be of pedogenic significance. Because relief and depth of loess over a substratum of low permeability may be closely correlated with subdrainage of the soil, the contrasts in relief between areas are reviewed here. Relief in the uplands in the northern area is greater than in the central or southern areas. The thickness of permeable to moderately permeable loess is great in the northern area; there is no restrictive substratum within depths of several feet, possibly 10 to 20 feet below the solum. In the central area, the relief in the uplands is not as strong. The depth to a water restrictive substratum is not so great as in the north, but the layer is not immediately below the lower horizons of the solum. The ridges in this central area are much wider than in the northern area; lateral movement of subsurface water is slow. In the southern area, the relief in the uplands is not strong and the loess is thin; a gumbotil paleosol of low permeability is commonly within 90 inches of the present surface. The ridges are not so wide as in the central area; lateral movement of subsurface water is probably somewhat more rapid than in the central area.

The individual species constituting the two major types of vegetation do not differ greatly from north to south, but the growth period is somewhat longer in the south than in the north for corresponding types of vegetation.

The seemingly minor trends in the climatic factor from north to south may be more important than previous workers believed. Small differences in precipitation and temperature occur from north to south in the study area; the general trend is toward higher winter temperatures and higher precipitation, particularly in the fall, winter and spring periods, from north to south. The significance of these climatic differences in relation to water percolation may be very great if duration of the period of soil freezing is examined. The usual excess water period, the season in which precipitation normally exceeds evapotranspiration, is from early September to early June. The most active deep percolation and/or water table recharge occurs during this period. The data in Table 13 represent an attempt to summarize the interactions of

Table 13. Estimated excess water under forest and grass on level areas at two locations[a] (assumes no runoff)

	Estimated excess water (inches)			
	Total		Non-frozen soil period	
Location	Forest	Grass	Forest	Grass
Toledo, Iowa[b]	9 to 10	7 to 8	6.5 to 7.5	4.5 to 5.5
Kirksville,[c] Missouri	15 to 17	12 to 14	14 to 15	11 to 12

[a]Johnsgard, G. A., Ames, Iowa. Estimates of excess water for percolation. Private communication. 1958.

[b]Near northern limit of study area.

[c]Slightly south of southern limit of study area.

various factors in relation to excess water and possible percolation intensities in the northern and southern segments of the study area.

Comparisons of these approximate data for Toledo, Iowa (northern area) and Kirksville, Missouri (southern area) suggest that the excess water available for deep percolation and water table recharge is appreciably greater in the southern than in the northern part of the study area. These estimates suggest that excess water may be approximately 1 1/2 to 2 times greater in the southern area than in the northern area.

The trends of soil characteristics from the northern to the southern segments of the study area, for soils with equivalent vegetation and natural drainage (slope) are given in the following paragraphs. Among well drained soils the trends are from the northern to the central areas; well drained soils from the southern area were not included in the study.

Trends in soil properties, from north to south, among soils of equivalent natural drainage class (slope) and type of vegetation are as follows: (a) the A_1 horizons become grayer, contain slightly less clay (especially among grassland members) and become weakly platy (especially among the forest soil members), (b) the A_2 horizons (present in forest-grass transition and forest soils only) become grayer and thinner, (c) the B_2 horizons become finer textured, thinner, darker in color and mottles are of higher contrast, (d) depth to mottles generally decreases, (e) decreasing total organic matter contents suggest that dominance of processes of organic matter decomposition over processes of organic matter contribution are greater for southern area than for northern area soils, (f) decreasing solum base saturation data suggest that dominance of processes of base depletion over processes of base renewal is greater in southern than in northern soils, (g) the ratio of exchangeable Ca/Mg for corresponding horizons generally decreases from north to south, (h) the increasing relative net clay data suggest dominance of processes of clay formation over clay destruction is generally greater in southern than in northern soils, (i) increasing A/B clay ratios suggest that clay stratification in the solum is generally greater in southern than in northern soils, and (j) clay translocation is greater in southern than in northern soils.

It is proposed that many of the trends given in the preceding paragraph can be related to differences in the amount and frequency of increments of infiltrating and percolating water. The implications of differentials in amount and frequency of percolating water in relation to base removal and clay translocation has been dealt with in the biosequence and topo-hydrosequence sections.

The trends of some features of the morphology of the A_1 horizons from north to south are probably related to the differentials in climate in relation to biological processes. The lighter color of the A_1 horizons of southern soils is probably due to somewhat lower organic matter content. The annual rates of addition of organic materials are probably fairly similar, because of small differences in growing season in the two areas, but the rates of decomposition are probably slower in northern soils than in southern soils. This may be due to an appreciably longer period during which soil temperatures would be warmer and more favorable to organic matter decomposition in the southern area.

The A_1 horizons of southern soils have a weak platy structure not present in soils of the northern area. This platiness appears in the forest soils (A_1 horizon) concurrent with a decreasing organic matter content and following removal of some of the clay from the zone. White (74) noted a decrease in organic matter and clay prior to or during the formation of platiness in the A_2 horizon in forest-grass transition soils.

The darker colors of B horizons of imperfectly and poorly drained southern area soils is probably due to organic material which is preserved by the high moisture content. Many of the present forest soils probably are former grassland soils that have been invaded by forest. The dark B horizons of some of the imperfectly and poorly drained forest soils may be relict from former grassland stages. Perhaps poor subsurface aeration was a factor in preservation of the organic matter at depth.

The presence of mottling nearer (or at) the surface and greater iron segregation in soils of equivalent drainage and vegetation in the south than in the north may be related in part to the presence of generally poorer aeration conditions. These conditions probably result from (a) greater amount and frequency of percolating water and (b) presence of a restrictive layer at shallower depth in southern soils. This restrictive layer at shallow depths would retard percolation of excess water below approximately the 90 inch depth. This may cause a water table or capillary fringe zone to persist for longer periods and may intensify alternations of "oxidizing" and "reducing" conditions in the sola of southern area soils. This would be especially true of soils of level areas (poorly drained soils).

The differential in base depletion from north to south, suggested by other investigators (13) (50) and supported by the results of this study, may be in part related to differential depletion of bases concurrent with loess deposition, but is probably closely correlated with the greater total quantity of water which has percolated through southern soils than through northern soils since time "zero".

Several reasons why the presence of a water table might retard base depletion were suggested in the section on hydrosequences. Soils of the southern area are imperfectly to poorly drained; they probably contain a water table and/or the sola are within a capillary fringe zone for a greater period than are soils of equivalent drainage (slope) and vegetation in the northern area. This may be due to a combination of factors. Narrow, somewhat rounded divides and a greater depth of loess over a restrictive layer in the northern area than in the southern area may facilitate both lateral and vertical removal of subsurface water. In the southern area, the combination of wider, flatter divides (conducive to slow lateral subsurface drainage), greater quantity of percolating water (see Table 13) and presence of a restrictive layer at shallow depth (slow vertical drainage) may operate to maintain a water table or capillary fringe in the sola of soils of the southern area for much longer periods. Effects induced by a restrictive subsurface layer at shallow depths in the southern area have probably tended to retard the process of base depletion. The greater amounts of percolating water have tended to intensify the process of base depletion in the southern area soils. It is proposed that the base depleting effects of the greater amounts of percolating water have dominated the effects of waterlogging and vegetation in reducing the rates of base loss.

The ratio of exchangeable Ca/Mg, for corresponding horizons among soils of equivalent drainage and vegetation, decreases from north to south. Longer periods during which soil temperatures are favorable for most organic and inorganic reactions and greater water percolation through the soil probably have combined to cause a greater degree of base depletion and mineral weathering in southern soils than in soils of the northern area.

The use of this ratio as an index to the intensity of weathering[1] among members of the geographic location sequence suggests greater intensities of weathering in soils of the southern area.

The probable importance of differentials in the amounts of water which enter and percolate downward in northern and southern soils has been pointed out in paragraphs above. Base removal and clay translocation from A to B horizons are probably quite strongly influenced by this differential in

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[1]Although some workers (12) have suggested that the ratio of exchangeable Ca/Mg may be of value as an index to the intensity of weathering, perhaps it is a better index of leaching intensity.

percolating water. The processes of clay formation probably dominate clay destruction more strongly in southern than in northern soils because of more favorable soil temperatures (shorter frozen soil period), because of greater quantities of excess water and because of effects of the substratum of low permeability at a shallow depth. The greater quantities of excess water would tend to hasten processes of hydrolysis. It would also tend to move decomposition products (soluble aluminum, silicon and organic matter) down to the water table. Clay transported by the percolating water may be flocculated in the B horizon as a result of increasing electrolyte concentration, by positively charged materials such as iron oxides, or the clay may be mechanically sieved from the suspensions on passing through small pores. It is possible that clay synthesis could occur as the materials move from one zone to another in the soil, or synthesis may occur by the mechanism outlined in the section on topo-hydrosequences, namely (a) capillary rise from the water table bringing up materials for clay synthesis, (b) concentration of solutes essential for clay synthesis, by root uptake of water or by evaporation, and subsequently (c) the synthesis of clays from the concentrated constituents.

The degree of base saturation may influence clay formation and clay illuviation in two ways. Firstly, as base saturation becomes lower, the processes of mineral decomposition may be accelerated. Secondly, as base saturation decreases in the upper solum, clay may be more easily dispersed and illuviated to the B horizon. The higher degree of clay stratification in southern than in northern soils may be evidence of (a) greater illuviation and sieving of clays as percolation water passes through the B horizon of high clay content, (b) it could be due to the mechanism described in the preceding paragraph, or (c) it could be due to a combination of both (a) and (b).

The slight differential in clay content of parent material from north to south must not be overlooked as a possible factor influencing clay content of soils and depth distribution of clay. Differential sorting of materials during loess deposition may have resulted in a higher proportion of the finer fractions in southern than in northern soils. This trend is not strongly substantiated by data presented earlier, but the trend is present. The suggestion of increasing dominance of processes of clay formation over processes of clay destruction from north to south may be related, in part, to differences in parent material texture.

SUMMARY

The objective of this study was an appraisal of relations of conditions of certain soil forming factors to the morphology and genesis of upland soils developed on loess in southeastern Iowa. The "sequence" approach was used as a framework for this study. Biosequences, including grassland, forest-grass transition and forest soils; topo-hydrosequences, including well drained (moderately sloping), imperfectly drained (gently sloping) and poorly drained (level) soils; and geographical location sequences, including soils developed under equivalent conditions of natural drainage and type of vegetation in northern, central and southern segments of the study area, are included in the study.

Contrasting vegetation (grass versus forest) or the invasion of grassland by forest, clearly modifies the character of pedogenic processes and certain major properties of the resulting soils. The characteristic horizon sequence of grassland soils is A_1, A_3, B_1, B_2, B_3, and C. The characteristic sequence in forest-grass transition and forest soils is A_1, A_2, A_3, B_1, B_2, B_3, and C. It is proposed that some of the modifications of processes and soil properties, related to the vegetation differential, represent changes in the kind of process operating and that other modifications are caused by differentials in the intensity of similar processes. A possible direct effect of the two contrasting types

of vegetation is reflected in contrasting organic matter contents and depth distribution of organic matter in the sola. The sola of forest soils contain less organic matter and are in general much lighter in color than layers at corresponding depths in the grassland soils. It is proposed that differences in annual quantity, quality, and depth of placement of organic materials by trees and grass might account, in part, for the differences in soil organic matter profiles between grassland and forest soils. Another effect of type of vegetation is suggested by the base saturation data; base depletion is greater in subsurface horizons under forest than under grass. It is proposed that this may be because trees feed on bases throughout a greater depth of soil than grasses and because the amount of effective percolation water is greater under forest than under grass. Differences in the amount of percolating water under the two types of vegetation are suggested as a factor of considerable consequence in causing various contrasts between forest and grassland soils. It is proposed that the quantity of water percolating to depth is greater in forest than in grassland soils. This differential is suggested as a possible factor in greater base depletion in forest soils than in grassland soils, and as a factor in differences in the total amount and distribution of clay in the sola of soils under the two contrasting types of vegetation.

The effects on soil morphology of variability in surface slope and associated natural soil drainage conditions were studied within a framework of topo-hydrosequences. Differences in kind and intensity of pedogenic processes are proposed to account for differentials in morphology of well drained (moderately sloping), imperfectly drained (gently sloping) and poorly drained (level) soils. Soil morphologic evidence indicates that changes in surface slope, within the range of conditions included in this study, influence soil aeration and natural drainage. Differentials in natural drainage and aeration conditions of the soils are suggested by surface and subsurface colors and by the presence or absence of concretions. Surface colors of grassland soils become darker and organic matter content increases as drainage becomes poorer; these changes are not apparent in forest soils. Imperfect and poor drainage conditions are expressed by the presence of mottlings, concretions and effects of gleization in both grassland and forest soils. Differences in geologic erosion rates and in the quantity, frequency and depth of penetration of percolating water are proposed as both direct and indirect results of changes in the surface slope. A water table or capillary fringe zone persists at or near the surface for extended periods in poorly drained soils and for shorter periods and at greater average depths in imperfectly drained soils; the sola of well drained soils probably do not contain water in excess of field capacity for significant periods. It is proposed that a persistent water table may be a factor in (a) recharge of the exchange complex with bases, and (b) facilitating clay formation.

Relations of soil morphology to location, in individual north to south segments of the area, were studied. The pedogenic significance of relief, loess thickness, texture of loess and climate among the individual area segments, were considered. Soils with similar types of vegetation and equivalent slopes or natural drainage class are compared from north to south. Some of the most striking changes in soils of equivalent natural drainage and native vegetation from north to south are generally lighter soil colors, decreasing depth to mottles and/or concretions, increasing solum clay content, stronger clay stratification and decreasing base saturation. Differences in the intensity of pedogenic processes from north to south are proposed to account for most differentials in morphology of soils. Quantities of percolating water increase, temperatures increase, length of non-frozen soil period increases and other factors of pedogenic significance change from north to south. Differences in relief and depth to a low permeability substratum, which affect subsoil drainage and the persistence of a water table, are conditions that vary with geographic location. Smoother topography, a greater volume of percolation water and shallower depths to low permeability substrata in the southern area are suggested as factors favoring greater persistence of a water table or capillary fringe in the imperfectly and poorly drained soils of that area. It is proposed that the interaction of several factors of soil formation account for the differences in soil color, organic matter content, base status, total clay content and depth distribution of clay in equivalent soils from north to south. It is proposed that sieving of clay by fine pores may have operated more intensively in southern than in northern soils because of conditions favoring generally stronger development of illuvial B horizons of clay accumulation in the southern soils. It is also proposed that the lower organic matter contents and lighter surface soil colors of southern areas soils are due to somewhat higher soil temperatures for longer periods, resulting in more rapid decomposition rates of organic matter in southern than in northern soils.

LIST OF REFERENCES

1. Aandahl, A. R. and Simonson, R. W. Soil survey of Tama County. U. S. Department of Agriculture. Series 1938. No. 22. 1950.

2. Aikman, J. M. Burning in the management of prairie in Iowa. Iowa Academy of Science Proceedings 62:53-62. 1955.

3. ________ and Gilly, C. L. A comparison of the forest flora along the Des Moines and Missouri Rivers. Iowa Academy of Science Proceedings 55:53-73. 1948.

4. Baldwin, M., Kellogg, C. E. and Thorp, J. Soil Classification. U. S. Department of Agriculture Yearbook 1938: 979-1001. 1938.

5. Barshad, I. Soil Development. In Bear, F. E., ed. Chemistry of the Soil. pp. 1-52. New York City, New York, Reinhold Publishing Corporation. 1955.

6. Bay, C. E., Wunnecke, G. W. and Hayes, O. E. Frost penetration into soils as influenced by depth of snow, vegetative cover and air temperatures. Transactions American Geophysical Union 33:541-546. 1952.

7. Benton, T. H. and Shearin, A. E. Soil survey of Poweshiek County, Iowa. U. S. Department of Agriculture. Series 1929. No. 29. 1929.

8. Black, C. A. Laboratory methods for soil investigations: Soil fertility. Department of Agronomy, Iowa State College, Ames, Iowa. Mimeo. 1949.

9. Blakely, B. D., Coyle, J. J. and Steele, J. G. Erosion on cultivated land. U. S. Department of Agriculture Yearbook 1957:290-307. 1957.

10. Bloomfield, C. A study of podzolization V. The mobilization of iron and aluminum by aspen and ash leaves. Journal of Soil Science 5:50-56. 1954.

11. Bray, R. H. The origin of horizons in claypan soils. American Soil Survey Association Bulletin 15:70-75. 1935.

12. ________ and De Turk, E. E. Chemical aspects of some Illinois soils as related to their genesis and morphology. Second International Congress Soil Science Proceedings and Papers, Leningrad-Moscow, U.S.S.R. (1930) 5:118-132. 1932.

13. Cain, C. C. Profile properties and sequence relationships of the Traer, Berwick and Marion series in southeastern Iowa. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1956.

14. Cardoso, J. Sequence relationships of Clarion, Lester and Hayden soil catenas. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1957.

15. Chandler, R. F., Jr. The amount and mineral nutrient content of freshly fallen leaf litter in the hardwood forests of central New York. Journal of the American Society of Agronomy 33:859-871. 1941.

16. Cline, M. G. Profile studies of normal soils of New York: I. Soil profile sequences involving Brown Forest, Gray Brown Podzolic and Brown Podzolic soils. Soil Science 68:259-272. 1949.

17. Foth, H. D. Profile properties of the Galva-Moody soil sequence of northwest Iowa. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1952.

18. Fraps, G. S. and Fudge, J. F. Chemical composition of sixty four species of range pasture grasses grown on a Victoria clay loam. Journal of the American Society of Agronomy 37:251-258. 1945.

19. Gieseking, J. E. The clay minerals in soils. Advances in Agronomy 1:159-204. 1949.

20. Handy, R. L., Lyon, C. A. and Davidson, D. T. Comparisons of petrographic and engineering properties of loess in southwest, east-central and northwest Iowa. Iowa Academy of Science Proceedings 62:279-297. 1955.

21. Hanna, R. M. and Bidwell, O. W. The relation of certain loessial soils of northeastern Kansas to the texture of the underlying loess. Soil Science Society of America Proceedings 19:354-359. 1955.

22. Hunter, R. Physical properties of some loess-derived prairie soils of southeastern Iowa. Unpublished M.S. Thesis. Iowa State College Library, Ames, Iowa. 1950.

23. ________, Riecken, F. F. and McClelland, J. E. Profile properties of some loess-derived Brunizem soils of southeastern Iowa. Iowa Academy of Science Proceedings 60: 380-389. 1953.

24. Hutton, C. E. The morphology and genesis of Prairie soils developed from Peorian loess in southwestern Iowa. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1948.

25. Hutton, C. E. Studies of loess-derived soils in southwestern Iowa. Soil Science Society of America Proceedings 12:424-431. 1948.

26. Hutton, C. E. Studies of the chemical and physical characteristics of a chronolitho-sequence of loess-derived Prairie soils of southwestern Iowa. Soil Science Society of America Proceedings 15:318-324. 1951.

27. Jeffries, C. D. A method for the removal of free iron oxides in soil prior to petrographic analysis. Soil Science Society of America Proceedings 11:211-212. 1947.

28. Jenny, H. Factors of Soil Formation. New York City, New York, McGraw-Hill Book Co., Inc. 1941.

29. ________ and Smith, G. D. Colloidal chemical aspects of claypan formation in soil profiles. Soil Science 39: 377-388. 1935.

30. Kaye, G. F. and Graham, J. B. The Illinoian and post-Illinoian geology of Iowa. Iowa Geological Survey 38: 1-262. 1943.

31. Kienholz, R. Frost depth in forest and open in Connecticut. Journal of Forestry 38:346-350. 1950.

32. Kik, M. C. Nutritive studies of forage plants. Arkansas Agricultural Experiment Station. Bulletin 434. 1943.

33. Kilmer, V. J. and Alexander, L. T. Methods of making mechanical analysis of soils. Soil Science 68:15-24. 1949.

34. Kirkham, D. W. Laboratory methods for soil physics laboratory. Soil Physics Department, Iowa State College, Ames, Iowa. Mimeo. 1957.

35. Kroth, E. M. and Page, J. B. Aggregate formation in soils with special reference to cementing substances. Soil Science Society of America Proceedings 11:27-34. 1946.

36. Lane, G. H. A preliminary pollen analysis of the east McCullock peat bed. Ohio Journal of Science 31:165-171. 1931.

37. Lane, G. H. Pollen analysis of interglacial peats of Iowa. Iowa Geological Survey Report 37:233-262. 1941.

38. Leighton, M. M. and Willman, H. B. Loess formations of the Mississippi Valley. Journal of Geology 58:599-623. 1950.

39. McComb, A. L. and Loomis, W. E. Subclimax prairies. Bulletin of the Torrey Botanical Club 71:46-76. 1944.

40. Metz, L. J. Weight and nitrogen and calcium content of the annual litter fall of forests in the South Carolina Piedmont. Soil Science Society of America Proceedings 16: 38-41. 1952.

41. Muckenhirn, R. J., Alexander, L. T., Smith, R. S., Shrader, W. D., Riecken, F. F., McMiller, P. R. and Krusekopf, H. H. Field descriptions and analytical data of certain loess-derived Gray Brown Podzolic soils in the upper Mississippi River valley. Illinois Agricultural Experiment Station. Bulletin 587. 1955.

42. Norman, A. G. and Moody, J. E. The application of delignifying procedures to soil organic matter. Soil Science Society of America Proceedings 5:171-176. 1940.

43. Orrben, C. L. and Buckhannan, W. H. Soil survey of Washington County, Iowa. U. S. Department of Agriculture. Series 1930. No. 17. 1930.

44. Peech, M., Alexander, L. T., Dean, L. A. and Reed, J. F. Methods of soil analysis for soil-fertility investigations. U. S. Department of Agriculture. Circular 757. 1947.

45. Peterson, J. B. Clay minerals in Iowa soils. Soil Science 61:465-475. 1946.

46. Potter, L. D. Yearly soil temperatures in eastern North Dakota. Ecology 37:62-70. 1956.

47. Reed, C. D. Supplementary climatic notes for Iowa. U.S. Department of Agriculture Yearbook 1941:871-872. 1941.

48. Riecken, F. F. Selection of criteria for the classification of certain soil types of Iowa into great soil groups. Soil Science Society of America Proceedings 10: 319-325. 1946.

49. Ruhe, R. V. and Scholtes, W. H. Ages and development of soil landscapes in relation to climatic and vegetational shifts in Iowa. Soil Science Society of America Proceedings 20:264-273. 1956.

50. Schafer, G. M. Profile properties of a loess-derived Wiesenboden sequence of southeastern Iowa. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1954.

51. Scholtes, W. H. The concentration of forest tree roots in the surface zone of some Piedmont soils. Iowa Academy of Science Proceedings 60:243-259. 1953.

52. Sears, P. B. Postglacial migration of five forest genera. American Journal of Botany 29:684-691. 1935.

53. Shrader, W. D. Differences in the clay contents of surface soils developed under prairie as compared to forest vegetation in the Central United States. Soil Science Society of America Proceedings 15:333-337. 1951.

54. de Sigmond, A. A. J. The Principles of Soil Science. London, England. Thomas Murby and Co. 1938.

55. Simonson, G. H., Prill, R. C. and Riecken, F. F. Free iron distribution in some poorly drained Prairie soils in Iowa. Iowa Academy of Science Proceedings 64:385-392. 1957.

56. Simonson, R. W., Riecken, F. F. and Smith, G. D. Understanding Iowa Soils. Dubuque, Iowa, Wm. C. Brown Co. 1952.

57. Smith, G. D. Illinois loess--variations in its properties and distribution. Illinois Agricultural Experiment Station. Bulletin 480. 1942.

58. ________, Allaway, W. H. and Riecken, F. F. Prairie soils of the Upper Mississippi Valley. Advances in Agronomy 2:157-205. 1950.

59. Soil Science Society of America. Terminology Committee. Report of definitions approved by the committee on terminology. Soil Science Society of America Proceedings 20:430-440. 1956.

60. Stansel, R. H., Reynolds, E. B. and Jones, J. H. Pasture improvement in the gulf coast prairie of Texas. Texas Agricultural Experiment Station. Bulletin 570. 1939.

61. Storey, H. C. Frozen soil and spring and winter floods. U. S. Department of Agriculture Yearbook 1955:179-184. 1955.

62. Swenson, R. M. Movement of iron, manganese and titanium in the development of loess-derived Prairie soils. Unpublished Ph.D Thesis. Iowa State College Library, Ames, Iowa. 1951.

63. Thorp, J. and Smith, G. D. Higher categories of soil classification: order, suborder, and great soil group. Soil Science 67:117-126. 1947.

64. Ulrich, R. Some physical and chemical properties of Planosol and Wiesenboden soil series as related to loess thickness and distribution. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1949.

65. U. S. Department of Agriculture. Glossary of special terms. U. S. Department of Agriculture Yearbook 1938: 1162-1180. 1938.

66. U. S. Department of Agriculture. Soil Survey Staff. Soil Survey Manual. Handbook No. 18. 1951.

67. U. S. Weather Bureau. Climatological data, Iowa Section. 55:153-154. 1944.

68. U. S. Weather Bureau. Climatological data, Missouri Section. 55:79-86. 1944.

69. Visher, S. S. Climatic Atlas of the United States. Cambridge, Massachusetts, Harvard University Press. 1954.

70. Voss, J. Pleistocene forest of central Illinois. Botanical Gazette 44:808-814. 1933.

71. Weaver, J. E. North American Prairie. Lincoln, Nebraska, Johnson Publishing Co. 1954.

72. ________, Hougen, V. H. and Weldon, M. D. Relation of root distribution to organic matter in prairie soil. Botanical Gazette 96:389-420. 1935.

73. ________ and Zink, E. Annual increase of underground materials in three range grasses. Ecology 27:115-127. 1946.

74. White, E. M. The genesis and morphology of some transitional Brunizem-Gray Brown Podzolic soils. Unpublished Ph.D. Thesis. Iowa State College Library, Ames, Iowa. 1954.

75. White, E. M. and Riecken, F. F. Brunizem-Gray Brown Podzolic biosequences. Soil Science Society of America Proceedings 19:504-509. 1955.

76. Wilde, S. A., Steinbrenner, E. C., Pierce, R. S., Dosen, R. S. and Pronin, D. T. Influence of forest cover on the state of the ground water table. Soil Science Society of America Proceedings 17:65-67. 1953.

77. Winters, E. The migration of iron and manganese in colloidal systems. Illinois Agricultural Experiment Station. Bulletin 472. 1940.

78. Zon, R. Climate and the nation's forests. U. S. Department of Agriculture Yearbook 1941:477-498. 1941.

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VITA

John Franklin Corliss, son of Harold T. and Lucille Whitehair Corliss, was born in Yakima, Washington, on March 26, 1931. He received his elementary and secondary public schooling at Yakima. He was admitted to Washington State College in the fall of 1949 and received his Bachelor of Science degree with honors from that institution in June, 1953. He was granted an assistantship from Iowa State College, enrolled in the Graduate School in September, 1953, and received a Master of Science degree in June, 1955. The minor was economics. In the fall of 1955, he continued his advanced study as a candidate for the degree of Doctor of Philosophy with minors in Economics and General Soils. In April, 1956, he married Dorothea Jane Marquis of Des Moines, Iowa.

APPENDIX A

Walford silt loam-607

Location:	Approximately 5 miles north of Brooklyn, in Poweshiek County, Iowa; 800 feet east of road junction of county roads K and T and 50 feet south of road, or, 50 feet south of fence and 80 feet east of Kent chapel gate in the SW1/4 SE1/4 Sec. 23, T81N, R14W, Madison Twp.
Land use:	Cultivated.
Slope:	0 to 1 per cent.
Collected by:	J. F. Corliss.
Date:	November 29, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-607-1	A_p	0-4	Very dark gray (10YR3/1) friable silt loam with few fine distinct black (10YR2/1) mottles; weak very fine granular structure.
P-607-2	A_2	4-8	Dark gray (10YR4/1) friable silt loam with few fine gray (10YR5/1) mottles; weak fine granular structure.
P-607-3	A_2	8-10	Gray brown (10YR5/2) friable silt loam with ped interiors of gray brown to brown (10YR5/2.5) with few thin discontinuous coatings of dark gray (10YR4/1) and gray (10YR6/1); weak coarse platy structure; breaks easily to moderate medium granular structure; upper sides of plates have more gray (10YR6/1) coating than lower; numerous pinholes.
P-607-4	A_2	10-12	Colors same as above in P-607-3 with larger tubes of very dark gray and dark gray (10YR3/1 and 4/1), probably worm casts; friable silt loam; very

[1]Moist colors

			weak coarse platy structure; breaks easily to fine and very fine moderate granular structure; numerous pinholes.
P-607-5	B_1	12-15	Gray brown to brown (10YR5/2.5) friable to slightly firm silty clay loam; very dark gray and dark gray (10YR3/1 and 4/1); weak to moderate very fine subangular blocky structure with many sharp corners and edges; nearly continuous gray (10YR6/1); numerous pinholes; coatings.
P-607-6	B_{21}	15-18	Gray brown (10YR5/2) to gray brown (2.5Y5/2) firm silty clay loam; few faint brown and yellowish brown (10YR5/3 and 5/4) mottles; less continuous gray (10YR6/1) coatings; moderate to strong very fine subangular blocky structure; numerous pinholes.
P-607-7	B_{22}	18-22	Gray brown to dark gray brown (10YR5/2 to 4/2) and gray brown (2.5Y5/2) firm silty clay with few faint fine yellowish brown (10YR5/4) mottles; thin discontinuous coatings of dark gray (10YR4/1) and gray (10YR6/1); very fine to fine moderate subangular blocky structure; weak vertical cleavage.
P-607-8	B_2	22-25	Gray brown (2.5Y5/2) firm silty clay loam with few thin discontinuous coatings of dark gray (2.5Y4/1); weak to moderate fine and very fine subangular blocky structure to weak columnar structure; Fe-Mn concretions.
P-607-9	B_2	25-31	Dark gray brown and gray brown (2.5Y4/2 and 5/2) mixed colors; friable to slightly firm silty clay loam; few thin discontinuous dark gray (2.5Y4/1); few to common fine distinct yellowish brown (10YR5/4 and 5/6 mottles; Fe-Mn concretions; numerous pinholes; weak fine subangular blocky structure with moderate vertical crackings.

P-607-10	B_3	31-38	Gray brown (2.5Y5/2) with dark gray (2.5Y to 5Y4/1) thin discontinuous coatings on vertical faces; yellowish brown (10YR5/4, 5/6 and 5/8) common fine distinct mottles; very few fine distinct strong brown (7.5YR5/8) mottles; friable silty clay loam; massive structure with weak vertical cracks; Fe-Mn concretions.
P-607-11	B_3	38-45	Olive gray (5Y5/2) with common fine distinct yellowish brown (10YR5/4 to 5/8) mottles; few tubes of black (10YR2/1), very dark gray (10YR3/1), and dark gray (10YR4/1); few fine distinct strong brown (7.5YR5/8) mottles; friable silty clay loam; numerous pinholes; Fe-Mn concretions; massive structure.
P-607-12	C	45-51	Same as P-607-11 except the yellowish brown (10YR5/4, 5/6 and 5/8) mottles do not have the strong brown (7.5YR 5/8) inclusions; friable silty clay loam; massive structure; few Fe-Mn concretions.
P-607-13	C	51-62	Olive gray (5Y5/2) with common faint fine yellowish brown (10YR5/4 and 5/6) mottles; olive gray color is not as predominant as in P-607-11 and 12; friable silty loam; massive structure; few Fe-Mn concretions.

Atterberry silt loam, P-608

Location:	Approximately 6 miles west and 4 miles north of Toledo, Tama County, Iowa; 125 feet east of the SW corner of NW1/4 NW1/4 Sec. 35, T84N, R16W, Carlton Twp.
Land use:	Cultivated.
Slope:	2 per cent.
Collected by:	J. F. Corliss and E. M. Richlen.

Date: November 30, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-608-1	A_p	0-4	Very dark gray (10YR3/1) friable silt loam with few pockets of gray (10YR 5/1), medium fine and very fine granular structure with some very weak tendency to fine platiness.
P-608-2	A_p	4-7	Dark gray (10YR4/1) friable silt loam with few pockets of gray (10YR6/1); medium fine and very fine granular with some very weak tendency for fine platiness; few Fe-Mn concretions.
P-608-3	A_2	7-11	Mixed colors of gray brown (10YR5/2) and very dark gray (10YR3/1) and dark gray (10YR4/1); more continuous coatings of gray (10YR6/1) on upper than lower side of plates; friable silt loam; weak fine platy structure; breaks easily to weak fine granular structure; few Fe-Mn concretions.
P-608-4	A_2	11-15	Dark gray (10YR4/1) friable silt loam with pockets of dark gray brown to gray brown (10YR4.5/2); few coatings of gray (10YR6/1); weak medium platy structure breaks easily to weak to moderate very fine subangular blocky structure; few Fe-Mn concretions.
P-608-5	A_3	15-19	Dark gray brown (10YR4/2) friable silt loam with few discontinuous coatings of dark gray (10YR4/1) and few pockets of brown (10YR5/3); weak to moderate very fine subangular blocky structure; few Fe-Mn concretions.
P-608-6	B_1	19-24	Very dark gray brown to dark gray brown (10YR3.5/2) slightly firm silty clay loam; with few discontinuous coatings of gray (10YR6/1); very few pockets of brown (10YR5/3); moderate very fine subangular blocky structure; few Fe-Mn concretions.

[1]Moist colors.

P-608-7	B_2	24-29	Dark gray brown (10YR to 2.5Y4/2) firm silty clay loam with many very dark gray (10YR3/1) coatings; few gray (10YR6/1) coatings; moderate very fine subangular blocky structure; few Fe-Mn concretions.
P-608-8	B_2	29-35	Gray brown (2.5Y5/2) firm silty clay loam; mixed with dark gray to dark gray brown (10YR4/1.5); few fine distinct strong brown (7.5YR5/8) mottles and few medium distinct strong brown (7.5YR5/6) mottles; very few gray (10YR6/1) coatings; moderate very fine subangular blocky; numerous pinholes; Fe-Mn concretions.
P-608-9	B_3	35-41	Gray brown (2.5Y5/2) mixed with dark brown (10YR4/3) friable to slightly firm silty clay loam; with few fine distinct strong brown (7.5YR5/8) mottles; very few thin discontinuous very dark brown (10YR2/2) coatings along vertical cracks; weak medium subangular blocky structure; numerous pinholes; Fe-Mn concretions.
P-608-10	B_3	41-54	Olive gray (5Y5/2) mixed with brown (10YR5/3) friable silty clay loam; few yellowish red (5YR5/8) fine distinct mottles; very few thin discontinuous very dark brown (10YR2/2) coatings along vertical cracks; Fe-Mn concretions; numerous pinholes; massive structure with few vertical cracks.
P-608-11	C	54-68	Olive gray (5Y5/2) and dark brown (10YR4/4) mixed colors; friable silty clay loam; very few yellowish red (5YR4/6) very fine distinct mottles; Fe-Mn concretions; pinholes nearly absent; massive structure.

Stronghurst silt loam, P-609

Location: Two and one-half miles west of Toledo, Tama County, Iowa; 150 feet north of the center of the triangle at the

	gravel road junction in SE corner of NW1/4 SW1/4 Sec. 17, T83N, R15W, Toledo Twp.
Land use:	Cultivated.
Slope:	3 per cent.
Collected by:	J. F. Corliss and E. M. Richlen.
Date:	November 30, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-609-1	A_p	0-4	Very dark gray brown to dark gray (10YR3/2 to 3.5/1) friable silt loam; weak fine granular structure with a very weak tendency to platiness.
P-609-2	A_2	4-7	Mixed colors of dark gray to gray (10YR4.5/2) and dark gray (10YR3.5/1) friable silt loam; weak to moderate fine and very fine platy structure.
P-609-3	A_2	7-11	Dark brown to brown (10YR4.5/3) friable silt loam with few tubules of very dark gray (10YR3/1); few darker areas of dark brown (10YR4/3); weak to moderate fine platy structure.
P-609-4	A_2	11-15	Reddish brown (10YR4/3 and 5/3) friable silt loam with many pockets and coatings of pinkish gray and light gray (10YR7/2-7/1); few fine distinct strong brown (7.5YR5/8) mottles; few fine distinct strong brown (7.5YR5/8) mottles; few ped faces with dark brown (10YR3/3) coatings; weak fine platy structure; Fe-Mn concretions; common pinholes.
P-609-5	B_1	15-18	Dark yellowish brown to yellowish brown (10YR4.5/4) friable firm silty clay loam with thin dark gray brown (10YR4/2) coatings; faint light gray (10YR7/2-7/1) coatings; very fine weak to moderate subangular blocky structure; Fe-Mn concretions.

[1]Moist colors.

P-609-6	B_2	18-22	Dark gray brown (10YR4/2) firm silty clay loam with few dark brown (10YR 3/4-4/4) and very dark brown (10YR 2/2) thin discontinuous coatings; moderate very fine subangular blocky structure; Fe-Mn concretions; glossy clay skins.
P-609-7	B_2	22-25	Dark gray brown (10YR4/2) firm silty clay loam with few dark brown (7.5YR 3/4-4/4) coatings and common very dark brown (10YR2/2) streaks on peds; structure coarser and more difficult to crush than above; fine moderate to strong subangular blocky structure; Fe-Mn concretions.
P-609-8	B_2	25-29	Dark gray brown (10YR4/2) firm silty clay loam with common fine distinct dark brown (7.5YR3/2) mottles; the reddish colors are noticeably stronger in this horizon than P-609-7; Fe-Mn concretions. Structure same as P-609-7.
P-609-9	B_3	29-33	Dark gray brown (10YR4/2) firm silty clay loam with common fine distinct dark brown (7.5YR3/2) mottles; very few ped interiors of olive gray (5Y 5/2); fine moderate subangular blocky structure; Fe-Mn concretions; numerous pinholes.
P-609-10	B_3	33-38	Dark gray brown (10YR4/2), brown (10 YR4/3), and dark brown (10YR3/3) mixed colors; friable to firm silty clay loam; few pockets of gray brown (2.5Y5/2); weak to moderate fine subangular blocky structure; Fe-Mn concretions; numerous pinholes.
P-609-11	B_3	38-45	Dark gray brown and brown (10YR4/2 and 4/3), gray brown (2.5Y5/2) mixed colors; friable silty clay loam, stains on peds of dark reddish brown (5YR3/4) to dark brown (7.5YR3/4); weak fine subangular blocky to massive structure; numerous pinholes; Fe-Mn concretions.

P-609-12	C_1	45-53	Dark gray brown to gray brown (10YR 4/2 to 5/2) mixed colors; friable silty clay loam with common fine faint yellowish brown (10YR5/6) mottles; massive structure; Fe-Mn concretions; few pinholes.
P-609-13	C_1	53-65	Mixed colors of gray brown and yellowish brown (10YR5/2 and 5/6); friable silty clay loam; massive structure; few Fe-Mn concretions.

Muscatine silt loam, P-94

Location:	About 9 miles north of Toledo, Tama County, Iowa; NE corner NW1/4 NE1/4 Sec. 3, T84N, R15W, Howard Twp. (Near small tree 150 feet east of old farmstead; this location may be in error[1]).
Land use:	Bluegrass roadside sod.
Slope:	2 per cent.
Collected by:	F. F. Riecken, M. B. Russell, E. R. Duncan and A. M. O'Neal.
Date:	August 24, 1943.

Sample number	Horizon designation	Depth (inches)	Description[2]
P-94-1	A_1	0-3	Black to very dark gray (10YR2/1.5) silt loam; moderate fine granular structure; numerous roots.
P-94-2	A_1	3-6	As in P-94-1.
P-94-3	A_1	6-9	As in P-94-1.

[1]Riecken, F. F., Ames, Iowa. Information on the Muscatine soil series. Private communication. 1957.

[2]Moist colors.

P-94-4	A_1	9-12	As in P-94-1, except roots are less numerous.
P-94-5	A_1	12-15	Same as P-94-4.
P-94-6	A_3	15-18	Very dark brown (10YR2/2) heavy silt loam; weak medium subangular blocky structure.
P-94-7	B_1	18-21	Very dark brown to very dark grayish brown (10YR2.5/2) light silty clay loam; weak medium subangular blocky structure.
P-94-8	B_2	21-24	Mixed dark yellowish brown (10YR4/4) and dark grayish brown (10YR4/2) silty clay loam; weak medium subangular blocky structure.
P-94-9	B_2	24-27	Dark yellowish brown (10YR4/4) silty clay loam with faint mottlings of yellowish red (5YR4/8) and dark gray (7.5YR4/0); weak medium subangular blocky structure.
P-94-10	B_2	27-30	Dark yellowish brown (10YR4/4) silty clay loam; faint mottling of yellowish red (5YR4/8) and olive gray (5Y 5/2); weak subangular blocky structure.
P-94-11	B_2	30-33	Same as P-94-10.
P-94-12	B_3	33-36	Dark yellowish brown (10YR4/4) heavy silt loam; faint mottling of yellowish red (5YR4/8) and olive gray (5Y 5/2); weak coarse subangular blocky structure.
P-94-12	B_3	36-44	Mixed dark yellowish brown (10YR4/4) and olive gray (5Y5/2) silt loam with faint yellowish red (5YR4/8) and light gray (5Y7/1) mottlings; massive structure with some vertical cracks.
P-94-14	C_1	44-80	Mixed colors of olive gray (5Y5/2), light gray (5Y7/1) and yellowish red (5YR4/8); silt loam; massive structure.

Mahaska silt loam, 52-Ia-51-7

Location:	1 mile west and 1 mile north of Packwood, Jefferson County, Iowa; about 100 yards into field from road in NW1/4 NW1/4 Sec. 10, T73N, R11W, Polk Twp.
Land use:	Bluegrass pasture.
Slope:	2 per cent.
Collected by:	G. M. Schafer and A. J. Cline.
Date:	July 2, 1952.

Sample number	Horizon designation	Depth (inches)	Description[1]
52-Ia-51-7-1	A_p	0-6	Very dark brown (10YR2/2); friable silt loam; moderate fine crumb structure.
52-Ia-51-7-2	A_1	6-11	Very dark brown (10YR2/2); friable silt loam; moderate fine granular structure.
52-Ia-51-7-3	A_3	11-14	Very dark brown (10YR2/2); friable silty clay loam; strong medium granular structure.
52-Ia-51-7-4	B_1	14-18	Very dark grayish brown (10YR3/2); firm silty clay loam; moderately strong fine subangular blocky structure; slight mottling of light olive brown (2.5Y5/6).
52-Ia-51-7-5	B_2	18-24	Dark grayish brown (2.5Y4/2); firm silty clay; strong medium subangular blocky structure; mottling of light olive brown (2.5Y5/6).
52-Ia-51-7-6	B_2	24-31	Olive gray (5Y5/2); firm light silty clay; weak medium subangular blocky structure; intense mottling of light olive brown (2.5Y5/6).

[1]Moist colors.

52-Ia-51-7-7	B_3	31-40	Olive gray (5Y5/2); firm silty clay loam; weak coarse subangular blocky structure; intense mottling of light olive brown (2.5Y5/6).
52-Ia-51-7-8	C	40-60	Light olive gray (5Y6/2); friable silt loam; structureless-massive; common large mottles of strong brown (7.5Y5/8).

Rubio silt loam, P-610

Location: About 10 miles west and 1 1/2 miles north of Washington, Washington County, Iowa; 630 feet east and 50 feet north of SW corner of SW1/4 Sec. 3, T75N, R9W, Dutch Creek Twp.

Land use: Cultivated.

Slope: 0 to 1 per cent.

Collected by: J. F. Corliss and F. F. Riecken.

Date: November 2, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-610-1	A_p	0-6	Very dark gray (10YR3/1) friable silt loam; weak granular structure; few fine distinct dark brown (7.5YR4/4) mottles.
P-610-2	A_2	6-10	Dark gray (10YR4/1) with very dark gray (10YR3/1) coatings; friable silt loam; fine and very fine moderate platy structure with upper surface only very slightly lighter colored than lower; few fine distinct dark brown (7.5YR4/4) mottles.
P-610-3	A_2	10-13	Very dark gray (10YR3/1) with gray (10YR5/1) mixed colors; friable; silty clay loam; weak fine subangular blocky

[1]Moist colors.

			structure; gray carries down over most ped faces; few very fine distinct dark brown (7.5YR4/4) mottles.
P-610-4	A_3	13-15	Very dark gray (10YR3/1) friable to slightly firm silty clay loam with numerous dark gray (10YR4/1) pockets and gray (10YR5/1) coatings; weak to moderate fine and very fine subangular blocky structure.
P-610-5	B_1	15-16	Same as P-610-4 with fewer gray (10YR5/1) coatings than in P-610-3; slightly firm silty clay.
P-610-6	B_2	16-18	Very dark gray (10YR3/1) firm silty clay with thick black (10YR2/1) coatings; clay skins very glossy; weak prismatic, breaks easily to well formed peds; moderate fine and very fine subangular blocky structure; some prismatic faces very dark gray to dark gray (10YR3.5/1); few fine distinct yellowish brown (10YR5/4) common fine distinct yellowish brown (10YR5/8); Fe-Mn concretions.
P-610-7	B_2	18-20	Dark Gray to very dark gray (10YR 3.5/1) vertical faces; black to very dark gray (10YR2.5/1) ped faces; very dark gray (10YR3/1) interiors; firm silty clay; common fine distinct brown (10YR5/3) and yellowish brown (10YR5/6) mottles; Fe-Mn concretions; weak coarse prismatic structure breaks easily to well formed moderate to strong fine subangular blocky structure; Fe-Mn concretions; the black (10YR2/1) faces of P-610-6 are not so prominent in this horizon.
P-610-8	B_2	20-26	Very dark gray and dark gray (10YR 3/1 and 4/1) mixed color coatings over dark gray (2.5Y4/1) ped interiors; firm silty clay; brown and yellowish brown (10YR5/3 and 5/6) mottles distinct common fine; Fe-Mn concretions; weak coarse prismatic breaks with some resistance to fine moderate subangular blocky; vertical and horizontal cleavage faces.

P-610-9	B_2	26-32	Olive gray (5Y5/2) firm to slightly firm silty clay with few discontinuous very dark gray and dark gray (10YR3/1 and 4/1) coatings; common fine distince brown (10YR5/4) mottles with yellowish red (5YR4/6) centers; vertical and horizontal cleavage faces; fine moderate subangular blocky structure; Fe-Mn concretions.
P-610-10	B_3	32-38	Olive gray (5Y5/2) slightly firm silty clay loam with some streaks of very dark gray (2.5Y3/1); numerous black (10YR2/1) pinholes; common medium diffuse reddish brown and yellowish red (5YR5/4 and 5/6); weak medium subangular blocky structure; Fe-Mn concretions; few very dark gray (10YR3/1) clay tubes and very few ped faces.
P-610-11	B_3	38-45	Olive gray (5Y5/2) slightly firm to friable silty clay loam with discontinuous very dark gray (10YR3/1) stains on few ped and vertical faces; numerous Fe-Mn concretions; common medium diffuse yellowish brown (10YR 5/4 and 5/8) mottles; few clay tubes very dark gray (10YR3/1); lesser number of black (10YR2/1) tubes; massive structure.
P-610-12	B_3	45-55	Olive gray (5Y5/2) mixed about half with variegated colors of yellowish brown (10YR5/6) and yellowish red (5YR5/8); friable silty clay loam; numerous pinholes and very few vertical faces; massive structure.
P-610-13	C_1	55-65	Mixed colors of olive gray (5Y5/2) (about 2/3) and yellowish red (5YR 4/8) (About 1/3); friable silty clay loam with very few tubes of black (10YR2/1); numerous pinholes; few coarse diffuse mottles of yellowish brown (10YR5/6); massive structure.

Givin silt loam, P-611

Location:	Approximately 5 miles south and 1 mile east of Washington city square, Washington County, Iowa; 750 feet east and 200 feet south of the NW corner of SW1/4 Sec. 9, T74N, R7W, Marion Twp.
Land use;	Cultivated.
Slope:	2 per cent.
Collected by:	J. F. Corliss and R. C. Prill.
Date:	November 9, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-611-1	A_p	0-6	Very dark gray (10YR3/1); friable silt loam; weak fine granular structure.
P-611-2	A_p	6-9	Very dark gray (10YR3/1); friable silt loam; weak medium platy structure; breaks easily to weak fine subangular blocky structure.
P-611-3	A_2	9-12	Dark gray and dark gray brown (10YR 4/1 and 4/2) mixed colors; friable silt loam; weak to moderate fine platy structure.
P-611-4	A_2	12-15	Dark gray and dark gray brown (10YR 4/1 and 4/2) with 4/2 the dominant color on lower side of plates; friable silt loam; weak to moderate fine and medium platy structure.
P-611-5	A_2	15-18	Yellowish brown (10YR5/4) and dark gray (10YR4/1) mixed colors; friable silt loam; few fine distinct yellowish brown (10YR5/8) mottles; weak medium platy structure breaking to weak to moderate very fine subangular

[1] Moist colors.

			blocky structure.
P-611-6	B_1	18-21	Gray brown (10YR5/2) to gray brown (2.5Y5/2); few fine distinct (10YR 5/6) mottles; slightly firm silty clay loam; moderate fine and very fine subangular blocky structure.
P-611-7	B_1	21-23 1/2	Mixed colors of dark gray and very dark gray (10YR4/1 and 3/1) and dark gray brown (2.5Y4/2); firm silty clay; few fine distinct yellowish brown (10YR5/6) mottles; fine moderate subangular blocky structure; Fe-Mn concretions.
P-611-8	B_2	23 1/2-25 1/2	Olive gray (5Y5/2) and light olive brown (2.5Y5/4) mixed colors; firm silty clay; very few fine distinct yellowish brown (10YR5/6) mottles; fine moderate to strong subangular blocky structure; few Fe-Mn concretions.
P-611-9	B_2	25 1/2-28	Olive gray (5Y5/2), light olive brown (2.5Y5/4), strong brown (7.5YR5/6) and yellowish red (5YR4/8) mixed colors; firm silty clay; fine moderate subangular blocky structure; Fe-Mn concretions.
P-611-10	B_2	28-33	Light olive brown and gray brown (2.5Y5/4 and 5/2) mixed colors; firm silty clay; common fine distinct strong brown (7.5YR5/6) and few fine distinct yellowish red (5YR4/8) mottles; weak medium subangular blocky structure with some prismatic tendency; Fe-Mn concretions; common pinholes.
P-611-11	B_3	33-43	Olive gray (5Y5/2) and gray brown (2.5Y5/2) mixed colors and olive gray (5Y5/2) coatings on blocky surfaces; friable to slightly firm silty clay loam; few fine distinct strong brown (7.5YR5/6) mottles; massive with some weak tendency to blocky structure; Fe-Mn concretions.

P-611-12	B_3	43-52	Olive gray to light olive gray (5Y5/2 to 6/2) mixed equally with brownish yellow (10YR6/6); friable silty clay loam; few Fe--Mn concretions; few clay tubes; numerous pinholes; massive structure.
P-611-13	C	52-60	Light brownish gray (2.5Y6/2) mixed half with brownish yellow (10YR6/6); silty clay loam; friable; few Fe-Mn concretions; few clay tubes; numerous pinholes; massive structure.

Ladoga silt loam, P-612

Location:	1 mile south of Washington city square, Washington County, Iowa; 60 feet east of N-S road (Iowa Ave.) fence and 10 feet north of private driveway fence in the NW1/4 SE1/4 SW1/4 Sec. 20, T75N, R7W, Washington Twp.
Land use:	Bluegrass pasture.
Slope:	3 to 4 per cent.
Collected by:	J. F. Corliss.
Date:	November 24, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-612-1	A_p	0-4	Very dark gray (10YR3/1) friable silt loam with common dark gray brown (10YR4/2) tubes; tubes appear to be result of earthworm activity; weak fine platy structure breaks easily to weak fine granular structure.
P-612-2	A_p	4-6	Very dark gray (10YR3/1) friable silt loam with more common dark gray brown (10YR4/2) tubes than in P-612-1; weak to moderate fine platy structure

[1]Moist colors.

			breaks easily to weak fine granular structure; upper side of plate, when dry, has slightly more grayish coatings than lower but not strong enough to affect moist color.
P-612-3	A_2	6-8	Very dark gray (10YR3/1) casts common; dark gray brown (10YR4/2) about 1/2 of upper plate surface color and 1/4 of lower; dark gray (10YR4/1) about 3/4 of lower plate surface color and 1/2 of upper; common very dark gray (10YR3/1) casts interspersed through and between plates; light gray (10YR7/1 dry) coatings more prominent than P-612-1 and 2; these coatings are gray (10YR5/1 and 6/1) when moist; friable silt loam; moderate fine platy structure.
P-612-4	A_2	8-10	Dominantly gray brown (10YR5/2) on upper and dark gray brown (10YR4/2) on interior and lower plate surfaces; friable silt loam; few very dark gray (10YR3/1) casts; weak medium to coarse platy structure breaks easily to very fine subangular blocky structure.
P-612-5	A_3	10-13	Dark gray brown and dark brown (10YR 4/2 and 4/2) mixed colors; dark brown (10YR4/3) grades to dark brown (7.5YR 4/3); very little light gray (10YR7/1 dry); friable silt loam; weak fine subangular blocky structure breaks easily to very fine moderate subangular blocky structure.
P-612-6	B_1	13-16	Dark gray brown-dark brown (10YR4/2.5) friable to slightly firm silty clay loam with few discontinuous light gray brown (10YR6/2) mottles; weak fine subangular blocky structure breaks easily to moderate very fine subangular blocky structure.
P-612-7	B_2	16-21	Dark brown (10YR4/3); slightly firm silty clay loam; very fine moderate subangular blocky structure.
P-612-8	B_2	21-25	Dark gray brown (10YR4/2); slightly firm silty clay loam; very fine to

			fine moderate subangular blocky structure.
P-612-9	B_2	25-31	Dark gray brown (10YR4/2) dominant mixed with brown (10YR5/3); firm silty clay loam; few light gray (10YR7/2) coatings; fine moderate subangular blocky structure; common Fe-Mn concretions.
P-612-10	B_3	31-37	Dark brown and dark gray brown (10YR 4/3 and 4/2) dominant mixed with gray brown and brown (10YR5/2 and 5/3); slightly firm silty clay loam; common pockets of light brownish gray (10YR6/2); light gray (10YR7/2) coatings more common than above; fine and medium weak to moderate subangular blocky structure with tendency for vertical cleavage; numerous pinholes and common tubes few with very dark gray (10YR3/1) casts; common Fe-Mn concretions.
P-612-11	B_3	37-47	Mixed colors of dark gray brown and yellowish brown (10YR4/2 and 5/6) with dominantly light brownish gray (10YR6/2) grading to light brownish gray (2.5Y6/2); slightly firm silty clay loam; few fine faint dark brown (7.5YR4/4) mottles; fine and medium weak subangular blocky to massive structure with some vertical cleavage; common Fe-Mn concretions; numerous pinholes.
P-612-12	B_3	47-55	Yellowish brown (10YR5/4 and 5/6) mixed with light brownish gray (10YR 6/2); friable silty clay loam; few fine faint dark gray brown (10YR4/2) mottles; numerous pinholes; common Fe-Mn concretions; massive structure.
P-612-13	C_1	55-60	Brown and yellowish brown (10YR5/3 and 5/4) mixed with gray and light brownish gray (10YR6/1) grading to gray and light brownish gray (2.5Y 6/1 and 6/2); friable silty clay loam; few Fe-Mn concretions; common pinholes; massive structure.

Keomah silt loam, P-613

Location: Approximately 1 mile north and 10 miles west of Washington, Washington County, Iowa; 40 feet west and 50 feet north of the west gate at 2,375 feet (0.45 mile) west along the private lane starting from the SE corner of NE 1/4 Sec. 9, T75N, R9W, Dutch Creek Twp.

Land use: Bluegrass pasture.

Slope: 2 per cent.

Collected by: J. F. Corliss and R. C. Prill.

Date: November 9, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-613-1	A_p	0-4	Dark gray (10YR4/1); friable silt loam; weak medium platy structure; few distinct dark brown (7.5YR4/4) mottles.
P-613-2	A_p	4-7	Dark gray (10YR4/1) friable silt loam with few distinct dark brown (7.5YR 4/4) mottles; weak to moderate fine platy structure.
P-613-3	A_2	7-10	Mixed colors of dark gray and dark gray brown (10YR4/1 and 4/2); friable silt loam; few fine distinct dark brown (7.5YR4/4) mottles; dark gray (10YR4/1) more prominent on lower plate surfaces; dark gray (10YR 4/1) of mixed colors appears to be coarse irregular worm casts; weak to moderate fine platy structure.
P-613-4	A_2	10-12	Brown (10YR5/3) friable silt loam with few discontinuous dark gray (10YR4/1) coatings and few fine distinct dark brown (7.5YR4/4) mottles; weak fine platy structure breaks easily to weak to moderate fine subangular blocky structure; few dark gray (10YR4/1) casts.

[1]Moist colors.

P-613-5	A_3	12-14	Yellowish brown to dark yellowish brown (10YR5/4 to 4/4) friable to slightly firm silty clay loam with few fine dark gray brown (10YR4/2) coatings; thin discontinuous gray brown (10YR5/2) coatings and dark gray (10YR4/1) casts; moderate fine and very fine subangular blocky structure.
P-613-6	B_1	14-16	Dark yellowish brown (10YR4/4) slightly firm silty clay loam with thin discontinuous gray brown (10YR 5/2) coatings; few fine faint dark gray (10YR4/1) mottles; moderate fine and very fine subangular blocky structure; few Fe-Mn concretions.
P-613-7	B_{21}	16-18	Dark gray brown (10YR4/2) to dark gray brown (2.5Y4/2) firm silty clay loam with ped interiors of dark yellowish brown (10YR4/4) to olive brown (2.5Y4/4); fine moderate to strong subangular blocky structure; few Fe-Mn concretions.
P-613-8	B_{22}	18-21	Gray brown (2.5Y5/2) coatings over dark yellowish brown (10YR4/4); firm silty clay; fine moderate subangular blocky structure; Fe-Mn concretions.
P-613-9	B_{221}	21-24	Gray brown to dark gray brown (2.5Y 5/2 to 4/2) over olive brown (2.5Y 4/3) ped interiors; firm silty clay; prismatic structure with some tendency to break to fine moderate subangular blocky structure.
P-613-10	B_{222}	24-30	Dark gray brown (2.5Y4/2) coatings over mixed colors of dark yellowish brown and yellowish brown (10YR4/4, 5/4 and 5/6); firm silty clay; few fine distinct strong brown (7.5YR 5/6) mottles; massive with weak tendency to prismatic or blocky structure.
P-613-11	B_3	30-37	Dark gray brown (2.5Y4/2) over mixed colors of yellowish brown (10YR5/4, 5/6 and 5/8); friable to slightly firm silty clay loam; brown (10YR5/4,

			5/6 and 5/8); friable to slightly firm silty clay loam; massive with some tendency to break to prismatic structure.
P-613-12	B_3	37-47	Dark gray brown and gray brown (2.5 Y4/2 and 5/2) and yellowish brown (10YR5/4, 5/6, 5/8); friable silty clay loam; medium distinct mottles; massive structure; few Fe-Mn concretions.
P-613-13	C_1	47-60	Olive gray (5Y5/2) and yellowish brown (10YR5/4, 5/6, and 5/8) with 10YR colors about 3/4 of area; friable silty clay loam; numerous fine black (10YR2/1) pinholes; few Fe-Mn concretions; massive structure.

Belinda silt loam, P-614

Location: Approximately 3 1/2 miles east and 1 mile north of Stockport, Van Buren County, Iowa; 500 feet west and 500 feet north of the SE corner of SW1/4 Sec. 10, T70N, R8W, Cedar Twp.

Land use: Cultivated.

Slope: 0 to 1 per cent.

Collected by: J. F. Corliss and F. F. Riecken.

Date: November 1, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-614-1	A_p	0-4	Very dark gray (10YR3/1) friable silt loam; weak fine granular to very weak platy structure; few small dark concretions.

[1]Moist colors.

P-614-2	A_p	4-7	Very dark gray (10YR3/1) friable silt loam with fine common pockets of gray (10YR6/1); weak fine platy structure breaking easily to weak fine granular structure.
P-614-3	A_2	7-12	Dark gray (10YR4/1) and gray (10YR 6/1) friable silt loam with gray colors more strongly expressed on upper than lower plate surfaces; moderate fine platy structure; few yellowish red (5YR4/6) fine faint mottles.
P-614-4	A_2	12-14	Dark gray (10YR4/1) and gray (10YR 5/1 and 6/1) friable silt loam with upper surfaces more completely coated with gray than lower; moderate medium platy structure; few faint fine yellowish red (5YR4/6) mottles.
P-614-5	A_2	14-17	Gray (10YR5/1) slightly firm silty clay loam with thin discontinuous coating of light gray (10YR7/1) on peds; very weak medium platy structure; breaks easily to weak medium subangular blocky structure; common faint fine yellowish brown (10YR 5/4) mottles.
(no sample taken)	B_1	17-19	Transition zone between P-614-5, depth 14-18, and P-614-6, depth 18-21 inches. Gray (10YR5/1) firm silty clay with thin very discontinuous coatings of light gray (10YR7/1); common faint fine yellowish brown (10YR5/4) mottles; gray grades rapidly to dark gray (10YR4/1) with coatings on vertical cracks of very dark gray (10YR3/1); moderate medium subangular blocky structure.
P-614-6	B_2	19-21	Black to very dark gray (10YR2.5/1) and dark gray to dark gray brown (10YR4/1.5) firm clay with distinct common fine yellowish brown (10YR 5/4) mottles; strong medium subangular structure; black to very dark gray is the color of coatings on peds of dark gray to dark gray brown; dark coatings are thick

			(about 1 mm) and very continuous over peds.
P-614-7	B_2	21-24	Thick continuous coatings of black to very dark gray (10YR2.5/1) over dark gray to dark gray brown (10YR 4/1.5) firm clay with common fine distinct yellowish brown (10YR5/4) mottles; moderate to strong medium subangular blocky structure.
P-614-8	B_2	24-28	Dark gray to dark gray brown (10YR 4/1.5) and gray brown (2.5Y5/2) mixed colors; firm silty clay with many fine distinct brown (10YR5/3) mottles grading in color into the yellowish brown (10YR5/6) center; moderate to strong medium subangular blocky structure; glossy coatings along vertical cracks and along tubes up to 2 cm. in diameter; Fe-Mn concretions present; glossy coatings of black to very dark gray (10YR2.5/1) also cover horizontal surfaces in the lower portion of this horizon; mottling in this horizon becomes intense.
P-614-9	B_3	28-33	Dark gray to gray (10YR4.5/1) firm silty clay with many fine distinct brown to yellowish brown (10YR5/3 to 5/6) mottles and very dark gray and black (10YR3/1 and 2/1) streaks; moderate to strong medium subangular blocky structure; Fe-Mn concretions present; dark gray (10YR4/1) coated faces occur horizontally and vertically; a very few vertical faces are very discontinuously coated with gray to light gray (10YR6/1).
P-614-10	B_3	33-38	Light brownish gray (5Y6/2) slightly firm silty clay with few very dark gray (10YR3/1) coatings; common medium distinct strong brown (7.5YR5/8) mottles; weak coarse subangular blocky structure; Fe-Mn concretions; clay skins evident on some vertical faces.

P-614-11	B_3	38-46	Light brownish gray (5Y6/2) slightly firm silty clay loam with common to many yellowish brown (10YR5/4) distinct mottles; few black to very dark gray (10YR2/1-3/1) fine clay tubes; Fe-Mn concretions common; few clay skins evident on some vertical faces; weak coarse subangular blocky to massive structure.
P-614-12	B_3	46-54	Light brownish gray (5Y6/2) and yellowish brown (10YR5/4 and 5/8) mixed (50-50) colors; friable silty clay loam; few black to very dark gray (10YR2/1-3/1) clay tubes; massive structure; very few very dark gray (10YR3/1), thin and discontinuous; few medium Fe-Mn concretions.
P-614-13	C_1	54-66	Light brownish gray (5Y6/2) and yellowish brown (10YR5/4) mixed colors (50-50); friable silty clay loam; many black (10YR2/1) pinholes; very few thin discontinuous very dark gray (10YR3/1) coatings on vertical faces; few medium Fe-Mn concretions; massive structure.

Pershing silt loam, P-615

Location:	Approximately 5 1/2 miles east and 0.9 mile south of Stockport, Van Buren, County, Iowa; 30 feet south, 110 feet west of fence corner 0.1 mile north of SE corner of SW1/4 Sec. 24, T70N, R8W, Cedar Twp.
Land use:	Bluegrass pasture.
Slope:	2 to 3 per cent.
Collected by:	J. F. Corliss and F. F. Riecken.
Date:	November 1, 1956.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-615-1	A_p	0-4	Very dark gray (10YR3/1); friable silt loam; weak fine granular structure; few small dark concretions.
P-615-2	A_p	4-8	Very dark gray (10YR3/1); friable silt loam; weak fine granular structure with few fine very dark gray brown (10YR3/2) concretions.
P-615-3	A_2	8-13	Dark gray to dark gray brown (10YR 4/1.5) mixed with 30% dark gray brown to brown (10YR4/2.5); friable silt loam; weak medium platiness breaks easily to moderate fine granular structure.
P-615-4	B_1	13-17	Dark gray brown (10YR4/2) friable silty clay loam with some medium pockets of gray brown (10YR5/2); weak to moderate medium subangular blocky structure; few Fe-Mn concretions.
(no sample taken)	B_1	17-18	Dark gray brown (10YR4/2) to brown (10YR5/3); friable silty clay loam; moderate medium subangular blocky structure; peds more clearly defined and break out with more ease than from horizons below (P-615-5).
P-615-5	B_{21}	17-21	Gray brown (10YR4/2) to brown (10YR 5/2); slightly firm silty clay; moderate medium subangular blocky structure; peds show more coherence to mass than above; few Fe-Mn concretions; ped faces lightly coated with gray brown (2.5Y5/2).
P-615-6	B_{22}	21-26	Dark gray brown (2.5Y4/2); slightly firm silty clay; moderate medium subangular blocky structure; peds have thick (1mm) clay skins; many prominent to distinct fine yellowish brown (10YR5/4 to 5/8) mottles; few

[1]Moist colors.

			Fe-Mn concretions; few discontinuous black (10YR2/1) streaks and pinholes.
P-615-7	B_{23}	26-30	Dark gray brown slightly firm silty clay (2.5Y4/2); many fine distinct yellowish brown (10YR5/4) mottles; weak coarse subangular blocky structure with horizontal and vertical cleavage faces coated with gray brown (2.5Y5/2) clay skins; dark gray (10YR 4/1) and very dark gray (10YR3/1) pinholes and streaks; common Fe-Mn concretions.
P-615-8	B_3	30-36	Gray brown (2.5Y5/2) slightly firm silty clay loam with common fine diffuse brown to yellowish brown (10YR 5/3-5/4-5/8) mottles and few horizontal and vertical faces with olive gray (5Y5/2) coatings; Fe-Mn concretions; weak coarse blocky structure.
P-615-9	B_3	36-42	Gray brown (2.5Y5/2) friable silty clay loam with common fine diffuse brown to yellowish brown (10YR5/3-5/4) mottles; silty clay loam; very few horizontal and vertical cleavage faces; weak coarse blocky structure; Fe-Mn concretions; few very dark gray (10YR3/1) root channels; massive structure.
P-615-10	B_3	42-50	Light olive gray (5Y6/2) friable silty clay loam with many medium distinct yellowish brown (10YR5/4, 5/6, 5/8) mottles; very dark gray (10YR3/1) channels few to common; few discontinuous gray brown (2.5Y5/2) clay skins; numerous pinholes; Fe-Mn concretions; massive structure.
P-615-11	C	50-58	Gray brown to light gray brown (2.5Y 5/2-6/2) friable silty clay loam with many medium diffuse yellowish brown (10YR5/6) and olive (5Y5/8) mottles; few tubes of black to very dark gray (10YR3/1-2/1) material; few stains on very few vertical cleavage surfaces of dark gray (10YR4/1); numerous pinholes; Fe-Mn concretions; massive structure.

at 92	Buried humic gley till derived material, dark gray (5Y4/1); firm clay.

Weller silt loam, P-616

Location:	In Van Buren County, approximately 1/2 mile west and 1 1/2 miles north of the west edge of the town of Hillsboro, Henry County, Iowa, which is just east of the Van Buren-Henry County line; 300 feet west and 30 feet south of the NE corner of the SE1/4 NW1/4 Sec. 24, T70N, R8W, Cedar Twp.
Land use:	Bluegrass pasture.
Slope:	2 to 3 per cent.
Collected by:	J. F. Corliss.
Date:	August 24, 1957.

Sample number	Horizon designation	Depth (inches)	Description[1]
P-616-1	A_p	0-3	Very dark gray (10YR3/1); friable silt loam; very fine weak granular to fine platy structure.
P-616-2	A_2	3-5	Gray (10YR5/1) and gray brown (10YR 5/2) friable silt loam with pockets of dark gray (10YR4/1) and few thin discontinuous coatings of very dark gray (10YR3/1); few fine distinct dark reddish brown (5YR3/4) mottles; silt loam; weak fine granular to weak fine platy structure.
P-616-3	A_2	5-8	About equally mixed colors of gray brown (10YR5/2) and light brownish gray (10YR6/2); friable silt loam with few dark reddish brown (5YR3/4) fine

[1] Moist colors.

			distinct mottles; numerous pinholes; moderate to weak fine platy structure.
P-616-4	A_2	8-11	About equally mixed colors of gray brown (10YR5/2) and brown (10YR5/3); friable silt loam with few fine distinct yellowish brown (10YR5/8) mottles; weak fine to very fine platy structure.
P-616-5	A_3	11-14	Brown (10YR5/3) to light brownish gray (10YR6/2) friable silt loam with few fine distinct yellowish brown (10YR 5/6) mottles; numerous pinholes; weak very fine subangular blocky structure.
P-616-6	B_1	14-16	Light gray (10YR7/1) grains very prominent and numerous over gray (10YR5/1) peds; friable to slightly firm silt loam; moderate very fine to fine subangular blocky structure; many peds rounded.
P-616-7	B_2	16-17 1/2	Gray brown (10YR5/2) firm silty clay with few to common faint yellowish brown (10YR5/8) mottles; fine to very fine moderate to strong subangular blocky structure.
P-616-8	B_2	17 1/2 -21	Brown (10YR5/3) firm silty clay with few thin discontinuous gray brown (10YR5/2) ped coatings; common faint yellowish brown (10YR5/6) mottles and few gray (10YR5.5/1) faint mottles; fine to very fine strong subangular blocky structure.
P-616-9	B_2	21-24	About equally mixed colors of brown (10YR5/3) and gray brown (10YR5/2) firm silty clay with common yellowish brown (10YR5/6) faint mottles; fine to very fine moderate to strong subangular blocky structure.
P-616-10	B_3	24-27	Mixed colors of brown (10YR5/3) firm silty clay about 75% and gray brown (10YR5/2) about 25% with few yellowish red (5YR4/8) distinct mottles; few yellowish brown (10YR5/4) medium faint mottles; few 5-10 mm pockets

			of gray (10YR5/1) probably marking filled former root channels; moderate medium subangular blocky structure.
P-616-11	B_3	27-34	About equally mixed colors of gray (10YR5/1) and yellowish brown (10YR 5/4); friable to firm silty clay; weak to moderate medium to fine subangular blocky structure; diffuse Fe-Mn concretions common.
P-616-12	B_3	34-41	About equally mixed colors of gray (10YR5/1) and yellowish brown (10YR 5/4); friable silty clay loam; weak fine subangular blocky structure; elongate vertical pockets of gray (10YR5/1) along probable former root channels which occupy about 50% of exposure; also much smaller very dark gray (5YR3/1) tubules probably along old root channels; few distinct dark yellowish brown (10YR4/6) mottles.
P-616-13	B_3	41-48	Same as P-616-12 except massive structure.
P-616-14	B_3	48-58	Same as P-616-12 except dominant matrix colors are an equal mixture of yellowish brown (10YR5/6 and 5/4) and gray (10YR6/1) and structure is massive.
P-616-15	C_1	58-70	Same as P-616-14 except that texture is silt loam.

APPENDIX B

Table 14. Laboratory data for the 24 soils of the study

Soil name	Profile number	Sample number	Depth (inches)	Per cent of soil sample: 2 u clay	"Free" iron	Organic carbon	Total nitrogen	Ratio C/N	pH	Exchangeable cations, m.e. per 100 g. soil: Ca	Mg	H	Sum	Per cent base saturation	Ratio exchangeable Ca/Mg
Garwin	P-415	1	0-7	30.7	0.64	2.89	0.227	12.7	5.6	18.9	4.4	8.3	31.6	74	4.3
		2	7-11	34.6	0.71	2.45	0.190	12.9	5.0	17.1	5.0	8.7	30.8	72	3.4
		3	11-15	35.4	0.74	1.96	0.155	12.6	5.0	16.9	5.5	7.8	30.2	74	3.1
		4	15-18	37.0	0.79	1.56	0.128	12.2	5.2	17.1	6.3	7.2	30.6	76	2.7
		5	18-21	38.5	0.87	1.26	0.110	11.5	5.4	17.7	7.1	6.8	31.6	78	2.5
		6	21-24	39.4	0.82	0.96	0.087	11.0	5.2	18.1	7.2	6.0	31.3	81	2.5
		7	24-28	41.0	0.87	0.68	0.067	10.1	5.4	19.4	8.3	5.2	32.9	84	2.3
		8	28-33	38.5	0.68	0.46	0.053	8.7	5.6	19.3	8.3	3.9	31.5	88	2.3
		9	33-40	34.8	0.88	0.32	0.042	7.6	6.4	18.7	7.2	2.4	28.3	91	2.6
		10	40-50	32.0	0.95	0.22	0.033	6.7	6.8	18.2	7.0	1.6	26.8	94	2.6
		11	50-64	30.3	1.11	0.15			7.2			1.0			
Walford	P-607	1	0-4	13.9	0.75	1.66	0.147	11.2	7.1						
		2	4-8	18.5	0.80	1.50	0.135	11.0	7.1	13.4	2.3	0.2	15.9	99	5.9
		3	8-10	22.7	0.84	0.67	0.077	8.7	6.1						
		4	10-12	24.8	0.78	0.52	0.065	8.0	5.6	10.7	3.5	1.3	15.5	92	3.0
		5	12-15	30.0	0.82	0.45	0.065	6.9	5.5						
		6	15-18	36.8	0.90	0.43	0.061	7.0	5.2						
		7	18-22	40.9	0.90	0.37	0.048	7.6	5.3	18.6	7.9	3.4	29.9	89	2.4
		8	22-25	38.9	0.86	0.33	0.045	7.4	5.3	18.0	8.3	3.1	29.4	90	2.2
		9	25-31	38.1	1.03	0.31	0.046	5.0	5.1						
		10	31-38	36.8	1.02	0.29	0.039	7.6	5.1						
		11	38-45	35.1	0.96	0.26	0.033	8.0	5.5	16.3	8.4	2.8	27.5	90	1.9
		12	45-51	32.1	0.87	0.21	0.030	6.9	5.8						
		13	51-62	27.3	0.92	0.15	0.027	5.7	7.0						
Traer	P-422	1	0-7	18.4	0.71	1.48	0.130	11.4	6.3	11.6	2.0	2.6	16.2	84	5.8
		2	7-10	25.8	0.75	0.63	0.059	10.7	4.8	9.1	3.0	5.6	17.7	68	3.0
		3	10-13	30.9	0.88	0.62	0.061	10.2	4.8	11.4	4.3	6.5	22.2	71	2.6
		4	13-19	38.7	0.89	0.62	0.060	10.4	4.8	15.4	6.5	7.2	29.1	75	2.4
		5	19-23	39.5	0.78	0.48	0.050	9.5	4.9	18.3	8.0	5.5	31.8	83	2.3
		6	23-29	35.9	0.93	0.36	0.041	8.7	5.0	17.3	7.7	4.9	29.9	84	2.2
		7	29-35	34.4	0.92	0.31			5.6	18.6	8.3	3.3	30.2	89	2.2
		8	35-41	33.4	0.82	0.27	0.033	8.2	6.8	20.9	9.0	1.7	31.6	95	2.3
		9	41-50	29.1	0.78	0.55			7.7	22.4	8.2	0.0	30.6	100	2.7
		10	50-55	24.1		1.20	0.017		7.8	21.4	7.0	0.0	28.4	100	3.1
Muscatine	P-94	1	0-3	31.0	1.14	3.67	0.312	11.7	5.8	19.7	4.0	6.4	30.1	79	4.9
		2	3-6		1.11	2.98	0.256	11.6							
		3	6-9	33.9	1.14	2.50	0.219	11.4	5.3	18.4	5.3	5.3	29.0	82	3.5
		4	9-12		1.20	1.77	0.195	9.1	5.4						
		5	12-15	34.2	1.28	1.90	0.176	10.8	5.4						
		6	15-18		1.31	1.64	0.137	12.0	5.4						
		7	18-21	35.3	1.32	1.28	0.119	10.8	5.4	15.9	6.0	3.5	25.4	86	2.6
		8	21-24		1.41	0.93	0.092	10.2							
		9	24-27	35.0	1.35	0.77	0.082	9.4	5.3	23.1	6.5	2.5	32.1	92	3.5
		10	27-30		1.28	0.61	0.072	8.5							
		11	30-33	32.7	1.32	0.51	0.063	8.1	5.4						
		12	33-36												
		13	36-40	29.7	1.29	0.37	0.044	8.4	5.6						
		14	40-44												
		15	44-48	28.8	1.28	0.23	0.039	5.8	5.9						
		16	48-52												

		11	30–33	32.7	1.32	0.51	0.063	8.1	5.4						
		12	33–36												
		13	36–40	29.7	1.29	0.37	0.044	8.4	5.6						
		14	40–44												
		15	44–48	28.8	1.28	0.23	0.039	5.8	5.9						
		16	48–52												
		17	52–56	28.5	1.10	0.18	0.040	4.5	6.7	23.3	7.3	0.1	30.7	100	3.2
		18	56–62												
		19	62–70	23.7											
		20	70–80												
Atterberry	P-608	1	0–4	21.1	0.70	2.31	0.207	11.1	7.0						
		2	4–7	21.2	0.67	2.28	0.198	11.5	6.8	15.4	2.5	1.8	19.7	91	6.3
		3	7–11	23.2	0.93	1.19	0.114	10.4	5.6	10.1	2.2	3.5	15.8	78	4.6
		4	11–15	24.4	0.93	1.04	0.097	10.6	5.1						
		5	15–19	26.2	1.09	0.99	0.096	10.3	5.0						
		6	19–24	32.1	1.08	0.81	0.084	9.6	5.0						
		7	24–29	35.2	1.06	0.58	0.060	9.8	5.1	14.6	6.1	4.9	25.6	81	2.4
		8	29–35	35.4	1.05	0.43	0.054	8.1	5.1	15.4	6.2	4.6	26.2	82	2.5
		9	35–41	31.9	1.03	0.37	0.044	8.4	4.9						
		10	41–54	31.0	1.12	0.27	0.035	7.7	5.3						
		11	54–68	29.0	1.09	0.21	0.041	5.1	5.5	14.4	6.4	2.9	23.7	88	2.2
Stronghurst	P-609	1	0–4	17.1	0.73	1.46	0.146	10.0	7.1						
		2	4–7	17.2	0.75	1.43	0.136	10.5	7.1	12.6	1.7	1.4	15.7	91	7.4
		3	7–11	21.0	0.90	0.48	0.058	8.2	6.5	9.5	2.3	1.6	13.4	88	4.1
		4	11–15	27.6	1.06	0.40	0.059	6.8	6.0						
		5	15–18	33.9	1.07	0.33	0.045	7.4	4.9						
		6	18–22	38.7	1.06	0.32	0.041	7.9	4.8	14.9	6.8	4.7	26.4	82	2.2
		7	22–25	38.2	1.06	0.30	0.040	7.6	5.1	14.2	6.8	5.1	26.1	80	2.1
		8	25–29	36.5	1.03	0.31	0.040	7.7	5.1						
		9	29–33	35.0	1.13	0.30	0.037	8.0	5.1						
		10	33–38	32.9	1.08	0.27	0.051	5.4	4.9						
		11	38–45	31.8	1.19	0.23	0.042	5.4	5.4						
		12	45–53	30.4	1.13	0.21	0.038	5.5	5.5	13.9	6.6	3.3	23.8	86	2.1
		13	53–65	31.4	1.14	0.20	0.036	5.5	5.6	14.7	6.6	3.4	24.7	86	2.2
Tama	P-27	1	0–6	27.5	1.01	2.86	0.249	11.5	5.1	11.3	4.1	8.0	23.4	66	2.8
		2	6–9			2.44	0.210	11.6	5.3	13.3	4.6	6.3	24.2	74	2.9
		3	9–12	31.7	1.12	1.98	0.178	11.1		13.1	4.8	5.2	23.1	78	2.7
		4	12–15			1.74	0.156	11.2	5.5	13.4	4.4	4.4	22.2	80	3.0
		5	15–18	32.4	1.14	1.46	0.132	11.1		12.6	5.6	4.2	22.4	81	2.3
		6	18–21			1.12	0.104	10.8	5.4	12.9	6.1	4.1	23.1	82	2.1
		7	21–24	34.0	1.25	0.91	0.088	10.3							
		8	24–27			0.71	0.072	9.9	5.2	15.0	6.5	3.3	24.8	87	2.3
		9	27–30	34.2	1.22	0.59	0.062	9.5							
		10	30–33			0.47			5.3	14.8	7.8	3.1	25.7	88	1.9
		11	33–36	31.8	1.24	0.41									
		12	36–39			0.34	0.040	8.5	5.5	15.1	7.6	2.4	25.1	90	2.0
		13	39–42	27.9	1.24	0.31				13.8	7.2	1.8	22.8	92	1.9
		14	42–45			0.29			5.8						
		15	45–48		[illegible]	[illegible]									

		[illegible]	[illegible]			1.74	0.156	11.2	5.5	13.4	4.4	4.4	22.2	80	3.0
		5	15-18	32.4	1.14	1.46	0.132	11.1		12.6	5.6	4.2	22.4	81	2.3
		6	18-21			1.12	0.104	10.8	5.4	12.9	6.1	4.1	23.1	82	2.1
		7	21-24	34.0	1.25	0.91	0.088	10.3							
		8	24-27			0.71	0.072	9.9	5.2	15.0	6.5	3.3	24.8	87	2.3
		9	27-30	34.2	1.22	0.59	0.062	9.5							
		10	30-33			0.47			5.3	14.8	7.8	3.1	25.7	88	1.9
		11	33-36	31.8	1.24	0.41									
		12	36-39			0.34	0.040	8.5	5.5	15.1	7.6	2.4	25.1	90	2.0
		13	39-42	27.9	1.24	0.31				13.8	7.2	1.8	22.8	92	1.9
		14	42-45			0.29			5.8						
		15	45-48		1.23	0.25									
		16	48-54			0.18	0.031	5.8	5.8	13.4		1.0			
		17	54-65												
Downs	P-428	1	0-3	23.1	0.90	4.06	0.342	11.9	6.5	18.3	4.0	2.9	25.2	89	4.6
		2	3-6	23.6	1.02	2.16	0.173	12.5	6.1	11.4	3.6	4.3	19.3	78	3.2
		3	6-9	24.7	1.13	1.60	0.132	12.1	5.6	8.9	3.6	5.5	18.0	69	2.5
		4	9-12	26.8	1.21	1.36	0.107	12.7	5.2	8.1	4.0	6.0	18.1	67	2.0
		5	12-15	30.2	1.30	0.95	0.087	10.9	5.1	8.6	4.7	6.0	19.3	69	1.8
		6	15-18	31.1	1.39	0.67	0.069	9.7	5.0	9.2	5.5	5.2	19.9	74	1.7
		7	18-22	35.6	1.56	0.62	0.062	10.0	4.9	9.8	6.8	4.6	21.2	78	1.4
		8	22-26	34.6	1.65	0.47	0.056	8.4	4.9	11.2	6.9	4.6	22.7	80	1.6
		9	26-30	33.8	1.66	0.39	0.036	10.8	4.9	10.7	6.9	5.1	22.7	78	1.6
		10	30-34	31.9	1.64	0.37	0.036	10.3	5.0	11.0	7.0	5.4	23.4	77	1.6
		11	34-40	31.1	1.52	0.31	0.032	9.7	5.0	10.7	6.8	6.1	23.6	74	1.6
		12	40-46	30.3	1.43	0.27			5.1	11.4	6.8	5.3	23.5	77	1.7
		13	46-52	30.3	1.42	0.25			5.2	12.1	7.2	4.9	24.2	80	1.7
Fayette	P-32	1	0-1 1/2	23.6	0.85	4.11	0.338	10.8	5.5	18.3	3.7	5.9	27.9	79	4.9
		2	1 1/2-4		0.86	2.11	0.184	11.5	4.1	5.4	2.3	11.0	18.7	41	2.3
		3	4-7	20.6		1.56	0.133	11.7	3.8			11.2			
		4	7-10		0.85	0.92	0.089	10.3	3.9			7.5			
		5	10-13	20.5		0.60	0.078	7.7	4.2	2.4	2.3	4.8	12.2	39	1.0
		6	13-16			0.53	0.062	8.6	4.4			4.6			
		7	16-19	29.7		0.44	0.057	7.7	4.4	6.9	3.9	4.3	15.4	70	1.8
		8	19-22		1.10	0.41	0.052	7.9	4.4			4.5			
		9	22-25	35.5		0.41	0.050	8.2	4.4	11.2	6.1	5.2	21.8	79	1.8
		10	25-28	35.3	1.34	0.46	0.048	9.6	4.4	12.8	6.8	5.6	25.2	78	1.9
		11	28-31		1.30	0.36			4.4			5.7			
		12	31-34	32.3		0.37			4.4	12.7	6.9	5.6	25.2	78	1.8
		13	34-37			0.33			4.5			5.4			
		14	37-40	31.5	1.40	0.35				12.3	6.8		24.3	79	1.8
		15	40-43			0.38	0.039	9.7	4.7			5.0			
		16	43-46	29.4		0.27				12.7	6.8		24.2	81	1.9
		17	46-49			0.25			4.7			4.5			
		18	49-54			0.23	0.031	7.4	4.6	12.6	6.7		23.6	82	1.9

Table 14 (Continued)

Soil name	Profile number	Sample number	Depth (inches)	Per cent of soil sample: 2 u clay	"Free" iron	Organic carbon	Total nitrogen	Ratio C/N	pH	Exchangeable cations, m.e. per 100 g. soil: Ca	Mg	H	Sum	Per cent base saturation	Ratio exchangeable Ca/Mg
Taintor	P-412	1	0-7	36.9	0.45	3.04	0.241	12.6	6.2	27.3	7.7	4.6	39.6	88	3.5
		2	7-11	39.8	0.54	2.34	0.184	12.7	6.2	27.4	9.2	3.6	40.2	91	3.0
		3	11-15	40.4	0.62	1.70	0.136	12.5	6.2	25.5	9.3	3.0	37.8	92	2.8
		4	15-18	41.4	0.74	1.19	0.097	12.3	6.4	24.3	10.3	2.6	37.2	93	2.4
		5	18-21	43.2	0.89	0.81	0.067	12.1	6.5	23.9	10.6	2.2	26.7	92	2.3
		6	21-24	41.3	1.14	0.58	0.052	11.2	6.8	23.2	10.4	1.9	25.5	93	2.2
		7	24-28	39.7	1.14	0.39	0.046	8.5	6.7	22.2	10.9	1.6	34.7	95	2.0
		8	28-35	35.9	1.66	0.29	0.036	8.1	6.8	20.6	10.1	1.5	32.2	95	2.0
		9	35-42	32.5	0.32	0.17	0.028	6.1	7.0	18.1	8.5	0.9	27.5	97	2.1
		10	54-66	26.6	0.86	0.70			7.7						
Rubio	P-610	1	0-6	21.0	0.87	1.78	0.170	10.4	6.5						
		2	6-10	24.6	0.74	1.18	0.114	10.3	5.6	11.2	3.4	3.3	17.9	82	3.3
		3	10-13	30.1	0.79	0.86	0.081	10.6	5.3	12.4	5.1	3.6	21.1	83	2.4
		4	13-15	39.1	0.98	0.88	0.081	10.9	5.2						
		5	15-16												
		6	16-18	45.2	1.15	0.85	0.077	11.1	4.7	18.0	9.3	4.5	31.8	86	1.9
		7	18-20	48.2	1.19	0.72	0.071	10.2	4.9	19.5	10.5	4.6	34.6	87	1.9
		8	20-26	47.8	1.22	0.49	0.049	10.1	5.2						
		9	26-32	44.2	1.00	0.38	0.051	7.3	5.2						
		10	32-38	38.9	1.05	0.32	0.040	7.9	5.5						
		11	38-45	35.9	1.06	0.29	0.030	9.8	6.0						
		12	45-55	35.2	0.74	0.20	0.024	8.0	6.6						
		13	55-65	31.5	0.66	0.15	0.026	5.9	7.0	16.5	9.9	0.0	26.4	100	1.7
Berwick	P-423	1	0-6	14.1	1.00	1.18	0.111	10.7	5.8	6.3	1.8	3.6	11.7	69	3.5
		2	6-8	14.7	0.98	1.11	0.102	10.9	5.7	6.4	1.8	4.4	12.6	65	3.6
		3	8-11	17.8	0.98	0.43	0.042	10.2	5.4	5.4	2.3	4.1	11.8	65	2.4
		4	11-14	23.9	1.01	0.30	0.037	8.1	5.1	6.3	3.8	5.3	15.4	66	1.7
		5	14-17	38.2	1.02	0.24	0.040	6.1	4.8	10.2	7.4	8.2	25.8	68	1.4
		6	17-22	50.3	0.77	0.30	0.046	6.5	4.6	14.1	10.8	10.6	35.5	70	1.3
		7	22-26	46.6	0.95	0.24	0.039	6.0	4.6	13.5	10.9	10.3	34.7	70	1.2
		8	26-32	44.4	0.96	0.20	0.036	5.5	4.7	13.8	11.1	9.0	33.9	74	1.2
		9	32-38	39.8	1.00	0.16	0.037	4.3	4.9	13.8	10.9	7.5	32.2	77	1.3
		10	38-44	37.8	0.99	0.14			5.1	14.4	11.1	5.2	30.7	83	1.3
		11	44-50	34.8	1.14	0.15	0.028	5.2	6.0	15.0	11.3	3.1	29.4	89	1.3
		12	50-60	32.9		0.16			6.3	14.8	11.0	2.0	27.8	93	1.4
Mahaska	none	1	0-6	32.1	1.20	2.23	0.219	10.2	5.2						
		2	6-11	34.4	1.26	1.80	0.200	9.0	5.3	12.3	5.2	7.5	25.0	70	2.4
		3	11-14	37.6	1.34	1.51	0.150	10.1	5.3						
		4	14-18	38.8	1.45	1.14	0.129	8.8	5.4	14.0	6.8	4.6	25.4	82	2.1
		5	18-24	38.6	1.50	0.68	0.097	7.0	5.5	14.9	7.4	3.4	25.7	87	2.0
		6	24-31	36.0	1.35	0.20	0.053	3.8	5.6						
		7	31-40	34.6	1.30	0.18	0.046	3.9	5.6						
		8	40-60	29.3	0.53	0.00	0.032		6.0	13.3	7.1	0.8	21.2	96	1.9
Givin	P-611	1	0-6	20.2	0.63	2.04	0.178	11.4	6.3						

		12	[illegible]	[illegible]		[illegible]			6.3	14.8	11.0	2.0	27.8	93	1.4
Mahaska	none	1	0-6	32.1	1.20	2.23	0.219	10.2	5.2						
		2	6-11	34.4	1.26	1.80	0.200	9.0	5.3	12.3	5.2	7.5	25.0	70	2.4
		3	11-14	37.6	1.34	1.51	0.150	10.1	5.3						
		4	14-18	38.8	1.45	1.14	0.129	8.8	5.4	14.0	6.8	4.6	25.4	82	2.1
		5	18-24	38.6	1.50	0.68	0.097	7.0	5.5	14.9	7.4	3.4	25.7	87	2.0
		6	24-31	36.0	1.35	0.20	0.053	3.8	5.6						
		7	31-40	34.6	1.30	0.18	0.046	3.9	5.6						
		8	40-60	29.3	0.53	0.00	0.032		6.0	13.3	7.1	0.8	21.2	96	1.9
Givin	P-611	1	0-6	20.2	0.63	2.04	0.178	11.4	6.3						
		2	6-9	19.4	0.55	2.72	0.241	11.3	6.7	17.2	3.3	0.5	21.0	98	5.2
		3	9-12	20.7	0.59	1.70	0.138	12.3	5.4	10.4	3.1	3.5	17.0	79	3.4
		4	12-15	22.5	0.66	1.07	0.095	11.2	5.4	8.6	3.2	1.7	13.5	87	2.7
		5	15-18	25.1	0.74	0.76	0.072	10.7	5.3						
		6	18-21	34.1	0.80	0.65	0.070	9.2	5.1						
		7	21-23	41.0	0.89	0.66	0.068	9.7	5.1	15.2	9.2	3.6	28.0	87	1.6
		8	23-25	45.6	0.83	0.56	0.062	9.1	5.1	17.3	10.6	3.6	31.5	89	1.6
		9	25-28	44.7	0.83	0.48	0.062	7.7	5.2						
		10	28-33	43.3	0.83	0.37	0.050	7.4	5.4						
		11	33-43	39.2	0.77	0.27	0.039	6.9	5.8						
		12	43-52	35.8	0.70	0.20	0.030	6.5	6.1						
		13	52-60	31.5	0.70	0.21	0.033	6.4	6.2	13.9	9.7	0.8	24.4	97	1.4
Keomah	P-613	1	0-4	17.6	0.83	1.51	0.154	9.8	5.4						
		2	4-7	16.3	0.79	1.24	0.127	9.8	5.6	7.2	2.2	3.6	13.0	72	3.2
		3	7-10	22.3	0.75	0.68	0.076	8.9	5.8						
		4	10-12	26.6	0.84	0.49	0.060	8.3	5.6	8.8	4.1	2.3	15.2	85	2.2
		5	12-14	28.3	0.84	0.42	0.055	7.7	5.0						
		6	14-16	33.5	0.92	0.36	0.052	7.0	5.4						
		7	16-18	36.5	0.93	0.31	0.057	5.5	5.0						
		8	18-21	40.9	0.95	0.38	0.053	7.0	4.9	14.4	8.1	3.7	26.2	86	1.8
		9	21-24	42.3	0.98	0.31	0.054	5.7	5.1	15.3	8.8	4.2	28.3	85	1.8
		10	24-30	42.1	1.01	0.28	0.042	6.7	5.1	14.2	8.8	4.7	27.7	83	1.6
		11	30-37	38.2	1.03	0.20	0.032	6.1	5.3						
		12	37-47	34.6	1.05	0.21	0.032	6.6	5.3						
		13	47-60	30.0	1.00	0.20	0.033	6.0	6.3	14.0	8.3	2.3	24.6	91	1.7
Otley	P-262	1	0-7	29.2	1.03	1.73	0.173	10.0	5.3	10.4	4.0	6.4	20.8	69	2.6
		2	7-12	34.2	1.11	1.10	0.112	9.8	5.1	10.1	4.6	5.8	20.5	72	2.2
		3	12-17	38.1	1.30	0.76	0.087	8.7	5.0	12.1	7.2	4.9	24.2	80	1.7
		4	17-23	39.3	1.28	0.55	0.064	8.6	5.3	13.8	8.2	4.3	26.3	84	1.7
		5	23-30	36.1	1.24	0.40	0.059	6.7							
		6	30-36	33.5	1.18	0.29			5.9	13.9	8.1	3.9	25.9	85	1.7
		7	36-42	33.3	1.20	0.24									
		8	42-48	32.0	1.15	0.18			6.1	14.1	8.4	2.7	25.2	89	1.7
		9	48-54	29.3	1.11	0.16									
Ladoga	P-612	1	0-4	23.9	0.63	3.55	0.344	10.3	5.9						
		2	4-6	24.4	0.65	2.61	0.233	11.2	5.5	11.8	2.9	4.5	19.2	77	4.1
		3	6-8	23.8	0.66	1.82	0.164	11.0	5.5						
		4	8-10	23.6	0.64	1.39	0.126	11.0	5.4	7.8	2.6	3.2	13.6	76	3.0
		5	10-13	26.8	0.75	1.18	0.110	10.7	4.8						
		6	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

		7	30-42	33.3	1.20	0.24									
		8	42-48	32.0	1.15	0.18			6.1	14.1	8.4	2.7	25.2	89	1.7
		9	48-54	29.3	1.11	0.16									
Ladoga	P-612	1	0-4	23.9	0.63	3.55	0.344	10.3	5.9						
		2	4-6	24.4	0.65	2.61	0.233	11.2	5.5	11.8	2.9	4.5	19.2	77	4.1
		3	6-8	23.8	0.66	1.82	0.164	11.0	5.5						
		4	8-10	23.6	0.64	1.39	0.126	11.0	5.4	7.8	2.6	3.2	13.6	76	3.0
		5	10-13	26.8	0.75	1.18	0.110	10.7	4.8						
		6	13-16	29.5	0.83	0.89	0.096	9.3	5.2						
		7	16-21	32.8	0.87	0.75	0.075	10.0	5.1						
		8	21-25	36.2	0.92	0.58	0.063	9.2	5.4	11.8	7.4	3.8	23.0	84	1.6
		9	25-31	37.8	0.93	0.43	0.047	9.2	5.2	12.9	8.2	3.4	24.5	86	1.6
		10	31-37	35.3	0.92	0.35	0.044	8.0	5.5						
		11	37-47	33.8	1.11	0.25	0.041	6.3	5.5						
		12	47-55	32.3	1.11	0.21	0.033	6.4	5.4						
		13	55-60	29.7	1.09	0.19	0.032	6.0	5.5	11.7	7.3	2.6	21.6	88	1.6
Clinton	P-126	1	0-5	19.0	0.75	1.71	0.165	10.3	6.9	8.9	1.9	3.8	14.6	74	4.7
		2	5-9	19.8	0.86	1.14	0.119	9.6	5.9	5.9	2.0	5.2	13.1	60	3.0
		3	9-12	22.1	0.90	0.59	0.066	9.0	5.8	5.9	2.3	5.3	13.5	61	2.6
		4	12-15	25.7					5.9						
		5	15-18	29.5	1.09	0.35	0.044	8.0	5.6	8.4	4.6	5.2	18.2	72	1.8
		6	18-21	33.3					5.4						
		7	21-24	37.5	1.35	0.34	0.046	7.3	5.2	10.9	6.7	8.2	25.8	68	1.6
		8	24-27	37.8	1.49	0.32	0.040	8.2	5.1	11.8	7.2	8.2	27.2	70	1.6
		9	27-30	37.4					5.1						
		10	30-33	36.6	1.30	0.27	0.043	6.1	5.2	12.5	7.8	7.7	28.0	72	1.6
		11	33-35	35.8					5.2						
		12	35-37	35.4	1.32	0.24	0.037	6.6	5.5	12.4	7.7	7.0	27.1	74	1.6
		13	37-40	35.0					5.3						
		14	40-43	34.5	1.30	0.20	0.033	6.1	5.3	12.8	7.7	6.2	26.7	77	1.7
		15	43-46	33.0					5.4						
		16	46-49	31.6					5.4						
		17	49-53	31.6	1.26	0.17	0.036	4.8	5.5	12.6	7.7	5.2	25.5	81	1.6
		18	53-57	28.1					5.5	11.6	7.0	4.7	23.3	80	1.7
		19	57-63	28.8					5.6	11.6	7.1	4.5	23.2	81	1.6
		20	63-70	28.2	1.18	0.15	0.030	4.8	5.6	10.9	6.8	4.2	21.9	81	1.6
Haig	P-164	1	0-6	26.7	0.53	3.48	0.274	12.7							
		2	6-10	29.2	0.56	1.84	0.139	13.2	5.3	14.8	5.0	7.6	27.4	72	3.0
		3	10-14	33.9	0.63	1.40	0.106	13.2	5.3	13.8	5.3	6.4	25.4	75	2.6
		4	14-18	37.7	0.71	1.22	0.090	13.6	5.4	14.7	6.7	5.4	26.8	80	2.2
		5	18-24	48.4	0.84	1.01	0.074	13.6	5.4	16.4	8.1	5.1	29.6	83	2.0
		6	24-30	45.5	0.81	0.47	0.044	10.7	5.6	21.5	12.0	4.8	38.3	87	1.8
		7	30-36	39.4	1.02	0.33	0.035	9.4	6.0	20.8	12.1	3.0	35.9	92	1.7
		8	36-43	36.8	0.85	0.21	0.030	7.0	6.2	19.4	11.2	2.4	33.0	93	1.7
		9	43-50	33.6	1.18	0.18	0.022	8.2	6.3	18.1	10.0	1.8	29.9	94	1.8
		10	50-60	29.2	0.30	0.10			6.4	16.9	9.3	1.4	27.6	95	1.8
									6.6			0.8			

Table 14 (Continued)

Soil name	Profile number	Sample number	Depth (inches)	Per cent of soil sample: 2 u clay	"Free" iron	Organic carbon	Total nitrogen
Belinda	P-614	1	0-4	18.1	0.89	1.72	0.139
		2	4-7	18.2	0.77	1.65	0.130
		3	7-12	20.8	0.96	0.99	0.084
		4	12-14	23.9	1.08	0.72	0.074
		5	14-17	29.8	1.33	0.68	0.063
			17-19	No sample collected			
		6	19-21	48.7	1.20	0.81	0.082
		7	21-24	52.3	1.15	0.73	0.072
		8	24-28	52.4	1.14	0.61	0.067
		9	28-33	46.2	0.98	0.44	
		10	33-38	40.3	0.99	0.27	0.031
		11	38-46	38.0	0.98	0.23	0.030
		12	46-54	36.8	0.80	0.16	0.034
		13	54-66	31.8	0.90	0.15	0.043
Beckwith	P-421	1	0-6	17.2	0.77	2.22	0.206
		2	6-9	17.1	0.96	0.61	0.078
		3	9-14	17.7	1.07	0.42	0.050
		4	14-16	30.5	1.33	0.34	0.053
		5	16-19	49.3	1.04	0.42	0.072
		6	19-22	52.3	0.91	0.41	0.058
		7	22-25	51.9	0.90	0.33	0.040
		8	25-31	47.9	0.88	0.24	0.040
		9	31-38	43.2	0.96	0.24	0.033
		10	38-45	41.5	0.96	0.21	
		11	45-52	35.9	0.82	0.16	0.023
		12	55-65	32.2		0.12	
		13	75-85	28.4		0.12	0.021
Grundy	P-264	1	0-7	26.5	1.11	2.02	0.177
		2	7-13	31.0	1.20	1.33	0.121
		3	13-18	36.3	1.28	0.91	0.094
		4	18-24	44.1	1.40	0.62	0.073
		5	24-30	42.6	1.30	0.38	0.059
		6	30-36	38.9	1.20	0.26	
		7	36-42	38.5	1.15		
		8	42-48	37.3	1.08	0.18	
Pershing	P-615	1	0-4	21.3	1.02	1.96	0.209
		2	4-8	21.7	1.08	1.64	0.161
		3	8-13	24.6	1.10	1.00	
		4	13-17	31.8	1.11	0.62	0.072
			17-18	No sample collected			
		5	17-21	42.1	1.24	0.48	0.056
		6	21-26	43.2	1.21	0.42	0.055
		7	26-30	42.7	1.30	0.37	0.046
		8	30-36	39.5	1.16	0.28	0.037
		9	36-42	37.1	1.10	0.22	0.035
		10	42-50	33.0	1.08	0.18	0.027
		11	50-58	29.9	1.04	0.16	0.021
Weller	P-616	1	0-3	18.4	0.75	2.47	0.235
		2	3-5	16.9	1.06	1.13	0.107
		3	5-8	17.6	1.05	0.56	0.063
		4	8-11	18.3	1.14	0.37	0.046
		5	11-14	20.6	0.90	0.30	0.040
		6	14-16	26.6	1.07	0.28	0.045
		7	16-17	42.3	1.10	0.33	0.042
		8	17-21	51.7	1.10	0.34	0.045
		9	21-24	51.8	1.07	0.34	0.042
		10	24-27	46.3	1.11	0.28	0.034
		11	27-34	45.0	1.12	0.26	0.030
		12	34-41	38.5	1.01	0.20	0.025
		13	41-48	35.3	1.04	0.18	0.024
		14	48-58	31.4	0.92	0.15	0.025
		15	58-70	24.4	1.13	0.14	

le Total nitrogen	Ratio C/N	pH	Exchangeable cations, m.e. per 100 g. soil Ca	Mg	H	Sum	Per cent base saturation	Ratio exchangeable Ca/Mg
0.139	12.4	7.3						
0.130	12.6	6.9	12.1	2.7	1.8	16.6	89	4.5
0.084	11.8	5.6						
0.074	9.7	5.5	7.5	3.7	3.7	14.9	75	2.0
0.063	10.9	5.4						
0.082	9.8	5.3	15.3	9.7	7.8	32.8	76	1.6
0.072	10.1	5.3	16.6	11.0	8.0	35.6	78	1.5
0.067	9.2	5.3	16.0	11.8	6.7	34.5	81	1.4
		5.5						
0.031	8.7	5.9						
0.030	7.5	6.1						
0.034	4.8	6.1						
0.043	3.5	6.2	14.5	9.4	3.3	27.2	88	1.6
0.206	10.8	5.1	6.2	2.1	6.2	14.5	57	3.0
0.078	7.8	5.0	3.8	1.6	4.0	9.4	57	2.4
0.050	8.4	5.1	3.4	2.2	3.6	9.2	61	1.6
0.053	6.4	4.5	6.7	5.8	5.8	18.3	68	1.2
0.072	5.8	4.2	11.9	10.5	8.2	30.6	73	1.1
0.058	7.0	4.4	13.1	11.8	8.3	33.2	75	1.1
0.040	8.3	4.4	14.1	12.5	8.2	34.8	76	1.1
0.040	6.0	4.6	14.2	12.4	6.7	33.3	80	1.2
0.033	7.3	4.8	14.1	12.3	5.6	32.0	83	1.2
		5.2	15.2	12.6	3.6	31.4	89	1.2
0.023	7.0	5.8	14.4	11.8	2.9	29.1	90	1.2
		5.9	13.2	10.6	2.1	25.9	92	1.2
0.021	5.6	6.2	11.4	9.0	1.4	21.8	94	1.3
0.177	11.4	5.5	12.3	3.8	5.5	21.6	74	3.2
0.121	11.0	5.5	10.6	5.0	5.1	20.7	75	2.1
0.094	9.7	5.6	11.5	6.8	4.2	22.5	81	1.7
0.073	8.5	5.8	14.2	9.3	3.8	27.3	86	1.5
0.059	6.4							
		5.9	14.9	9.8	2.8	27.5	90	1.5
		6.1	16.6	10.8	2.1	29.5	93	1.5
0.209	9.3	5.2						
0.161	10.2	5.3	7.5	2.7	8.0	18.2	56	2.8
		5.3	6.8	3.3	8.0	18.1	56	2.1
0.072	8.7	5.4						
0.056	8.6	5.2	12.2	8.2	8.0	28.4	72	1.5
0.055	7.6	5.3	14.6	9.2	7.3	31.1	76	1.6
0.046	7.9	5.4	14.6	9.8	6.1	30.5	80	1.5
0.037	7.6	5.5						
0.035	6.4	5.9						
0.027	6.8	6.3						
0.021	7.4	6.5	13.7	8.1	4.4	26.2	83	1.7
0.235	10.5	6.0	15.2	3.0	5.1	23.3	78	5.1
0.107	10.6	5.9			4.8			
0.063	8.9	5.4	15.6	3.4	4.5	23.5	81	4.6
0.046	8.0	5.1			5.6			
0.040	7.5	5.0	7.2	5.3	6.5	19.0	66	1.4
0.045	6.2	4.4			8.1			
0.042	7.9	4.1			10.5			
0.045	7.6	4.3	18.3	7.0	12.0	37.3	68	2.6
0.042	8.1	4.6	18.2	6.1	12.2	36.5	67	3.0
0.034	8.2	4.7			11.1			
0.030	8.7	5.0			9.0			
0.025	8.0	5.1			5.9			
0.024	7.5	5.3			2.3			
0.025	6.0	5.8	21.1	7.1	1.1	29.3	96	3.0
		6.4			0.3			