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MORPHOLOGY AND COMPOSITION OF SOME SOILS OF THE MIAMI FAMILY AND THE
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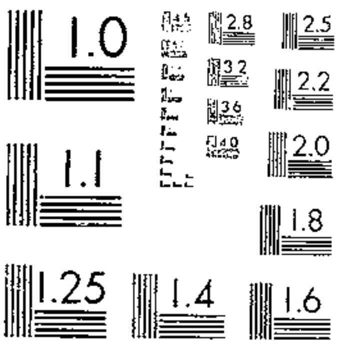

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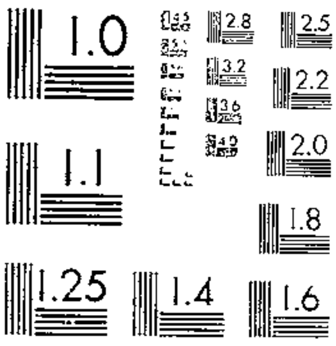

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Morphology and Composition of Some Soils of the Miami Family and the Miami Catena[1]

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INTRODUCTION

As several thousand soil types have been recognized in the United States, it is now possible to establish their systematic classification. Soils may be grouped in many different ways according to the objectives sought in the classification, but for convenience two systems have been followed in the United States. In the taxonomic system of soil classification the soils are classified according to their morphology and other characteristics that indicate their most probable genesis. Soils that are closely related taxonomically, therefore, are not necessarily closely associated geographically. In the geographic system of soil classification, the soils are grouped largely on the basis of their geographic association. They may differ radically one from another in morphology and other features that would distribute them in widely separated groups in the taxonomic system.

Geographically associated soils, therefore, form the basis for soil-association landscapes that may be of several different types.

The object of this bulletin is to bring out some of the morphological and chemical characteristics of representative soils of the Miami family and Miami catena. The Miami family was selected for study because it is one of the most important taxonomic groups of soils in the

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North Central United States from the standpoint of agriculture. The Miami catena has one soil series in common with the Miami family, and it is one of the most important geographic associations of soils in the North Central United States. With the Miami series as a starting point for both family and catena, the relationships between the two kinds of classifications can be brought out clearly.

In order to clarify further the differences between the two systems, it is desirable to review certain historical details and explanations regarding the development of the taxonomic system and of the soil catena in the geographic system and to show the relationship between them.

STATUS OF SOIL CLASSIFICATION

What Is a Soil Family?

In the introductory paragraphs of his last monograph, the late Dr. C. F. Marbut (*20*)[2] outlined and explained his scheme of soil classification. His first two categories include soil types and soil series, respectively, so well known and generally understood that there is no need for clarification. His third category, local environmental groups (family groups), he defined as follows:

> Category III includes groups, the units in each of which have some features in common, developed by local rather than general environmental conditions. The units in each group consist of the series groups of Category II, these being grouped into the units of Category III because the characteristic features common to the members in each are the product of local conditions, such as differences in drainage and relief; specially striking characteristics of parent material, such as the presence of high content of calcium carbonate or of sodium or other salts; parent materials made up of organic matter; or any other local condition. This category would include groups of infantile, young, and mature soils, under good drainage; the long and complex list of poor and imperfectly drained soils; peat soils; Rendzinas; salty and alkali soils; mountain meadow soils; mountain carbonate soils; and others.

A careful reading of this statement, and a study of Marbut's table of classification, indicates that he intended each soil family to include soils having similar profile characteristics. These similar profile characteristics have developed from similar but not identical parent materials. The common characteristics of a given family were less inclusive than those of the great soil groups. For example, referring to his table of classification, his "Groups of Mature but Related Soil Series" would undoubtedly include several subdivisions or families of a given Great Soil Group. In the Gray-Brown Podzolic soils, Chernozems, Podzols, etc., each would include several families.

From Marbut's definition it is evident that he intended each soil family to include only those soils having similar morphology and necessarily having developed under similar environmental conditions. An attempt was made to abbreviate the description of soil family in the 1938 Yearbook of Agriculture (*32*). The definition follows: "A category in soil classification between series and great soil group: a taxonomic group of soils having similar profiles, composed of one or more distinct soil series." This definition is perhaps somewhat vague, but it was not made more specific at the time of writing because no attempt had been made to group all of the soil series of the United States into families. Some work along this line is now in progress,

[2] Italic numbers in parentheses refer to Literature Cited, p. 53.

but until it is complete it will not be feasible to formulate a definition that will be specific as to the points of similarity that must exist between soils before they can be placed in the same family.

Certain principles regarding characteristics of soils that should be considered in establishing a family might be mentioned: (1) The number, sequence, and general characteristics of genetic soil horizons within each member of a soil family should be similar. (2) The texture and mineralogical composition of parent materials or parent rocks should be similar, although by no means necessarily the same. For example, glacial till varies greatly in lithological composition, but if the same rocks and minerals are represented even in considerably varying proportions and if the texture of these materials does not have too wide a range, it is reasonable that all soil series of a given sequence of horizons should be classified in one family. Furthermore, stratified outwash deposits, such as those of the glaciated region, may have essentially the same lithological composition as the glacial till with which they are associated. In such a case, soils of equal drainage conditions and profile development can be placed in the same family as the soils developed from glacial till. On the other hand, if parent materials of glacial till or outwash deposits are exceedingly sandy and of a lithological composition differing considerably from the somewhat heavier-textured till and outwash deposits, this would be a basis for the establishment of new families. (3) The natural drainage condition of a soil is another basis for the establishment of soil families, because differences in natural drainage have a very important effect on the number, sequence, and characteristics of soil horizons. (4) The factors of slope and climate also have an important bearing on soil morphology, and, to the extent that they do, they must be considered in the establishment of soil families. (5) Vegetation must be considered in establishing soil families to the extent that broad differences in vegetation fundamentally affect profile characteristics. (6) The age of a soil, insofar as it affects morphology and fundamental chemical characteristics, also has a bearing on how the soil will fit in a family grouping.

If natural drainage, character of parent material, and the number, sequence, and characteristics of soil horizons must be similar in order for soils to be placed together in one family, it is evident that the members of a family may be scattered widely over a very large area and separated by members of other families that are either developed under different drainage conditions or are developed from radically different kinds of parent material. From this it may be seen that members of a given soil family are not always as closely associated geographically as are members of different families. In fact, a great many members of soil families are rather widely separated geographically, and they are not very frequently associated closely enough to form distinct local landscapes. The only important exception to this is that two or more types of a soil series may be sufficiently closely associated geographically to form local landscapes.

In Marbut's classification, however, it is impossible to trace one of the so-called abnormal soils, such as those of swamps or salty areas from the soil type (Category I) through the soil series (Category II) and family (Category III) to Categories IV, V, and VI. All of these so-called abnormal soils fail to fit into any of the higher categories, but Marbut recognized that they could be grouped into a number of families. In the Atlas (*20*) he did not describe individual families as such, partly because he did not feel fully prepared to decide on the grouping of all known soil series into families and partly because he was more concerned with geographic groupings now known as catenas and noncatenary complexes.

In the Yearbook of Agriculture for 1938 (*3*) Baldwin and others modified Marbut's table sufficiently to make it possible to trace any soil from the lowest to the highest category (see *3*, table 2). This meant, of course, a rearranging of the higher categories to include all soils. In this classification the highest category includes zonal, intrazonal, and azonal soils. In the same table an attempt was made to indicate one or more families for each great soil group. It should be possible to place every soil series of the United States, or of the world for that matter, into a suitable family group and to group these families into great soil groups and thence into the still higher categories. This is a problem that will take a great amount of time and study.

What Is a Soil Catena?

In a great many places soils of several different drainage conditions are developed from essentially the same kind of parent rock, and these different soils go to make up the foundation for complete local landscapes. The differences in profiles of closely associated soils are due almost entirely to drainage differences that are brought about by local relief.

To meet this condition the term catena (Latin for chain) was introduced by Milne (*23*) to cover geographic groups of soils developed from one kind of parent rock but under different drainage conditions induced by differences in slope. Ideally, the soils comprising a catena occur as consecutive bands along slopes from one hilltop, across a level valley to another hilltop—all on essentially the same kind of rock. For example, soils of the Miami catena are members of the Miami, Crosby, Bethel, Brookston, and Clyde series, and in a few places there are small areas of Hennepin soils (see table 1, p. 8). The parent glacial tills of all of these soils are alike in all essential respects, although the proportion of different rocks and minerals within the till may vary considerably; and in the Brookston and Clyde soils a certain amount of silty and clayey material may have accumulated through the action of local wash, gravity, and frost heave.

Soils of the Hennepin series are developed on very steep slopes where the intensity of soil-formation activity is at a minimum and where rapid runoff prevents the accumulation of a deeply leached strongly weathered deposit. Hennepin soils are shallow and usually neutral in reaction, or nearly so, and calcareous glacial till occurs within a few inches of the surface in most places. Miami soils are well-developed Gray-Brown Podzolic soils in which the lime carbonate has all been leached from the glacial till to a depth of from

2 to about 3½ feet in most places. Miami soils are well drained internally and externally, but as a rule they occur neither on very steep slopes nor on level land. Crosby soils are developed from the same kind of calcareous glacial till as the Miami soils but, since they occur on nearly level or gently undulating land, surface runoff is slow and much of the rain water sinks into the ground or evaporates from the surface. Some of the water flows to the level and depressed areas where other soils are developed. Under these conditions a profile somewhat like that of the Miami soil has developed, but a clay pan or, at least, a very heavy subsoil, heavier than the subsoil of the Miami, has developed, and slow internal drainage has caused the lower horizons to be mottled. Bethel soils are developed in association with Crosby soils on dead-level areas, usually on divides. These soils are more slowly drained than the Crosby soils and usually the development of clay pan is more pronounced.

Surface water from the Miami, Crosby, and Bethel soils moves away toward the slight depressions in the till plain. Subsoil water moves slowly through the entire Miami profile, but in the Crosby and Bethel profiles much of it is held up by the heavy subsoil and, where it moves at all, it works its way in a more or less horizontal direction above the clay pan toward the lower-lying areas. From this it can be seen that excess soil water in the Miami, Crosby, and Bethel soils moves away toward lower areas. Brookston and Clyde soils occur in level depressed areas where more water accumulates than falls on the surface. These areas receive water that drains away from the Miami, Crosby, and Bethel soils and, since natural outlets are higher than most of the areas, the water stands on the surface until it evaporates or moves very slowly through the underlying glacial till to form springs along water courses. Both the Brookston and Clyde soils are very dark-colored and approximately neutral in reaction, although the other soils of the catena are light-colored and acid in reaction. Details of the soil profiles of each of the members of the Miami catena, except the Hennepin, are described later.

In the establishment of catenas a certain amount of leeway can be allowed in the character of the parent rock. Milne (*23*), who first gave a name to the catena concept, used the catena as a mapping unit and permitted some variation in the character of the parent rocks of soil series included in any one catena. He allowed greater variation in this respect than is allowed in the catenas of the United States. This is probably because he was using the catena as a mapping unit, whereas in the United States the concept is used as a means of making sure that new soil series be established systematically according to profile characteristics corresponding to definite drainage differences where it is necessary to establish several series on one kind of parent material within one soil zone.

The Relationships Between Soil Family and Soil Catena

The differences between the concept of family and that of catena may be illustrated by an analogy. A family of soils is a taxonomic unit of classification that is roughly analogous to a genus of plants, whereas the catena is analogous to an ecological unit of plants. For example, the genus *Pinus* includes the various species of pines and the genus *Quercus* includes the various species of oaks. These two genera may be considered to be analogous to two families of soils, whereas the oak-pine forest association may be considered to be an ecological analogue of a catena of soils.

Each member of the Miami family theoretically is the senior series of a different catena, although it is well known that some soil series do not have catenary associates. In some instances the same poorly drained series overlaps several catenas. For example, Brookston soils belong to the Miami, Hillsdale, and Galena catenas. There might be some argument for having different names for the Brookston soils that are associated with Hillsdale and Galena soils, but the differences between them are not sufficiently great to justify the establishment of new series even though certain minor differences no doubt could be demonstrated.

Each member of the Miami catena, conversely, is the senior series of a different family. Members of the Miami family include only Gray-Brown Podzolic soils; the Crosby and Bethel families both include only Planosols, but the soils of the Bethel family are more slowly drained than the first: Brookston and Clyde families, as mapped by the Division of Soil Survey, include Half-Bog soils, although the Clyde soils are dominantly and typically Wiesenböden.

To illustrate further the relationships between soil families and soil catenas, table 1 gives graphically the various members of the Miami family and the catenas of soils that go with each, and figure 1 illustrates a cross section through adjacent Miami and Fox catenas.

It is noted that for each member of the Miami catena there is a family of soils of similar drainage condition. There is not much basis for the establishment of families of organic soils, but it is felt that the mucks, because of their greater degree of decomposition, should be kept separate from the peats.

Table 2 gives a strictly taxonomic grouping of the soils shown in table 1.

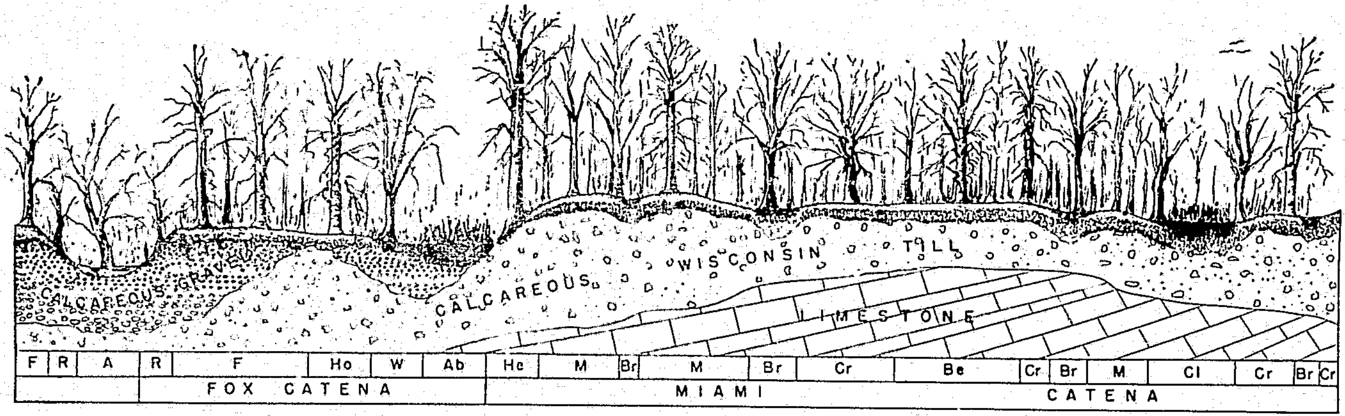

FIGURE 1.—Cross section of adjacent Miami and Fox catenas (soil types most commonly found in central Indiana and western Ohio). Fox catena: (R) Rodman gravelly loam; (F) Fox silt loam; (Ho) Homer silt loam; (W) Westland silty clay loam; (Ab) Abington silty clay loam. Miami catena: (He) Hennepin loam; (M) Miami silt loam; (Cr) Crosby silt loam; (Be) Bethel silt loam; (Br) Brookston silty clay loam; (Cl) Clyde silty clay loam. Alluvium (A) here includes members of the Genesee and Eel series, which belong neither to the Fox nor the Miami catenas.

TABLE 1.—*Relationships between some soil catenas and soil families in Ohio, Indiana, and southern Michigan. Families and catenas shown are not all complete*

Family	Dominant slopes	Natural drainage	Soils composing the catenas—								
			Miami	Milton	Bellefontaine	Galena	Hillsdale	Fox	Mill Creek	Wooster	Alexandria
Hennepin	Steep	Very rapid external	Hennepin		Rodman			Rodman	Rodman		
Miami	Level to steep; dominantly medium.	Medium to rapid external and internal.	Miami [1]	Milton	Bellefontaine	Galena	Hillsdale [1]	Fox [1]	Mill Creek	Wooster [2]	Alexandria.
Crosby	Gentle	Medium to slow external; slow internal; *moist-dry.*	Crosby [1]	Randolph		Otis				Ravenna [2]	Bennington.
Bethel	Level	Slow external and internal; wet-dry.	Bethel [1]					Homer	Homer	Trumbull [2]	Condit.
Brookston	Level; depressed	Undrained externally; very slow internal; moist-wet.	Brookston [1]	Millsdale		Brookston	Brookston	Westland	Westland	Chippewa [2]	Marengo.
Clyde	do.	Undrained externally; very slow internal; always wet.	Clyde [1]					Abington	Abington		
Carlisle [3]	do.	Permanently saturated.	Carlisle muck.		Carlisle muck.	Carlisle muck.	Carlisle muck.	Carlisle muck.			

[1] These soils were sampled for analytical work for this study.
[2] There is still considerable doubt as to whether or not these soils belong in the families shown.
[3] Includes several kinds of muck not listed here.

TABLE 2.—*Taxonomic grouping of the soils shown in table 1* [1]

Category VI order	Category V suborder	Category IV great soil group	Category III family	Category II series	Category I type
Zonal soils	Light-colored podzolized soils of timbered regions.	Gray-Brown Podzolic soils	Miami	Miami	Miami silt loam.[2]
				Milton	Milton silt loam.
				Bellefontaine	Bellefontaine loam.
				Galena	Galena loam.
				Hillsdale	Hillsdale fine sandy loam.[3]
				Fox	Fox silt loam.[2]
				Mill Creek	Mill Creek silt loam.
				Wooster [3]	Wooster silt loam.[2]
				Alexandria	Alexandria silt loam.
Intrazonal soils	Hydromorphic soils of marshes, swamps, and alternately wet and dry flats.	Wiesenböden (meadow soils)	Clyde [4]	Clyde	Clyde silty clay.[2]
				Abington	Abington silty clay loam.
		Half-Bog soils	Brookston	Brookston	Brookston silty clay loam.[3]
				Westland	Westland silty clay loam.
				Chippewa [3]	Chippewa silty clay loam.
				Marengo	Marengo silty clay loam.
		Planosols	Crosby	Crosby	Crosby silt loam.[2]
				Otis	Otis silt loam.
				Ravenna [3]	Ravenna silt loam.
				Bennington	Bennington silt loam.
			Bethel	Bethel	Bethel silt loam.[2]
				Homer	Homer silt loam.
				Trumbull [3]	Trumbull silt loam.
				Condit	Condit silt loam.

[1] Azonal soils (Hennepin) not shown.
[2] These soils were sampled and analyzed.
[3] There is still considerable doubt as to whether these soils really belong in the families indicated.
[4] Clyde and Abington soils, as mapped, are partly transitional between Half-Bog soils and Wiesenböden.

COLLECTION OF SAMPLES

Much of the area where soils of the Miami family and Miami catena are common has been cleared and is now under cultivation, so that it is very difficult to obtain samples of truly virgin soils of the series that were studied in this work. Even most of the remaining wooded areas of these soils are pastured by cattle or hogs or both. The areas sampled, however, showed relatively little disturbance, and it is felt that the samples well represent the series. It would have been very desirable to have collected the members of the Miami catena in close geographic association, so as to be sure that the parent glacial till was essentially identical. This was not possible because satisfactory virgin areas of all the soils of the catena do not occur anywhere in close association—at least, the authors were not able to find such a place. As a consequence, the Crosby and Brookston soils are the only two members of the Miami catena that were collected in close proximity to each other. They came from the same wood lot in Grant County, Ind.

Description of Soils Sampled

All of the soils studied, but the Fox silt loam, are developed on weathered Wisconsin glacial till, and all of the till, but that under the Wooster silt loam, is either medium or strongly calcareous. The Wooster soil is developed on weather till that will not effervesce with cold dilute hydrochloric acid at a depth of 4 feet; but field studies elsewhere show that deeper horizons of the till under Wooster soils are slightly to medium calcareous. The Fox silt loam is developed on strongly calcareous outwash gravel deposits of Wisconsin age and of much the same lithological composition as that of the till under soils of the Miami catena.

Climatic conditions are similar over the entire area from which the soils were selected. Thornthwaite (*30*) has classified the climate as "humid microthermal with adequate precipitation at all seasons"; but all of the samples are from the warmer part of the microthermal region where the temperature efficiency index is greater than 48. The Miami and Bethel samples were taken only 35 miles north of Thornthwaite's boundary between microthermal and mesothermal climatic belts. The mean annual rainfall varies from 35 to 40 inches, and the mean annual temperature is about 50° F., although it is lower in northeastern Ohio and southern Michigan than in Grant, Wayne, and Randolph Counties, Ind.

In assigning letters to soil horizons, two systems were followed. In the light-colored soils, including both Gray-Brown Podzolic soils and Planosols, the relatively light-textured upper horizons were listed as A_1, A_2, etc., the heavier-textured subsoils were listed as B_1, B_2, etc., and the slightly altered parent rock (till or outwash) was called

[3] The samples were collected by the authors with the assistance of Dr. G. W. Conrey, Ohio State College and Agriculture Experiment Station; Prof. J. O. Veatch, Michigan State College Agriculture Experiment Station; and T. M. Bushnell, Indiana Agriculture Experiment Station.

C_1, C_2, etc. A_1 stands for the surface mineral soil that is usually thin but contains the highest percentage of organic matter of the profile. The A_2 is the horizon that has the appearance of being the most highly leached. The A_3 and B_1 horizons in every instance are transitional horizons between the A and B and are called A_3 or B_1 according to whether they have more characteristics in common with A or with B horizons. B_2 horizons usually comprise the main part of the heavy subsoil, but the percentage of clay in several instances is somewhat less than in the B_3 horizon, which marks the transition between the soil proper and the parent material.

The kind and sequence of horizons in the Half-Bog soils and Wiesenböden are so different in several respects from those of the light-colored soils that a different system of designation has been followed. The system used is that of the Indiana soil survey and was originated by T. M. Bushnell (*9*). The upper horizons to considerable depth are dark in color and high in humus and are designated as H_1, H_2, etc. The intermediate horizons are gray and mottled and are listed as M_1, M_2, etc., or "modified parent material." The unleached calcareous material beneath is indicated as U_1, U_2, etc., to signify "underlying material" that may or may not be "parent material." In view of the fact that one cannot always be sure that the underlying material of soils is like the material from which the soils were formed, it might be as well to think of most underlying materials as U horizons rather than as "parent material" horizons.

Following are brief descriptions of the soils that were sampled and of the landscapes where they occur.

MIAMI SILT LOAM

Location.—This soil was found in virgin forest known as Lewis' Woods, Wayne County, Indiana; Green Township, about 1 mile south of Williamsburg in NE¼SE¼ sec. 7, T. 17 N., R. 14 E. Soil erroneously included on map with Crosby silt loam, probably because the area is small.

Landscape.—Miami silt loam is here typically developed on a gentle convex slope near the edge of a small stream. It is covered by a thrifty hardwood forest dominantly of sugar maple, beech, and oak, with many other species of trees of less importance. Cleared areas nearby support prosperous general-farming enterprises.

Parent rock.—The soil is developed on Wisconsin glacial till of "till billow" relief, and composed of mixed rock flour and fragments of many different kinds of igneous and sedimentary rocks with a preponderance of limestone and dolomitic limestone. The limestone fragments have all been leached away to a depth of 3 feet in the place sampled. Locally, the depth of leaching varies from about 24 to almost 40 inches.

Drainage.—Drainage is good both externally and internally, although the moderately heavy B horizon and somewhat compact till prevent rapid downward movement of water.

Soil profile.—

Sample No.	Horizon	Description of horizons
C4060	A_1.	0 to 2 inches, very dark brownish-gray, soft fine granular or crumblike silt loam containing much organic matter that has been intimately mixed with the mineral soil by worms, insects, and small mammals. It is a true granular mull. Numerous rodent and mole burrows follow this horizon immediately beneath the thin mat of decaying dead leaves. Fibrous feeder roots of trees and underbrush are abundant. The color is much lighter when the soil is dry.
C4061	A_2.	2 to 5 inches, light brownish gray when moist, fading to very light brownish gray when dry, silt loam containing worm burrows filled with dark soil from the A_1 horizon. This horizon grades into those above and below with an inch or two of transitional material in each case. The soil is friable and of phylliform (thin platy) structure and breaks into thin, easily crushed flakes. There are many small roots and a few large ones, but the feeder roots are less abundant than in the A_1.
C4062	A_3.	5 to 11 inches, pale yellowish-brown or brownish-yellow, friable silt loam with faint streaks of light brownish gray from the horizon above. This breaks into easily crumbled plates about 1/16-inch thick. Feeder roots considerably less abundant than in A_1 and A_2. This grades almost imperceptibly into the next horizon.
C4063	B_1.	11 to 15 inches, light yellowish-brown, friable heavy loam breaking into plates about 1/16-inch thick in the upper part and into somewhat flattened subangular nuciform (nut-shaped) aggregates ¼ to ½ inch in diameter in the lower part. A few large and small roots pass through this horizon. There is a tendency for slight variegation in color owing to penetrations of lighter-colored material from above and to thin brown colloidal accumulations on the surfaces of the structural aggregates, especially in the lower part.
C4064	B_2.	15 to 30 inches, yellowish-brown clay loam breaking into small somewhat rounded granular and nuciform aggregates from ¼ to ¾ inch in diameter. The surfaces of the aggregates and the walls of root holes and cracks are coated with brown and dark-brown colloidal material, probably carried down from upper horizons. The boundary between this and the next horizon varies from clear to diffuse and occurs at variable depths.
C4065	B_3.	30 to 36 inches, dark-brown, rather sticky clay loam with a slightly reddish tint, breaking into angular blocky aggregates ½ to ¾ inch in diameter. The dark color is more or less concentrated in streaks and coatings, and the material is much lighter-colored when pulverized. The horizon contains many fragments of more or less disintegrated rock fragments. The boundary between the B_3 and C_1 is sharp but varies locally in depth.
C4066	C_1.	36 inches+, olive-gray glacial till of loam texture composed of a large percentage of limestone and dolomitic limestone fragments and a smaller percentage of other sedimentary and igneous rocks of highly diverse character. The till includes a rather high percentage of rock flour and some clay. Some of the larger tree roots extend well into this parent rock.

WOOSTER SILT LOAM

Location.—Wooster silt loam was found in a small patch of unpastured woods in the SE¼NE¼ sec. 19, T. 15, R. 13, Wooster Township, Wayne County, Ohio, on State Route No. 226.

Landscape.—The terrain is undulating to gently rolling till plain with prosperous farms and occasional patches of woodland. General farming, including dairying, is characteristic. Woodlands are of the oak-hickory type with much sugar maple, wild cherry, basswood, and various other trees.

Parent rock.—The soil is developed from glacial till composed largely of sandstone and shale fragments with minor quantities of various igneous and metamorphic rocks. Much of the till beneath Wooster soils contains a very small proportion of limestone fragments. Lime carbonate is usually leached to a depth of 6 to 10 feet.

Drainage.—Internal and external drainage are good but not excessive. The *B* horizon is sufficiently heavy to check downward water movement but not heavy enough to cause poor drainage.

Soil profile.—

Sample No.	*Horizon*	*Description of horizons*
C4025	A_1.	0 to 1 inch, very dark-gray silt loam with a loose and fluffy fine granular or crumb structure. A true granular mull, in the language of foresters. Covered by ½ inch of partly decayed leaf litter that was not sampled.
No sample	A_1.	1 to 3 inches, dark-gray, light and fluffy silt loam of fine granular or crumb structure—a transitional horizon.
C4026	A_2.	3 to 12 inches, light yellowish-brown silt loam (pale yellowish brown when dry) containing a fairly high proportion of course silt. It has a well-developed phylliform (leaflike) structure and breaks into thin flakes when lightly crushed in the hand.
No sample	A_3.	12 to 14 inches, transitional layer of light-brown heavy silt loam with fine streaks of very light-gray silt.
C4027	B_1.	14 to 20 inches, light-brown, friable, heavy loam with nuciform aggregates ¼ to ¾ inch in diameter and streaks of very light gray silt.
C4028	B_2.	20 to 30 inches, cloddy brown heavy loam breaking, with slight pressure, into subangular nuciform aggregates ¼ to ½ inch in diameter. Aggregates are firm enough to be handled without breaking when in a moist condition.
No sample	B_3.	30 to 32 inches, transition material. Rather compact.
C4029	$B_3$1.	32 to 38 inches, yellowish-olive, cloddy, somewhat compact clay loam breaking into rough 1-inch-thick plates. Dark-brown colloidal films on the clods. Very faintly mottled.
C4030	C_1.	38 to 48 inches +, light brownish-yellow, friable, leached gritty loam till, with faint mottlings and streaks of rusty brown. This comprises the weathered and leached glacial till composed of fragments of fine-grained sandstone with considerable shale and minor quantities of many other kinds of rocks.

HILLSDALE FINE SANDY LOAM

Location.—Hillsdale fine sandy loam is located in cut-over oak-hickory forest in the SE¼NE¼ sec. 34, T. 1 N., R. 2 W., in Ingham County, Mich. Nearest town is Onondaga.

Landscape.—This soil is developed on rolling morainic country, partly devoted to general farming and partly remaining in woods. Slopes vary from gentle to steep. The sample was taken from gently sloping hilltop.

Parent rock.—Glacial till containing a high percentage of sandstone fragments, considerable limestone, and various igneous and metamorphic rocks is the parent rock of this soil.

Drainage.—The drainage is good, both internally and externally, although the downward movement of water through the soil is checked by the B horizon. Crops sometimes suffer for lack of water during dry periods.

Soil profile.—Occasional boulders are scattered over the surface and through the solum. Although there are many small stone fragments throughout the profile, most of those in the upper horizons are more or less disintegrated and chemically weathered.

Sample No.	*Horizon*	*Description of horizons*
C4031	A_1	0 to 3 inches, dark brownish-gray fine sandy loam breaking to a weak compound structure of nuciform and granular aggregates. Lighter colored in lower part. The horizon is covered by a thin layer of partly decayed leaves.
C4032	A_2	3 to 9 inches, very pale yellowish-brown, fine sandy loam with a weakly developed phylliform structure. This grades into the next horizon without a clear line of demarcation.
C4033	A_3	9 to 13 inches, very light-gray, fine sandy loam, streaked with yellowish brown. It is characterized by a strongly platy structure and moderate compaction. There is a slight tendency toward cementation.
C4034	B_2	13 to 28 inches, firm, rich-brown, heavy fine sandy loam with light-gray streaks, and some blackish streaks and stains on surfaces of the nuciform aggregates that vary in diameter from ½ to ¾ inch. Friable and mealy when crushed in the hand.
C4035	B_3	28 to 50 inches, brown and friable—somewhat sticky when wet—heavy fine sandy loam with some black spots and jellylike colloids on surfaces of nuciform aggregates.
No sample		50 to 54 inches. Transition material.
C4036	C_1	54 to 72 inches +, light olive, moderately to strongly calcareous glacial till composed of a mixture of fine sandy loam, many sandstone fragments, a little limestone, and a scattering of many other kinds of rock fragments.

FOX SILT LOAM

Location.—This soil was found in second-growth wooded pasture (never cultivated) on a high terrace of West Fork of Whitewater River, Washington Township, Wayne County, Ind., NW¼NE¼ sec. 19, T. 15 N., R. 13 E.—3.6 miles southeast of Milton. The sample was taken from a freshly dug trench under trees where the surface was covered with leaf litter and there was little grass.

Landscape.—Fox soils are developed on flat, high, glacial-fluvial terraces in the area sampled. The flat surface is broken occasionally by small drains and by low escarpments between different terrace levels. Most of the land has been cleared and is used for wheat, corn, clover, timothy, and pasture grasses.

Parent rock.—Fox silt loam is developed on stratified and assorted gravels of approximately the same lithological composition as the till materials of the soils of the Miami catena; i. e., mixed gravels with a predominance of limestone and dolomitic limestone. Limestones have been leached away and most of the other rocks have been strongly decomposed to a depth averaging approximately 3 feet.

Drainage.—The open, porous gravel substrata of Fox silt loam provide rapid to very rapid drainage in spite of the nearly level surface. Crops, especially corn, frequently suffer for lack of moisture during droughty periods of late summer.

Soil profile.—

Sample No.	*Horizon*	*Description of horizons*
C4048	A_1	0 to 2 inches, very dark gray, soft, granular or crumblike silt loam mull, containing much decomposed organic matter. Permeated by fine roots of shrubs and trees. The transition to the next horizon is about ½-inch thick.

Sample No.	Horizon	Description of horizons
C4049	A_2.	2 to 10 inches, pale yellowish-brown silt loam, fading, when dry, to light yellowish gray. The material has a phylliform structure in the upper part and breaks into thin plates in the lower part where it is in gradual transition with the next horizon.
C4050	A_3.	10 to 18 inches, light yellowish-brown silt loam breaking into rough prisms in which the vertical axis is shorter than the diameter, which averages a little less than ½ inch. This grades into the next horizon.
C4051	B_2.	18 to 32 inches, bright yellowish-brown somewhat compact heavy loam or light clay loam containing many yellowish-gray gritty fragments and having a somewhat reddish tint. The soil breaks into subangular nuciform aggregates, varying from ¼ to ¾ inch in diameter. The transition to the next horizon is rather sharp, but the line of transition is at quite variable depths from the surface.
C4052	B_3.	32 to 38 inches, dark-brown, gritty and sticky silty clay with a slight reddish tint and an indistinct blocky structure. Contains many pebbles, more or less disintegrated and, although the reaction is approximately neutral, no limestone fragments remain. This rests abruptly on the stratified gravels beneath. The lower boundary of the horizon is very irregular in shape and narrow tongues extend to 4 or 5 feet deep in many places.
C4053	C_1.	38 to 60 inches, gray- and buff-colored, rounded, stratified, mixed gravels, including a high percentage of limestone and dolomitic limestone.

CROSBY SILT LOAM

Location.—Sample taken from lightly pastured wood lot in the southwest corner of the NE¼SE¼ sec. 19, T. 23 N., R. 8 E., Fairmount Township, Grant County, Ind. The wood lot is just northwest of the city of Fairmount and is the same as that from which the Brookston silty clay loam sample was taken.

Landscape.—Crosby silt loam is developed from gently undulating till plain with Crosby soils on the slight elevations and flats and with Brookston soils in the depressions. Miami silt loam occupies the more strongly convex undulations nearby. Most of the land is cleared and devoted to general farming with corn, hay, and wheat the principal crops. Native vegetation is composed chiefly of beech, maple, black walnut, and basswood trees.

Parent rock.—The soil is developed on moderately compact Wisconsin glacial till composed of mixed rock flour and fragments of many different kinds of sedimentary metamorphic and igneous rocks, including a large proportion of limestone and dolomitic limestone. It is leached of carbonates to depths varying from 24 to 40 inches.

Drainage.—The surface drainage is moderately slow, but effective, and internal drainage is slow. Upper horizons become very dry during droughty periods.

Soil profile.—

Sample No.	Horizon	Description of horizons
C4037	A_1.	0 to 2 inches, very dark-gray silt loam with some tendency to phylliform structure and with a high proportion of worm casts. The thin covering of decaying leaves was not sampled.
C4038	A_2.	2 to 11 inches, light-gray, strongly phylliform silt loam with many worm holes filled with dark-gray casts. Sharply defined boundary with next horizon.

Sample No.	Horizon	Description of horizons
C4039	B_2.	11 to 18 inches, nuciform aggregates of silty clay loam about ¾ inch to 1 inch in diameter. Surfaces of aggregates are gray and silty, and internal parts are dull brown. The brown color is more prominent in the lower part. Boundary with next horizon well defined.
C4040	B_3.	18 to 36 inches, mottled-brown, yellowish-brown, and dark-gray prismatic clay with gray and dark-brown colloids on surfaces of structure aggregates. The prisms are 1 to 2 inches in diameter, with the vertical axis longer than the diameter. The prisms break down into smaller blocky aggregates. The proportion of sticky colloid is greater in the lower part, and to this extent the lower part of the horizon is similar to the B_3 horizon of Miami silt loam. Irregular wavy boundary with next horizon.
C4041	C_1.	36 to 44 inches, gray, rusty-yellow, and brown-mottled, somewhat compact weathered till of silty clay-loam texture. Carbonate of lime is accumulated in streaks and grayish-brown, sticky colloidal material like that in the lower part of horizon B_3 lines a few crevices.
C4042	C_2.	44 to 60 inches +, light-gray and rust-mottled, very calcareous gritty till composed of rock flour, clay, and rock fragments of highly diverse composition, and including much limestone and dolomitic limestone.

BETHEL SILT LOAM

Location.—Sample taken from lightly pastured wooded area in the NE¼NW¼ sec. 11, T. 16 N., R. 13 E., 2½ miles south of Green Fork, Wayne County, Ind.

Landscape.—Bethel silt loam is here developed in beech woods with occasional sugar maple trees on flat upland till plain; microrelief, about 2 feet. Most of the Bethel soil has been left in wood lots or pasture. Surrounding areas of Crosby and Brookston soils are devoted to general farming.

Parent rock.—This soil is developed from Wisconsin glacial till, composed of mixed rock flour, clay, and fragments of many different kinds of igneous, metamorphic, and sedimentary rocks with a preponderance of limestone and dolomitic limestone. The limestone fragments are leached away to an average depth of about 30 inches.

Drainage.—External and internal drainage are both slow. The soil is temporarily waterlogged during wet periods and becomes excessively dry in the upper part of the solum during protracted periods of dry weather.

Soil profile.—

Sample No.	Horizon	Description of horizons
C4054	A_1.	0 to 2 inches, very dark-gray, friable, fine granular silt loam. Grades in A_2.
C4055	A_2.	2 to 8 inches, very pale-gray, friable silt loam with small rust spots and some fine dark-brown concretions. Phylliform structure well developed. Moderately sharp, wavy contact with next horizon.
C4056	A_3.	8 to 14 inches, friable to somewhat plastic heavy silt loam with light-gray and rust-brown color coarsely mottled in approximately equal proportions. Grades into next horizon.
C4057	B_2.	14 to 20 inches, dark-brown silty clay loam mottled with brown and with prismatic structural aggregates more or less coated with jellylike gray colloids. This grades into the next horizon.
C4058	B_3.	20 to 30 inches, rusty-brown and yellowish-brown, more or less blocky, stiff, silty clay loam with very dark-gray sticky colloids on structural aggregates.
C4059	C_1.	30 to 48 inches +, gray, rusty-yellow, and brown-mottled calcareous till of approximately a gravelly loam texture. More or less compact. Stone fragments are of great lithological variety but limestone and dolomitic limestone predominate. Temporary water table at 32 inches at time sample was taken (early July).

BROOKSTON SILTY CLAY LOAM

Location.—Brookston silty clay loam was found in lightly pastured wood lot in the southwest corner of the NE¼SE¼ sec. 19, T. 23 N., R. 8 E., Fairmount Township, Grant County, Ind., just northwest of Fairmount. Sample taken about 150 feet west of the Crosby silt loam sample.

Landscape.—The soil occurs in a depression on a gently undulating till plain in association with Crosby and Miami silt loams, the former greatly predominating. Most of the land is cleared and devoted to general farming. Native vegetation is composed chiefly of elm, basswood, and ash—a hardwood swamp-forest association.

Parent rock.—This soil is developed from moderately compact Wisconsin glacial till composed of mixed rock flour and fragments of many different kinds of sedimentary, metamorphic, and igneous rocks including a large proportion of limestone and dolomitic limestone.

Drainage.—Natural drainage is very slow. Water formerly stood at or near the surface during much of each year. Water table has been lowered by tile drains so that water now stands on the surface only after protracted wet periods.

Soil profile.—

Sample No.	*Horizon*	*Description of horizons*
C4043	H_1.	0 to 6 inches, very dark grayish-brown, mellow, medium-granular, light silty clay loam, the aggregates of which are strong enough to be freely handled. Covering decayed leaves not sampled. Abrupt smooth boundary with the next horizon.
C4044	H_2.	6 to 20 inches, very dark brownish-gray, plastic silty clay loam breaking into firm coarse granular aggregates. Diffused irregular boundary.
C4045	H_3.	20 to 34 inches, dark-gray plastic silty clay breaking into angular blocky aggregates ¼ to ½ inch in diameter. Boundary with next horizon is irregular and broken.
C4046	M.	34 to 44 inches, mottled yellowish-gray, gray and dull-brown plastic silty clay loam with coarse block structure. Water table at time of sampling was about 42 inches below the surface. This is approximately the level of the nearby tile drain.
C4047	U.	44 to 85 inches+, dull-gray rusty-yellow mottled, somewhat compact clay loam till composed of rock flour, clay, and fragments of many kinds of rocks. Material is strongly calcareous and the coarser fragments include a large proportion of limestone and dolomitic limestone.

CLYDE SILTY CLAY

Location.—This soil was found in the SW¼NW¼ sec. 5, T. 17 N., R. 15 E., about 6 miles southeast of Winchester and 1¾ miles northwest of Bartonia, Randolph County, Ind.

Landscape.—Clyde silty clay occurs in very poorly drained depressions in an undulating upland till plain. Sample was taken from a swampy area at the end of a permanent pond. Vegetation consists of sedges, rushes, grasses, and elm trees. Land is in pasture. Hardwoods probably covered all but the wettest parts under virgin conditions. Nearby, Crosby, Brookston, and Bethel soil are mostly cleared and used for general farming.

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Parent rock.—This soil is developed on Wisconsin glacial till, composed of mixed rock flour, clay, and fragments of many different kinds of rock among which limestone and dolomitic limestones are most important. In the place sampled the parent material was saturated with water. It is leached of carbonates to depths varying from 48 to 72 inches.

Drainage.—Internal drainage is very poor and water stands on the surface during much of each year.

Soil profile.—

Sample No.	*Horizon*	*Description of horizons*
C4067	H_1.	0 to 8 inches, black coarse granular silty clay with strong aggregates. Sharp transition. Water table at surface.
C4068	H_2.	8 to 20 inches, black silty clay which falls apart readily into sharply angular blocky aggregates and prisms that can be handled roughly without breakage. These aggregates vary from about ¼ to ½ inch to about ½ to ¾ inch. They are not definitely oriented. Plastic when pressed in the fingers. Gradual transition.
C4069	H_3.	20 to 26 inches, dark-gray, plastic silty clay with some rust mottling. Breaks into prisms about ½ by 1 inch in thickness and length, respectively. Gradual transition.
C4070	M_1.	26 to 38 inches, gray, plastic silty clay, somewhat streaked and mottled with rusty brown. Breaks into prisms about ¾ by 1 or 1¼ inches. Gradual transition.
C4071	M_2.	38 to 66 inches, gray silty clay loam of blocky structure, mottled with yellowish rust. Sharp wavy transition.
C4072	U.	66 to 75 inches +, calcareous glacial till composed of rock flour, clay, and stone fragments of many kinds. The horizon is more or less mottled with rust and yellow because of poor drainage. It was not practicable to sample the unweathered till, because water ran into the excavation faster than it could be removed.

METHODS OF EXAMINATION

The methods used in the laboratory examination of the soil samples are essentially those in general use in this Bureau. Detailed descriptions of each may be found in the publications cited later.

The soils were received in a lumpy, partially dried condition. When air-dried, each sample weighed 10 to 15 pounds.

In the preparation of the soil samples for analysis, the air-dried samples were crushed to 1-inch, or smaller, lumps, thoroughly rolled, mixed, quartered, and separated into two parts. One-half was stored in glass jars. The other half was reduced to about 100 gm. by crushing and quartering until most of the particles did not extend 2 millimeters in diameter. The reject was saved for colloid separation. The sample was further rolled and quartered to about 20 gm. and passed through a 2-mm. sieve and ground to 100 mesh for chemical analysis. The unground residue was saved for pH determination and mechanical analyses.

The mechanical analyses were made by the pipette method described by Olmstead, Alexander, and Middleton (*25*). The pH values were determined by the hydrogen-electrode method as described by Bailey (*2*).

The chemical analyses of both soil and colloid were made according to the procedure outlined by Robinson (*27*). The organic matter was determined by the combustion method.

The colloids were extracted from the soils by means of a supercentrifuge essentially as described by Brown and Byers (*4*). No dispersion agent was used. The colloid from sufficient soil was dispersed in about 3 gallons of distilled water by a mechanical stirrer described by Holmes and Edgington (*17*). The suspension was decanted into about 7 gallons of water and centrifuged at a rate of 17 seconds per liter at a speed of 17,000 revolutions per minute (bowl diameter, 4 inches). The colloid still in suspension was dewatered by means of Pasteur-Chamberland filters and the filtrate used again to effect dispersion of the sediment from the bowl. The process was repeated 3 to 6 times until an adequate amount of colloid was collected. Very few of the discreet particles exceed 0.3μ in diameter. The final product was dried on a steam bath.

The data are presented in tables with a brief discussion of each table. Certain derived data have been segregated. In these magnesium, calcium, potassium, and sodium oxides only are segregated and referred to as bases, because of their particular significance in soil development.

In the discussion, various constituents are conveniently referred to as elements or as oxides as they are recorded in the tables, although they may more often occur in the soils as silicates, humates, and other compounds. Soluble silica occurs as silicates, not as quartz; iron oxide is presumably hydrated, and its state of oxidation is uncertain and probably varies considerably from one soil to another; other combinations of these and of other constituents of the component parts of the soil admittedly are not known precisely. This is particularly true of the organic matter.

None of the averages recorded in the tables is weighted for thickness, as the variations in composition are usually small, and simple calculations appear to disclose the relationships as well as those that are more complex.

ANALYTICAL RESULTS

Mechanical Analyses of the Soils

Mechanical analyses (table 3) of the members of the Miami family and of the Miami catena that were sampled bring out certain interesting facts regarding the mechanical composition of the soils. It will be noted that the textures of the parent materials of all of the soils except Fox silt loam and the Hillsdale fine sandy loam are comparable in clay content even though they are not exactly the same. The content of clay in the Hillsdale parent material is not as low as that of the Fox soil. This is because the Hillsdale parent material is a slightly clayey till whereas the parent material of the Fox soil is stratified gravel and sand in which the content of limestone is quite high. In spite of the very gravelly underlying material of the Fox, the soil profile is strongly developed and is comparable to the other members of the family. The parent material of the Bethel silt loam contains more clay than the Hillsdale and Fox, but it contains considerably less than the parent material of the Miami silt loam, which was sampled only a few miles away. Local differences in textures of glacial till are the rule rather than the exception so that this fact is not surprising.

TABLE 3.—*Mechanical analyses* [1] *of some soils of the Miami family and of the Miami catena*

Sample No.	Horizon	Depth	Gravel +2 mm.[2]	Fine gravel 2-1 mm.	Coarse sand 1-0.5 mm.	Medium sand 0.5-0.25 mm.	Fine sand 0.25-0.1 mm.	Very fine sand 0.1-0.05 mm.	Silt 0.05-0.002 mm.	Clay 0.002-0 mm.	Clay 0.005-0 mm.	Clay ratio $\frac{0.002}{0.005}\times 100$	Organic matter from H_2O_2	pH [3]	Iron oxide concretions [4]
MIAMI SILT LOAM															
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Percent*		*Percent*
C4060	A_1	0-2	----------	1.1	3.7	5.2	11.7	6.2	50.1	15.9	23.6	67	5.7	6.3	2
C4061	A_2	2-5	----------	1.2	3.8	5.7	12.6	6.7	50.9	15.5	23.0	65	3.3	5.9	2
C4062	A_3	5-11	----------	1.3	3.8	5.7	12.7	7.1	51.1	16.4	25.0	66	1.7	5.5	2
C4063	B_1	11-15	----------	1.7	3.9	5.4	12.3	6.8	45.9	22.7	30.8	74	1.1	5.5	2
C4064	B_2	15-30	10	1.9	5.1	6.5	12.5	7.4	28.9	36.9	42.9	86	.6	5.2	2
C4065	B_3	30-36	<10	3.2	5.9	6.5	13.0	7.4	25.7	37.4	42.6	88	.1	6.4	4
C4066	C_1	36+	10	4.3	6.7	6.5	13.6	9.9	37.1	21.3	27.0	77	.3	7.6	3
WOOSTER SILT LOAM [5]															
C4025	A_1	0-1	----------	0.4	0.6	0.5	1.5	3.7	54.9	9.9	17.9	55	27.2	6.1	3
C4026	A_2	3-12	5	.7	1.2	1.1	2.6	5.6	74.8	13.0	21.8	60	.7	4.4	3
C4027	B_1	14-20	<5	.9	1.1	1.1	2.7	6.0	67.8	19.8	28.3	70	.4	4.4	2
C4028	B_2	20-30	----------	.6	1.0	.9	2.2	4.8	66.0	24.1	33.7	71	.3	4.7	5
C4029	B_3	32-38	<10	.3	4.7	4.1	10.5	12.1	42.9	22.5	28.4	79	.1	4.7	10
C4030	C_1	38-48	10	3.5	5.3	5.4	13.0	14.0	40.2	18.4	24.2	76	.1	4.8	10
HILLSDALE FINE SANDY LOAM															
C4031	A_1	0-3	----------	1.0	5.3	14.0	27.3	11.5	29.5	7.5	12.5	60	3.4	5.5	1
C4032	A_2	3-9	<10	1.4	5.4	13.2	28.9	12.2	30.8	7.5	12.5	60	.4	4.6	1
C4033	A_3	9-13	<5	2.0	5.4	13.2	29.1	13.1	29.7	7.0	12.5	56	.3	5.1	1
C4034	B_2	13-28	----------	1.0	4.4	10.8	28.2	16.5	24.9	13.9	18.4	75	.1	5.0	1
C4035	B_3	28-50	<5	1.0	3.7	9.4	26.7	16.9	23.0	19.0	22.8	83	0	5.4	1
C4036	C_1	54-72	----------	1.3	4.4	10.8	26.4	18.2	27.9	10.8	14.3	76	.1	8.0	1
FOX SILT LOAM															
C4048	A_1	0-2	<10	0.6	3.0	5.8	10.9	4.7	51.5	12.7	20.8	61	9.6	6.6	2
C4049	A_2	2-10	----------	.3	3.2	5.9	11.4	5.2	55.9	16.0	23.0	70	1.7	5.4	2
C4050	A_3	10-18	----------	.4	3.1	5.9	11.3	4.8	58.5	14.9	25.0	60	.9	4.6	2
C4051	B_2	18-32	<10	1.4	6.6	11.7	22.8	7.8	21.0	28.3	32.6	87	.3	4.6	1
C4052	B_3	32-38	15	6.9	11.8	5.8	6.8	3.3	17.7	47.1	52.1	90	.4	6.7	10
C4053	C_1	38-60	70	22.0	40.8	19.5	7.5	1.1	6.1	2.9	3.4	85	0	8.1	5

CROSBY SILT LOAM

C4037	A_1	0-2	----------	0.5	1.5	1.8	5.4	4.5	60.1	16.4	25.1	65	8.9	6.6	10
C4038	A_2	2-11	----------	.5	1.2	1.9	5.6	4.7	66.3	17.8	28.1	64	1.8	5.9	20
C4039	B_2	11-18	----------	.1	.5	.8	2.7	2.9	57.1	35.0	44.4	79	.8	5.3	30
C4040	B_3	18-36	----------	.7	1.3	2.7	9.8	9.5	40.0	35.7	42.2	85	.1	6.4	20
C4041	C_1	36-44	<10	1.0	2.4	3.1	8.5	8.5	43.0	33.3	43.3	77	0	7.6	10
C4042	C_2	44-60+	<10	1.7	3.0	3.0	8.3	8.7	50.1	25.0	35.5	70	0	7.9	2

BETHEL SILT LOAM

C4054	A_1	0-2	----------	1.1	2.4	2.6	5.3	3.5	64.2	14.2	23.3	61	6.2	5.5	15
C4055	A_2	2-8	----------	2.0	3.0	2.7	5.7	3.9	67.3	13.4	22.5	60	1.8	5.3	40
C4056	A_3	8-14	----------	1.7	3.0	2.4	4.5	3.3	64.5	19.8	29.1	68	.6	5.5	60
C4057	B_2	14-20	----------	.2	1.4	1.7	3.8	2.9	49.7	39.4	46.3	85	.6	5.9	5
C4058	B_3	20-30	----------	.8	2.2	3.4	8.3	5.8	41.1	37.8	43.7	86	.4	7.1	20
C4059	C_1	30-48+	36	4.9	6.7	6.0	13.4	10.8	41.4	16.3	21.9	74	.3	7.8	5

BROOKSTON SILTY CLAY LOAM

C4043	[6] H_1	0-6	<10	0.5	1.4	2.0	5.3	4.5	52.0	24.3	33.8	72	9.4	6.8	10
C4044	[6] H_2	6-20	<10	.9	1.6	1.9	5.3	4.5	54.4	29.2	40.2	73	1.9	6.4	15
C4045	[6] H_3	20-34	<10	.9	1.4	1.6	4.6	3.9	50.2	36.5	44.9	81	.6	6.8	20
C4046	[6] M	34-44	<10	.9	1.7	2.3	6.3	5.3	47.6	35.9	46.3	78	0	7.2	60
C4047	[6] U	44-85	<10	1.7	3.0	3.4	9.1	7.9	46.1	28.6	38.4	74	0	7.8	40

CLYDE SILTY CLAY

C4067	[6] H_1	0-8	----------	0.9	1.1	1.4	4.2	3.7	31.1	41.2	49.1	84	12.9	6.4	5
C4068	[6] H_2	8-20	----------	.4	1.2	1.5	4.6	3.9	38.2	46.2	54.4	85	3.6	6.9	5
C4069	[6] H_3	20-26	----------	.4	1.1	1.6	4.8	4.2	40.1	46.1	54.5	85	1.3	7.2	5
C4070	[6] M_1	26-38	----------	.5	1.3	1.8	5.4	4.4	43.6	41.9	50.6	83	.8	7.2	10
C4071	[6] M_2	38-66	----------	.8	2.0	2.8	8.6	7.5	40.7	36.9	47.5	78	.4	7.1	10
C4072	[6] U	66-75	25	4.0	4.6	4.1	9.9	8.9	45.0	23.0	31.5	73	.2	8.0	5

[1] Analyses by E. F. Miles and F. N. Ward.
[2] Not included in total percentage of mechanical analysis; small percentages not recorded.
[3] Determined by E. H. Bailey.
[4] Estimated percentage of iron oxide concretions in the sand and fine gravel fractions.
[5] Wooster soils only tentatively listed in the Miami family.
[6] Horizon designations used by the Indiana Soil Survey; see p. 11.

The B horizons of all of the soils of the Miami family examined are more clayey than the A or C horizons, although the differences in clay content between the B and C horizons of the Wooster and Hillsdale soils are not as great as those of the Miami and Fox. The most marked textural B horizons are in the Crosby and Bethel soils, which belong to the Planosol group, and in the B_3 of the Fox soil, which is a true Gray-Brown Podzolic soil. In spite of the fact that the B_3 horizon of the Fox has an unusually high clay content, the physical properties of this horizon are such that the clay does not interfere seriously with the movement of water except when it is temporarily saturated. In fact, the crops grown on Fox soils are likely to suffer from drought in late summer.

The textural differences between the A and B horizons in the Planosols (Crosby and Bethel silt loam) are much more marked and more abrupt than in the normal Gray-Brown Podzolic soils. It will be noted in the Crosby soil that no transitional horizon was sampled because of the very abrupt change from A to B; and the B_2 horizon has almost twice as much clay as the A_2 horizon just above it. The A_3 horizon in the Bethel has about half again as much clay as the A_2, but the B_2 horizon immediately beneath it contains about twice as much clay.

The B_3 horizon is usually considered to be a transition between the true B horizon and the C horizon, although the data of the mechanical analyses do not bear this out entirely. The pH figures for the B_3 horizons of the Miami, Fox, Crosby, and Bethel soils are markedly higher than for the B_2 horizons just above them and in most of these soils the reaction is only slightly acid or neutral. In this sense, certainly, the B_3 horizon is transitional.

Another feature evident in the Miami, Fox, Crosby, and Bethel soils is the tendency for the sands and, in most of the profiles, for the proportion of fine gravel to increase sharply in the B_3 horizon as compared to horizons above it. In some instances the change takes place between other horizons of the subsoil. The usual explanation is that the soil material of the B_3 horizon is much less weathered than the material above. Whether this explanation is completely true to the facts cannot be proved at this time, but it is noticeable that the percentage of silt in upper horizons of the Miami, Wooster, Fox, Crosby, Bethel, and Brookston soils is high and that the percentage of sands, especially of the medium and coarse sands, is fairly low.

There is some evidence to indicate that a part of the silty and sandy material in the upper parts of many soils in or near the glaciated area was originally deposited by the wind. The presence of even a small proportion of fine gravel in the A horizons may be cited as evidence that the material is not loess. This explanation is, however, unreliable. The coarse particles of the Crosby, Bethel, and Brookston soils and, to a lesser extent, of the Miami, Wooster, Fox, and Clyde soils consist partly of dark-brown concretions of iron and manganese oxides. These undoubtedly formed in place at the same time the soils were developed. It is certain, however, that part of the coarse fraction is composed of quartz and other primary minerals that were undoubtedly a part of the original deposit. The quantities of coarse primary minerals, however, are not more than could have been carried to the A horizon by burrowing animals.

The last column in table 3 gives rough estimates of the percentage of brown concretions in the sand and fine gravel fractions of all of the soils. A large proportion of these concretions fall in the coarse sand and fine gravel fractions, especially in the light-colored soils.

Bryan (*8*) has emphasized the importance of the mixing of upper horizons of soil material through freezing and thawing soon after the glacial till and outwash materials were deposited; and he supposes that many of the coarser particles could be mixed, by this means, with a superficial coating or layer of loess. Mechanical analyses alone are not sufficient to solve this problem, but the soil scientist should bear in mind the possibility that part of the soil material might be the result of wind action rather than of simple glacial or alluvial deposition.

The usual explanation for the high percentage of silt in upper horizons of soils of the Gray-Brown Podzolic region is that silt is the product of weathering in situ; but where there is as sharp a break between the silt content of the B_1 and B_2 horizons as in the profile of Miami silt loam presented herewith, one may well recognize the possibility that some loess may have been deposited following the retreat of the Wisconsin ice. The possibility is even more plausible if one recalls that a fair share of the coarser separates are concretions that have formed in the soil.

It will be noted that the B_3 of the Wooster silt loam has a pH of 4.7 and that the C_1 has a reaction only 0.1 pH higher. The low pH of the B_3 and C_1 horizons needs some explanation. This profile is in marked contrast to the other three members of the Miami family reported here and suggests that the Wooster silt loam may belong in a different family. Furthermore, the A_2 horizon has the highest percentage of silt of any of the soils sampled. It is possible that the high silt content of the upper parts of the Wooster silt loam may be due to an accumulation of loess, but it is not less probable that the silt in the Wooster soils is supplied from disintegrating very fine-grained sandstones and siltstones, which are so abundant in the glacial till.

In most places where the till is deep it contains enough limestone particles to effervesce with cold dilute hydrochloric acid, but the percentage of limestone is usually low. In other places it has been noted that the lime carbonate of Wooster parent materials has often been leached to a depth of from 6 to perhaps 10 feet; and in places where the till is less than 5 or 6 feet deep no limestone is likely to be found in the till. Under conditions such as these the C horizon of the soil, according to the terminology of the Division of Soil Survey, is the weathered parent material beneath the B horizon, and if this parent material is leached of lime, the B_3 horizon will not have a notably higher pH than the horizon above it, as do the B_3 horizons of the Miami, Fox, Crosby, and Bethel soils. It was not practicable to sample the soil to a depth greater than 4 feet, and so it is not known whether a calcareous parent material and a darker-colored B_3-like horizon just above it occurs there or not. It is certain, however, that the Wooster silt loam observed in other areas has a dark-colored horizon beneath the so-called C_1 horizon and above the slightly calcareous glacial till, and this dark-colored horizon has a considerably higher pH than the material above it. It is evident that the system of nomenclature of horizons followed in this text is not entirely satisfactory for soils of this kind. According to the Indiana system (*9*), the C_1 horizon of Wooster silt loam would be called a Y horizon.

In all the light-colored soils except the Bethel and Wooster silt loams the quantities of clay and fine gravel are greater and the quantities of silt are less in the B_3 horizons than in horizons above. Morphological evidence indicates that this is caused by the greater weathering in horizons above the B_3, and the greater quantity of clay in the B_3 horizons is due quite largely to illuviation. Much of the clay in the B_3 horizons of all the light-colored soils except the Wooster silt loam is in the form of films of colloid on the surfaces of soil aggregates and in root holes and insect and worm burrows. Most of this colloid is dark-colored. Apparently it contains more organic matter than other parts of the soil, although the two parts were not studied separately or the organic matter in them determined separately. The accumulation of dark-colored colloid in B_3 horizons is very characteristic of soils developed from calcareous glacial till and outwash.

The clay content of the B horizons of the light-colored soils seems almost certainly to be only partly the result of illuviation, although it is evident that this process has been a factor in the formation of the B horizons. The portion of the colloid that occurs on the surfaces of structural aggregates appears to be illuvial in origin, but the colloid in the interiors of the aggregates may be largely the result of hydrolytic weathering of clay-forming minerals in place. Nikiforoff (*24*) stresses the importance of this process in desert soils. If it is active in the desert, the process probably is even more active in humid regions. No studies have been made to determine the proportion of clay in the B horizons that can be assigned to each of the causes outlined.

Column 13 of table 3 shows the ratio of the clay less than 2μ size to that less than 5μ. This ratio shows that the smaller particles or more colloidal portion of the clay is concentrated in the B horizons and especially so in the B_3 horizons of most of the soils, where the colloidal films on the surfaces of aggregates are most noticeable. Even in the C_1 horizons the soil morphology indicates that part of the colloids are illuvial and represent extensions of the B_3 horizon in the form of colloidal films in root holes and along joint planes.

One of the interesting features of the mechanical analyses of the Brookston silty clay loam is that horizons 3 and 4 are very considerably higher in clay than horizons 1, 2, and 5. This difference is somewhat less evident if the less-than-5μ fraction be considered clay. An examination of several other mechanical analyses of Brookston soils in the Bureau files shows that it is not uncommon to find that the textures of subsoils of Brookston silty clay loam are heavier than those of the surface soils and the underlying material. Why this is so has not been explained, but it is apparent in the clay ratios that the finer particles of clay have contributed largely to the accumulation in these two layers. It has been assumed by many soil scientists that the approximately neutral reaction and concentration of calcium ion in the Brookston soils would prevent eluviation and illuviation from taking place. Numerous analyses of profiles of alkaline, neutral, and acid reactions, both with and without appreciable quantities of calcium carbonate in the zone of illuviation, indicate that a part of the clay, particularly the finest portion, certainly is more abundant in the midportion of the profiles than in other parts. Such analyses may be found in Technical Bulletins 399 (*7*), 502 (*5*), 609 (*6*), and elsewhere. The mechanical analysis does not settle the question. It is quite possible, however, that the greater part of the difference in clay content in different horizons may be due to differences in the rate of hydrolytic weathering of clay-forming minerals in this part of the profile.

An apparent concentration of clay between 8 and 26 inches in the Clyde silty clay profile seems to correspond somewhat to the concentration of clay in the subsoil of Brookston silty clay loam, but it is not marked and disappears entirely if a correction is made for organic matter.

Chemical Analyses of the Soils

Table 4 gives the chemical analyses of all the soil profiles. These analyses make it apparent that there is considerable variation in the character of the parent materials of the different soils.

The high silica content of the parent materials of Wooster silt loam and the Hillsdale fine sandy loam is a reflection of the low proportion of calcium and magnesium carbonates in the glacial tills of these two soils. If allowance is made for the difference in carbonate content, the silica content of all of the soils would be at least closely comparable even though it were not exactly the same. The high silica content of all A_2 and A_3 horizons in the light-colored soils is an indication of the podzolization that has taken place in them.

It is of some interest to note that there is some concentration of iron in the subsoils of all of the soils studied, including the imperfectly drained Planosols (Crosby and Bethel) and the poorly drained dark-colored Half-Bog (Brookston silty clay loam) and Wiesenböden (Clyde silty clay). This concentration of iron in the subsoils of the light-colored soils is what is usually expected in podzolic profiles, but it has not been mentioned frequently in connection with Half-Bog soils. Studies to sufficient depth in the profiles of Half-Bog and other poorly drained soils (*31, pp. 357–401*) indicate that accumulations of rust stains and even of iron concretions are a common phenomenon in these soils, so that it is not surprising that concentrations of iron were found in the profiles of the Brookston and Clyde soils.

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TABLE 4.—*Chemical analyses of some soils of the Miami family and of the Miami catena*

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [2,3]	CO_2 [3,4]	N [3]
MIAMI SILT LOAM [1]																		
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
C4060	A_1	0–2	74.00	3.28	8.39	0.84	0.90	1.83	0.90	0.83	0.13	0.35	0.23	8.32	100.00	6.22	0.03	0.28
C4061	A_2	2–5	77.81	2.90	9.18	.83	.54	1.99	1.06	.68	.14	.09	.09	5.28	100.59	3.60	.13	.20
C4062	A_3	5–11	78.45	3.25	9.57	.80	.70	1.97	1.18	.68	.13	.08	.07	3.70	100.58	1.95	.09	.11
C4063	B_1	11–15	76.10	4.05	11.01	1.00	.60	2.05	1.05	.71	.12	.08	.07	3.56	100.40	1.37	.21	.08
C4064	B_2	15–30	69.80	6.23	14.23	1.42	.62	1.75	.68	.62	.11	.07	.07	4.28	99.88	.99	.11	.05
C4065	B_3	30–36	69.00	6.32	13.99	1.63	.98	2.28	1.00	.59	.12	.14	.09	4.36	100.50	1.11	.16	.07
C4066	C_1	36+	53.66	4.52	9.99	5.79	8.99	1.93	.74	.46	.09	.09	.09	13.99	100.34	.99	[1]11.28	.03
WOOSTER SILT LOAM [5]																		
C4025	A_1	0–1	50.58	2.70	6.86	1.86	2.60	1.26	0.79	0.61	0.27	0.34	0.46	31.95	100.28	30.30	0.27	0.93
C4026	A_2	3–12	77.15	3.56	9.02	1.70	.85	1.81	1.27	.88	.14	.16	.18	3.16	99.88	1.50	.03	.07
C4027	B_1	14–20	74.35	4.86	11.56	2.29	.60	2.02	1.01	.85	.08	.16	.20	3.09	100.07	.68	Trace	.04
C4028	B_2	20–30	70.44	5.78	12.70	2.53	.69	2.08	1.32	.85	.09	.13	.18	3.72	100.51	.61	Trace	.04
C4029	B_3	32–35	71.50	6.50	11.44	2.58	.81	2.11	1.01	.82	.10	.15	.22	3.30	100.54	.39	.04	.03
C4030	C_1	38–48	73.14	6.40	10.74	2.27	.75	1.97	1.12	.74	.11	.14	.14	2.93	100.45	.51	.03	.04
HILLSDALE FINE SANDY LOAM																		
C4031	A_1	0–3	81.94	2.58	5.70	0.64	1.66	1.39	1.12	0.35	0.09	0.08	0.11	4.87	100.53	4.28	0.10	0.18
C4032	A_2	3–9	84.12	3.06	6.74	.54	1.41	1.49	1.18	.35	.06	.05	.08	1.48	100.56	.72	.08	.04
C4033	A_3	9–13	84.59	3.06	6.42	.64	1.55	1.40	1.02	.35	.04	.05	.08	1.23	100.43	.43	.04	.03
C4034	B_2	13–28	81.41	3.71	7.87	.72	1.25	1.76	1.33	.40	.04	.06	.13	1.72	100.40	.30	.06	.02
C4035	B_3	28–50	78.22	4.68	9.47	.85	1.25	1.89	1.49	.40	.05	.08	.06	2.11	100.55	.30	.05	.04
C4036	C_1	54–72	74.32	3.78	7.37	1.98	4.42	1.62	1.18	.32	.05	.06	.08	5.40	100.58	.25	4.18	.02
FOX SILT LOAM																		
C4048	A_1	0–2	69.01	2.87	7.77	0.64	1.25	1.80	0.76	0.62	0.17	0.16	0.08	14.56	99.69	12.27	0.60	0.39
C4049	A_2	2–10	78.80	3.51	8.79	.60	.38	1.93	.92	.70	.15	.13	.02	3.60	99.53	2.31	.06	.14
C4050	A_3	10–18	79.38	3.44	9.24	.58	.26	1.95	.87	.70	.14	.11	.02	2.91	99.60	1.03	.02	.07
C4051	B_2	18–32	73.49	5.69	12.45	1.03	.41	1.86	.92	.70	.09	.11	.01	3.44	100.20	.35	.28	.04
C4052	B_3	32–38	62.91	8.25	16.22	2.00	1.06	2.11	.76	.61	.19	.18	.02	5.90	100.21	1.10	.75	.07
C4053	C_1	38–60	41.34	2.38	4.56	8.17	17.86	.90	1.48	.20	.09	.06	.02	22.78	99.84	.35	22.51	.01

CROSBY SILT LOAM[1]

C4037	A_1	0-2	69.96	3.09	8.87	0.62	1.34	1.91	0.94	0.65	0.11	0.13	0.15	12.39	100.16	10.42	0.30	0.47
C4038	A_2	2-11	77.93	3.21	9.64	.63	.68	2.11	1.06	.78	.11	.07	.05	3.98	100.25	2.33	.04	.14
C4039	B_2	11-18	72.12	4.95	13.34	1.11	.63	2.16	.75	.77	.06	.02	.05	4.18	100.14	.84	.17	.08
C4040	B_3	18-36	68.79	5.88	14.35	1.36	1.10	2.48	.99	.64	.10	.11	.03	4.16	99.99	.69	.16	.07
C4041	C_1	36-44	62.56	5.44	12.97	2.90	4.23	2.58	.91	.62	.10	.12	.03	7.64	100.10	.28	[1] 4.20	.06
C4042	C_2	44-60+	46.94	3.95	9.36	5.02	14.06	2.06	.70	.46	.08	.09	.04	17.07	99.83	.80	[1] 14.95	.04

BETHEL SILT LOAM

C4054	A_1	0-2	75.60	3.18	8.39	0.50	0.69	1.35	0.64	0.61	0.08	0.10	0.10	8.44	99.68	6.21	0.22	0.30
C4055	A_2	2-8	80.50	2.93	8.61	.48	.59	1.24	.54	.68	.10	.08	.05	3.88	99.68	2.14	.04	.12
C4056	B_1	8-14	78.52	3.89	10.31	.62	.53	1.45	.69	.65	.12	.06	.04	3.11	100.09	.89	.04	.05
C4057	B_2	14-20	69.80	6.00	14.17	1.27	.82	1.66	.69	.73	.17	.05	.03	4.58	99.97	.81	.18	.07
C4058	B_3	20-30	69.30	5.79	14.83	1.49	1.20	1.82	.81	.52	.11	.07	.02	4.62	100.58	.67	.21	.06
C4059	C_1	30-48+	41.15	3.02	8.80	8.01	15.70	1.53	.41	.36	.07	.09	.06	21.62	100.82	.79	19.53	.03

BROOKSTON SILT LOAM[1]

C4043	[6] H_1	0-6	64.11	4.02	11.08	1.12	1.85	2.23	0.99	0.68	0.08	0.20	0.19	13.68	100.23	10.42	0.49	0.36
C4044	[6] H_2	6-20	69.76	4.82	12.65	1.20	1.27	2.46	1.11	.72	.11	.14	.08	6.00	100.32	2.67	.08	.16
C4045	[6] H_3	20-34	69.68	5.13	13.70	1.35	1.12	2.46	.86	.74	.07	.10	.05	4.79	100.05	1.52	.21	.08
C4046	[6] M	34-44	68.88	5.80	14.20	1.48	1.05	2.90	.92	.71	.15	.13	.06	4.07	100.35	.79	.08	.07
C4047	[6] U	44-85	54.23	4.81	11.19	3.80	9.33	2.50	.85	.53	.10	.10	.09	12.49	100.02	1.84	[1] 9.54	.06

CLYDE SILTY CLAY[1]

C4067	[6] H_1	0-8	56.43	3.66	14.05	1.53	1.78	2.35	0.85	0.61	0.03	0.30	0.27	18.57	100.43	12.94	0	0.72
C4068	[6] H_2	8-20	63.66	4.78	15.84	1.65	1.36	2.46	.73	.67	.06	.21	.10	8.79	100.31	4.51	0	.25
C4069	[6] H_3	20-26	66.47	5.12	15.52	1.61	1.18	2.47	.83	.71	.06	.19	.07	6.24	100.47	2.16	0	.14
C4070	[6] M_1	26-38	69.25	4.80	14.84	1.47	1.10	2.54	.85	.67	.06	.15	.05	4.76	100.54	1.10	0	.07
C4071	[6] M_2	38-66	67.39	6.13	14.27	1.71	1.22	2.99	1.08	.70	.07	.21	.06	4.56	100.39	1.15	.35	.07
C4072	[6] U	66-75	41.84	3.42	8.64	7.51	14.78	1.83	.67	.41	.08	.10	.09	20.74	100.11	1.23	17.72	.03

[1] Analyses made by Glen Edgington, except No. C4060.
[2] Combustion method ($CO_2 \times 0.471$).
[3] Determined by A. E. Yelmgren.
[4] CO_2 of the carbonates.
[5] Analyses made by G. J. Hough. Wooster soils only tentatively listed in the Miami family.
[6] Horizon designation used by the Indiana Soil Survey; see p. 11.

Because the iron content of the surface horizons of most of the soils is not much different from the iron content of the parent material, it appears still more probable that lateral migration of the iron from higher areas rather than vertical transfer in the profile has caused at least a part of its accumulation in the subsoils. Marbut[4] gives this explanation for the formation of Bog iron. Much of this iron probably came from adjacent areas of Crosby, Bethel, and Miami soils. Very noticeable narrow bands of very light-colored leached soils bordering areas of Brookston and Clyde soils are so narrow that they cannot be mapped separately, but it is quite possible that they have furnished some of the iron that is now in the subsoils of the Brookston silty clay loam and the Clyde silty clay.

In all of the profiles there is a noticeably higher percentage of alumina in the subsoil as compared to the soil above. It is more marked in the light-colored soils, especially in the Miami, Crosby, and Bethel profiles. It is less marked in the dark-colored Brookston and Clyde soils. A comparison of this table with table 1 shows that there is a rather close correspondence between the alumina content and the percentage of clay in each horizon, but the relationship is far from uniform. Of course, this relationship is to be expected, as a good share of the alumina in well-developed soils is in the form of clay.

Special attention is directed to the percentages of carbon dioxide recorded in table 4. These percentages indicate that appreciable quantities of carbonates persist in the leached portion of all but the first four horizons of the Clyde profile. Although the quantities of carbon dioxide recorded often approach the limitation of the method of determination, it is believed that they are nevertheless real. This is indicated by the effervescence resulting from the addition of dilute hydrochloric acid to the sample previously boiled in distilled water.

It is probable that the bases liberated by decaying organic matter permit the retention of a part, or possibly all, of the carbonates in the surface horizon in spite of their acidity. It is not probable in the deeper and more acid parts of the soils. Microscopic observation of the evolution of carbon dioxide from these horizons indicated that most, if not all, of the effervescence originated from a few particles and that the carbonates were not generally disseminated throughout the sample. In a few samples the microscopically determinable physical properties clearly indicated that they were fragments of limestone or dolomite. In most of the samples the fragments were too deeply stained by iron oxide or other coloring matter to permit positive identification. In the preliminary test outlined in the previous paragraph it was also noted that the evolution of bubbles was apparently confined to a few particles and that the carbon dioxide was not generally liberated from the suspension of the soil. In view of the quantities of dolomite in the Wisconsin drift and the positive identification of limestone or dolomitic limestone in the samples tested, it appears certain that the carbon dioxide of the more acid parts of the profiles is largely, if not altogether, derived from small fragments of limestone or dolomite.

A relatively high percentage of magnesium oxide and calcium oxide occurs in the C horizons of all of the soils except Wooster silt loam, and it is quite likely that deeper parts of the C horizon of Wooster silt

[4] MARBUT, C. F. SOILS, THEIR GENESIS, CLASSIFICATION, AND DEVELOPMENT. Mimeographed lectures (unpublished), U. S. Dept. Agr. Lecture VI, p. 8.

loam would also show a similar abundance of magnesium and calcium if samples were taken to sufficient depth to reach the layer of carbonates. There is also a concentration of calcium of less importance in the A_1 horizons of all of the light-colored soils and of the H_1 horizons of the dark-colored Brookston and Clyde soils. This is undoubtedly a reflection of the ability of forest trees to store calcium in their leaves, which is incorporated in these horizons after the leaves fall.

The large quantity of calcium in the A_1 horizon of the Wooster soil indicates that the quantities supplied by the organic matter is about the same as in other soils and suggests that it may be obtained from a readily available supply. This suggests that its source, in part, is from limestone fragments in the glacial till below the sampled depth.

Attention is called to the slight concentration of manganese oxide in the B_3 horizons of the Fox silt loam and in the fourth or M horizon of the Brookston silty clay loam. Qualitative tests on many samples of soils having dark-brown B_3 horizons indicate the presence of manganese in larger amounts than in horizons immediately above and below. In many of these same soils the B_3 horizons also contain more organic matter than horizons immediately above and below.

The concentration of phosphorus is greatest in the A horizons of most of the soils and in several of them there is also a concentration in the B_3 horizon. The concentration of this element in the A horizon seems to be caused by the increase in organic matter undoubtedly resulting from residual effect of decaying leaves and other organic material that probably is relatively high in phosphorus. One of the striking things about the phosphorus column in table 4 is that the A and B horizons of the Wooster silt loam contain more phosphorus than corresponding horizons of any of the other light-colored soils. This is one of the many features that tends to set off Wooster silt loam from the other members of the Miami family and that suggests that it belongs in another family. The high phosphorus content of the Clyde silty clay soil is probably caused by additions from the drainage water from surrounding areas.

The organic matter is fairly high in the upper four horizons of the Miami profile and in the sixth horizon as well. Even the B_2 and C horizons have close to 1 percent. Organic matter is far more concentrated in the A_1 horizon of the Wooster silt loam and diminishes more rapidly in the lower horizons than in the Miami soils. However, only the upper 1-inch thick part of the A_1 horizon was sampled, and the lower part of this layer contains less organic matter and is lighter in color than the part sampled. The Hillsdale profile resembles the Wooster soil in distribution of organic matter, and the Fox soil is more like the Miami soil. The imperfectly drained Crosby and Bethel silt loams of the Planasol group show very marked differences in organic matter content between the A and B horizons. The relatively high organic matter content in the Brookston and Clyde soils extends to greater depth than in the other soils, and the total amount is greater than in any of the other soils. This is especially true of the Clyde silty clay in which the dark-colored layer is considerably thicker than in the Brookston silty clay loam.

The content of carbon dioxide apparently is largely proportional to the content of magnesium and calcium oxides with which it is combined in the soils in the form of carbonates; but certain amounts of the calcium and magnesium oxides are in the form of silicates.

The surface horizons are higher in calcium, phosphorus, and sulfur than in other subdivisions of the solums. This is doubtless a reflection of the association of these elements with the organic matter. The association is more noticeable in the Wooster, Fox, and Crosby for calcium and in the Miami, Wooster, and Clyde for phosphorus and sulfur.

The data also indicate that the vegetation carries much less magnesium than calcium to the surface of the soils. The cause is indicated by the low content of magnesium as compared to calcium in plant ash (*28*). For this reason the circulation of magnesium in the soil profile is not as great as calcium, although abundant supplies of both elements occur in the deeper parts of all of the soils.

Although the relationships of various elements to the organic matter in the deeper parts of the profiles are somewhat obscure, the increase in manganese and phosphorus with organic matter in the B_3 horizon of the Miami and Fox is notable. This is not so in the other soils, and it is probable that the accumulation of these two elements in the deeper parts is caused as much by the proximity to carbonates as by any other factor.

Because of the wide variations in organic matter and carbonates the variation of mineral components are wider with respect to each other than they would be if the data were recalculated in an organic matter and calcium-carbonate-free basis. Relationships are not lost in a comparison of the constituents that are evaluated to a few or fractional percentages, but they are obscured or lost if the percentages are great or if material quantities of organic matter and carbonates are present. Therefore, in order to clarify the relationships of the silica, iron oxide, alumina, and combined water, the tables have been recalculated and presented in table 5. An unavoidable error is introduced in these calculations as an uncertain amount of magnesium occurs with the calcium in the dolomitic limestone in the soils. For the most part, however, the error is small.

TABLE 5.—*Inorganic composition*[1] *of some soils of the Miami family and of the Miami catena*

MIAMI SILT LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*
C4060	A_1	0–2	79.95	3.50	8.05	2.21
C4061	A_2	2–5	81.00	3.04	9.55	1.61
C4062	A_3	5–11	80.19	3.32	9.78	1.70
C4063	B_1	11–15	77.30	4.13	11.18	2.01
C4064	B_2	15–30	70.60	6.30	14.37	3.22
C4065	B_3	30–36	70.05	6.32	14.20	3.15
C4066	C_1	36+	72.90	6.14	13.56	2.34
Profile average	------	------	76.00	4.68	11.65	2.32

WOOSTER SILT LOAM[3]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4025	A_1	0–3	74.25	3.97	10.09	1.53
C4026	A_2	3–12	78.50	3.62	9.20	1.72
C4027	B_1	14–20	74.82	4.89	11.65	2.43
C4028	B_2	20–30	70.95	5.82	12.78	3.13
C4029	B_3	32–38	71.80	6.51	11.48	2.88
C4030	C_1	38–48	73.65	6.44	10.80	2.36
Profile average	------	------	73.98	5.21	11.05	2.34

See footnotes at end of table.

TABLE 5.—*Inorganic composition*[1] *of some soils of the Miami family and of the Miami catena*—Continued

HILLSDALE FINE SANDY LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*
C4031	A_1	0-3	85.75	2.70	5.97	0.51
C4032	A_2	3-9	84.90	3.09	6.80	.60
C4033	A_3	9-13	85.05	3.07	6.45	.70
C4034	B_2	13-28	81.75	3.72	7.90	1.37
C4035	B_3	28-50	78.58	4.70	9.51	1.57
C4036	C_1	54-72	82.20	4.18	8.16	1.07
Profile average			83.01	3.58	7.46	.98

FOX SILT LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4048	A_1	0-2	79.95	3.32	8.09	1.96
C4049	A_2	2-10	80.48	3.95	9.00	1.26
C4050	A_3	10-18	80.25	3.46	9.34	1.88
C4051	B_2	18-32	78.00	5.74	12.56	2.64
C4052	B_3	32-38	64.70	8.48	16.07	4.17
C4053	C_1	38-60	84.35	4.80	16.07	.53
Profile average			77.95	4.98	12.30	2.11

CROSBY SILT LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4037	A_1	0-2	78.62	4.65	11.78	1.88
C4038	A_2	2-11	79.55	3.70	9.49	1.65
C4039	B_2	11-18	73.00	5.01	13.50	3.21
C4040	B_3	18-36	69.50	5.94	14.51	3.37
C4041	C_1	36-44	69.81	6.05	12.76	3.52
C4042	C_2	44-60+	71.60	6.02	14.26	3.17
Profile average			73.73	5.23	12.68	2.80

BETHEL SILT LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4054	A_1	0-2	80.70	3.39	8.95	2.27
C4055	A_2	2-8	82.30	3.00	8.80	1.74
C4056	A_3	8-14	79.41	3.93	10.41	2.20
C4057	B_2	14-20	70.65	6.08	14.35	3.53
C4058	B_3	20-30	70.10	5.88	14.99	3.78
C4059	C_1	30-48+	74.40	5.46	15.81	2.35
Profile average			76.26	4.62	12.22	2.61

BROOKSTON SILT LOAM

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4043	[4] H_1	0-6	72.10	4.51	12.48	3.12
C4044	[4] H_2	6-20	71.80	4.96	13.02	3.35
C4045	[4] H_3	20-34	71.14	5.24	13.97	3.12
C4046	[4] M	34-44	69.59	5.86	14.35	3.23
C4047	[4] U	44-85	72.15	6.40	14.88	1.53
Profile average			71.40	5.43	13.73	2.87

CLYDE SILTY CLAY

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water[2]
C4067	[4] H_1	0-8	64.80	4.20	16.14	6.40
C4068	[4] H_2	8-20	60.70	5.00	16.58	4.48
C4069	[4] H_3	20-26	67.95	5.23	15.86	4.17
C4070	[4] M_1	26-38	70.00	4.80	15.00	3.70
C4071	[4] M_2	38-66	69.40	6.32	14.70	3.15
C4072	[4] U	66-75	70.95	5.80	14.65	5.07
Profile average			68.30	5.22	15.49	4.50

[1] Recalculated on an organic matter and calcium-carbonate-free basis; 4 major constituents recorded.
[2] Ignition loss less organic matter and carbon dioxide; corrected for organic matter and calcium carbonate.
[3] Wooster soils only tentatively listed in the Miami family.
[4] Horizon designation used by the Indiana Soil Survey; see p. 11.

It will be observed from this restatement that the silica content of the zonal soils is higher in the A and C horizons than in the B_2 and B_3 horizons, which reflects the higher clay content of the latter. The iron and silica are apparently not as closely related to the clay as alumina. Both iron and aluminum have been eluviated with the clay, but the uncertainty as to how much iron is in the more or less unaltered minerals of the soils makes it still more uncertain how much of each has accumulated in the C horizon without indicating a corresponding increase in the clay.

Taken as a whole, it is apparent that the parent drift exerts a profound effect on the composition of this group of soils. The parent drift has not been greatly altered during soil formation except in the solution of the carbonates. Most of the differences in composition are caused by the distribution of the clay in their various parts. Apparently, the combined water is more closely associated with the clay minerals than with the primary or other secondary minerals containing aluminum and iron.

Chemical Analyses of the Colloids

The complete chemical analyses of the colloids extracted from the soils are presented in table 6. Extraction of the colloids excludes variations in composition caused by the presence of quartz and other primary minerals, and greater uniformity of composition may be expected than in the analyses of whole soils. Most of the differences shown in the colloids are likely to be caused by variations in parent material, natural drainage, and vegetation of the soils.

It is apparent in table 6 that the process of colloid extraction gives a product essentially free from carbonates in soils that do not contain much, and comparatively small amounts if the quantities in the soil are high. All of the colloids extracted from the parent material contain carbonates ranging from that equivalent to traces of carbon dioxide—0.06 percent in the Wooster and Hillsdale profiles to 1.95 percent in the Crosby profiles.

Organic matter shows wide variations both between and within the profiles. In the surface horizon the organic content of the colloids ranges from 8.54 percent in the Clyde silty clay to 28.61 percent in the Wooster silt loam, but it should be borne in mind that the A_1 horizon of the Wooster soil was sampled to a depth of only 1 inch where the organic matter was most concentrated and the Clyde surface soil was sampled to a depth of 8 inches. The quantities of organic matter in the surface layer of a soil depend so much on the density and kind of vegetation as well as on the conditions favoring organic matter accumulation and its decomposition, that the percentages in the colloid may range widely from place to place and often within very short distances on the same soil. From the surface horizon downward the quantities of organic matter in the colloids become rapidly less in the solum.

TABLE 6.—*Chemical analyses of the colloids of the Miami family and of the Miami catena*

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter[1]	CO_2[2]	N[3]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
MIAMI SILT LOAM COLLOID																		
C4060	A_1	0-2	41.52	8.84	21.83	2.30	1.04	2.42	0.15	0.63	0.29	0.59	0.25	20.46	100.32	11.94	0	1.00
C4061	A_2	2-5	43.10	9.12	23.16	2.37	.87	2.31	.15	.63	.15	.49	.20	17.58	100.13	8.56	0	.72
C4062	A_3	5-11	43.61	10.28	23.82	2.53	.65	2.25	.14	.68	.19	.49	.14	15.54	100.32	5.67	0	.50
C4063	B_1	11-15	44.41	10.94	24.48	2.50	.75	2.24	.08	.72	.39	.25	.09	13.17	100.02	3.71	0	.32
C4064	B_2	15-30	45.10	12.10	24.11	2.71	.64	2.44	.12	.72	.42	.26	.07	11.63	100.32	2.18	0	.18
C4065	B_3	30-36	44.75	12.13	24.27	2.94	.78	2.55	.08	.65	.46	.24	.09	11.36	100.30	2.19	0	.20
C4066	C_1	36+	45.10	12.23	23.87	3.09	1.15	3.56	.16	1.14	.13	.19	.10	9.45	100.17	1.36	.18	.15
WOOSTER SILT LOAM COLLOID[4]																		
C4025	A_1	0-1	31.25	7.76	17.08	1.69	1.72	1.95	0.20	0.80	0.36	0.83	0.46	36.21	100.31	28.61	0	2.03
C4026	A_2	3-12	41.39	11.59	24.55	1.93	.62	2.03	.17	1.03	.55	.63	.14	15.60	100.23	6.56	0	.48
C4027	B_1	14-20	42.79	13.21	25.37	1.95	.52	2.19	.15	1.19	.22	.43	.13	12.09	100.24	2.79	0	.23
C4028	B_2	20-30	43.51	13.46	25.20	2.01	.49	2.13	.17	1.24	.20	.31	.09	11.14	99.95	2.05	0	.16
C4029	B_3	32-38	44.15	13.56	25.47	2.19	.64	2.87	.15	1.00	.18	.28	.05	9.54	100.17	1.23	0	.15
C4030	C_1	38-48	43.41	14.00	25.65	2.25	.56	3.15	.07	.58	.22	.32	.03	9.91	100.12	.97	.06	.16
HILLSDALE FINE SANDY LOAM COLLOID																		
C4031	A_1	0-3	38.66	8.58	21.77	1.85	0.90	1.95	0.03	0.64	0.42	0.77	0.43	24.42	100.42	16.15	0	1.02
C4032	A_2	3-9	41.50	10.74	25.45	1.86	.31	1.90	.04	.64	.45	.59	.24	16.71	100.43	7.05	0	.50
C4033	A_3	9-13	43.52	12.11	25.54	2.08	.47	2.62	0	.70	.32	.40	.16	12.18	100.10	3.55	0	.28
C4034	B_2	13-28	43.45	13.70	25.23	2.37	.46	2.58	.05	.71	.22	.30	.12	10.50	99.69	1.47	0	.13
C4035	B_3	28-50	43.70	14.85	23.94	2.51	.58	3.17	0	.64	.17	.32	.07	9.92	99.87	1.07	0	.11
C4036	C_1	54-72	43.70	13.77	24.52	2.72	1.10	3.41	.03	.58	.20	.23	.04	10.45	100.75	1.30	.06	.19
FOX SILT LOAM COLLOID																		
C4048	A_1	0-2	30.50	8.17	21.73	1.83	1.69	1.53	0.42	0.52	0.40	0.68	0.37	23.10	99.94	15.33	0	1.05
C4049	A_2	2-10	44.21	9.47	24.35	1.95	.91	1.50	.41	.56	.31	.62	.22	15.64	100.15	6.38	0	.50
C4050	A_3	10-18	44.20	10.75	25.64	1.92	.51	1.53	.25	.60	.31	.49	.21	13.65	100.06	4.04	0	.32
C4051	B_2	18-22	46.30	11.78	25.70	2.39	.55	1.59	.39	.58	.12	.35	.10	10.68	100.53	1.38	0	.14
C4052	B_3	32-38	45.78	11.27	25.77	2.72	.80	1.64	.57	.53	.14	.26	.09	10.54	100.11	1.41	.18	.14
C4053	C_1	38-60	44.45	11.03	22.64	3.13	1.56	3.28	.23	.50	.35	.38	.17	11.19	99.81	2.47	.83	.22

See footnotes at end of table.

TABLE 6.—*Chemical analyses of the colloids of the Miami family and of the Miami catena*—Continued

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	MgO	CaO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	SO_3	Ignition loss	Total	Organic matter [1]	CO_2 [2]	N [3]
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
CROSBY SILT LOAM COLLOID																		
C4037	A_1	0-2	41.95	7.30	20.83	1.97	1.62	2.12	0.21	0.48	0.29	0.54	0.41	23.04	100.73	14.92	0	1.13
C4038	A_2	2-11	46.85	8.18	23.07	2.31	1.33	1.78	.20	.52	.23	.32	.19	15.57	100.55	6.07	0	.54
C4039	B_2	11-18	47.80	11.15	23.77	2.31	1.11	1.25	.16	.54	.09	.14	.08	11.66	100.06	2.08	0	.31
C4040	B_3	18-36	47.81	11.95	23.91	2.60	1.08	2.99	.16	.52	10	.17	.08	9.73	100.10	1.10	0	.15
C4041	C_1	36-44	46.42	12.00	23.85	2.91	1.26	3.86	.19	.58	.12	.15	.12	9.09	100.55	.94	.23	.14
C4042	C_2	44-60+	45.20	11.09	23.27	3.00	2.84	3.88	.33	.53	.10	.14	.26	9.42	100.06	.62	1.95	.14
BETHEL SILT LOAM COLLOID																		
C4054	A_1	0-2	43.65	6.23	20.38	1.57	1.00	1.31	0	0.61	0.12	0.36	0.31	24.43	99.97	16.40	0	1.32
C4055	A_2	2-8	47.15	9.11	21.20	1.73	1.00	1.24	.05	.69	.11	.26	.12	17.35	100.01	8.75	0	.60
C4056	A_3	8-14	48.55	9.41	24.44	1.09	1.02	1.02	.04	.65	.09	.10	.11	12.40	99.82	3.31	0	.27
C4057	B_2	14-20	48.60	10.45	24.27	2.48	1.11	1.10	.00	.63	.07	.06	.04	10.85	99.66	1.49	0	.16
C4058	B_3	20-30	48.41	11.34	23.41	2.79	1.31	1.47	.00	.63	.06	.02	.06	10.30	99.80	1.21	0	.15
C4059	C_1	30-48+	46.11	11.01	23.02	3.24	2.42	3.30	.11	.52	.06	.10	.04	9.76	99.69	.90	1.45	.16
BROOKSTON SILTY CLAY LOAM COLLOID																		
C4043	[5] H_1	0-6	42.89	9.06	21.33	2.35	1.76	2.62	0.24	0.47	0.09	0.45	0.30	19.10	100.66	9.40	0	0.78
C4044	[5] H_2	6-20	46.50	10.42	22.29	2.65	1.50	2.37	.15	.51	.07	.28	.18	13.31	100.23	4.77	0	.32
C4045	[5] H_3	20-34	48.35	12.96	21.00	2.66	1.29	2.49	.11	.51	.07	.18	.18	10.56	100.36	2.15	0	.20
C4046	[5] M	34-44	46.60	12.68	23.52	2.84	.93	4.07	.18	.49	.10	.19	.12	8.76	100.48	1.15	0	.14
C4047	[5] U	44-85	46.21	11.98	23.92	2.96	1.09	4.86	.24	.45	.10	.21	.13	8.33	100.48	1.12	.21	.13
CLYDE SILTY CLAY COLLOID																		
C4067	[5] H_1	0-8	45.20	6.33	23.32	2.34	1.58	2.47	0.06	0.58	0.04	0.37	0.26	17.18	99.73	8.54	0	0.66
C4068	[5] H_2	8-20	47.70	7.46	23.96	2.51	1.55	2.52	.05	.57	.04	.24	.13	13.34	100.07	4.47	0	.35
C4069	[5] H_3	20-26	48.20	9.40	24.11	2.56	1.28	2.70	.03	.60	.04	.16	.13	10.56	99.77	1.93	0	.23
C4070	[5] M_1	26-38	48.12	9.80	24.61	2.62	1.29	2.61	.06	.64	.04	.15	.09	10.16	100.19	1.58	0	.16
C4071	[5] M_2	38-66	44.53	14.84	23.20	2.85	.83	4.19	.07	.63	.06	.33	.13	8.91	100.47	1.28	.02	.15
C4072	[5] U	66-75	45.45	12.37	22.71	2.80	1.48	4.24	.14	.57	.08	.26	.09	9.38	99.66	1.65	.54	.16

[1] By combustion method.
[2] CO_2 of the carbonates.
[3] Determined by A. E. Yelmgren.
[4] Wooster soils only tentatively listed in the Miami family.
[5] Horizon designation used by the Indiana Soil Survey; see p. 11.

The quantities of sulfur and phosphorus, like those of the organic matter, are highest in the colloids of the surface horizon in each soil. Although these three constituents are not strictly proportional there or in other parts of the profile, the relationship appears sufficiently close to indicate that a large part of the phosphorus and sulfur is a constituent part of the organic matter, as shown by Dickman and De Turk (*12*). They found that 15 to 67 percent of the phosphorus of the soil is combined in the organic matter. The analysis in table 6 indicates that a large part of both sulfur and phosphorus is identified with the organic matter of the colloids. These data also show that a fairly large part of the calcium is associated with the organic matter. This is more evident in the surface horizons than in other parts of the profiles. The accumulation of calcium is not proportional to the organic matter in this horizon, but it appears to be related somewhat to the state of decomposition. and the kind of vegetation that furnishes the supply. The increase of this element in the colloid of the first horizons is not related to the quantities in the soil but rather to the moisture conditions. It may be noted that the proportion of calcium in the colloids not identified as a carbonate is greater in the first horizon of the well-drained Gray-Brown Podzolic profiles than in those not so perfectly drained.

In the lowest horizons of the Hillsdale, Fox, and Clyde soils the organic matter present in the colloids is greater than in the layers just above. This may be more fortuitous than real, but it should be noted (see table 3) that the lowest horizon of each of these three soils has a pH of 8.0 or more. It is possible that some of this organic matter has fallen through cracks from the B_3 horizon, but it does not seem likely that this is important because subsoils in this region seldom dry out sufficiently to permit much downward movement by mechanical action.

The profile relationships of the chief constituents of the colloids as well as relationships between profiles are so distorted by organic matter and carbonates, shown in table 6, that recalculations for these were made. The results are presented in table 7. To these the corrected combined water of the colloids is added, but minor constituents have not been calculated. As corrected, the sums of the means of the four constituents in the different profiles range from 91.54 percent for the Brookston silty clay loam to 93.55 percent for the Bethel silt loam. As these constituents represent so large a fraction of the total colloids, a detailed study should furnish much information concerning the chemical character of the mineral colloid complex.

TABLE 7.—*Inorganic composition*[1] *of the colloids of some soils of the Miami family and of the Miami catena*

MIAMI SILT LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
		Inches	*Percent*	*Percent*	*Percent*	*Percent*
C4060	A_1	0-2	47.11	10.03	24.80	9.07
C4061	A_2	2-5	47.10	9.97	25.32	9.80
C4062	A_3	5-11	46.25	10.80	25.20	10.46
C4063	B_1	11-15	46.12	11.30	25.41	9-82
C4064	B_2	15-30	46.10	12.36	24.66	9.00
C4065	B_3	30-36	45.73	12.40	24.80	9.38
C4066	C_1	36+	45.90	12.45	24.29	8.05
Profile average			46.31	11.34	24.93	9.50

See footnotes at end of table.

TABLE 7.—*Inorganic composition*[1] *of the colloids of some soils of the Miami family and of the Miami catena*—Continued

WOOSTER SILT LOAM COLLOID[2]

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
		Inches	*Percent*	*Percent*	*Percent*	*Percent*
C4025	A_1	0-1	43.75	10.86	23.92	10.66
C4026	A_2	3-12	44.26	12.61	26.25	9.67
C4027	B_1	14-20	44.00	13.50	26.40	9.56
C4028	B_2	20-30	44.45	13.75	25.73	9.28
C4029	B_3	32-38	44.70	13.73	25.79	8.41
C4030	C_1	38-48	43.00	14.15	25.90	8.98
Profile average			44.18	13.11	25.67	9.43

HILLSDALE FINE SANDY LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4031	A_1	0-3	46.12	10.23	27.10	9.86
C4032	A_2	3-9	44.65	11.55	27.39	10.39
C4033	A_3	9-13	45.10	12.65	26.48	8.04
C4034	B_2	13-28	44.10	13.81	25.61	9.16
C4035	B_3	28-50	44.19	15.01	24.20	8.95
C4036	C_1	51-72	44.35	13.96	24.90	9.22
Profile average			44.42	12.87	25.96	9.42

FOX SILT LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4018	A_1	0-2	46.05	9.65	25.69	9.18
C4019	A_2	2-10	47.20	10.11	26.00	9.89
C4050	A_3	10-18	46.09	11.20	26.71	10.01
C4051	B_2	18-32	46.95	11.91	25.05	9.43
C4052	B_3	32-38	46.65	11.48	26.25	9.12
C4053	C_1	38-60	46.10	12.50	24.63	8.38
Profile average			46.61	11.15	25.72	9.33

CROSBY SILT LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4037	A_1	0-2	49.30	8.54	24.50	9.54
C4038	A_2	2-11	49.85	8.71	24.51	10.11
C4039	B_2	11-18	48.80	11.38	24.26	9.78
C4040	B_3	18-36	47.35	12.08	24.10	8.73
C4041	C_1	36-44	47.10	12.47	24.19	8.04
C4042	C_2	44-60+	47.60	11.67	24.50	7.22
Profile average			48.33	10.75	24.38	8.90

BETHEL SILT LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4054	A_1	0-2	52.20	7.45	21.36	9.60
C4055	A_2	2-8	51.70	9.08	23.22	9.42
C4056	A_3	8-14	50.20	9.73	25.30	9.40
C4057	B_2	14-20	49.32	10.62	24.62	9.51
C4058	B_3	20-30	49.02	11.48	23.70	9.20
C4059	C_1	30-48+	48.10	11.48	24.00	7.73
Profile average			50.09	10.12	24.20	9.14

BROOKSTON SILTY CLAY LOAM COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4043	[3] H_1	0-6	47.40	10.01	23.57	10.01
C4044	[3] H_2	6-20	48.81	10.94	23.39	8.98
C4045	[3] H_3	20-34	49.40	13.25	24.45	8.60
C4046	[3] M	34-44	47.15	12.83	23.80	7.70
C4047	[3] U	44-85	46.85	12.17	24.31	7.11
Profile average			47.92	11.84	23.20	8.60

CLYDE SILTY CLAY COLLOID

Sample No.	Horizon	Depth	SiO_2	Fe_2O_3	Al_2O_3	Combined water
C4067	[3] H_1	0-8	49.40	6.92	25.50	9.44
C4068	[3] H_2	8-20	49.92	7.80	25.08	9.28
C4069	[3] H_3	20-26	49.15	9.59	24.60	8.80
C4070	[3] M_1	26-38	48.90	9.96	25.00	8.72
C4071	[3] M_2	38-66	45.14	15.07	24.50	7.70
C4072	[3] U	66-75	46.80	12.74	23.40	7.40
Profile average			48.22	10.35	24.51	8.56

[1] Recalculated on an organic matter and calcium-carbonate-free basis; major constituents recorded.
[2] Wooster soils only tentatively listed in the Miami family.
[3] Horizon designation used by the Indiana Soil Survey; see p. 11.

Examination of the detailed data of table 7 reveals that there is considerable variation of the four constituents, especially of the iron oxide. The horizon averages for silica range from 44.18 percent for the Wooster to 50.09 percent for the Bethel. The iron oxide averages range from 10.12 for Bethel to 13.11 for the Wooster. In every profile, except those of Bethel, the iron content is less in the two uppermost horizons than in any horizons below. The alumina averages range from 23.20 for the Brookston to 25.96 for the Hillsdale. The combined water averages range from 8.56 in the Clyde to 9.56 in the Miami. These averages are not weighted for thickness of horizon as the percentages of each constituent in the various profiles do not vary widely.

It is further noted that on the average the colloids of the Miami, Wooster, Hillsdale, and Fox soils, shown in table 7, are slightly lower in silica and higher in iron oxide, alumina, and combined water than those of the Crosby, Bethel, Brookston, and Clyde soils. The former are well-drained Gray-Brown Podzolic soils and the latter are the imperfectly drained Planosols and the poorly drained Half-Bog soils and Wiesenböden. The relative proportion of these four constituents in the colloids in the two groups is slight. This suggests that the skeletal framework of the colloids of which they form so large a part has not appreciably altered by their various local environments.

Within the profiles silica and alumina, for the most part, decrease with depth, to compensate approximately for a corresponding increase in iron oxide. In the Wooster, Hillsdale, and Fox soils the range of silica is not as great, and no very definite profile trend is noted. Alumina in these three soils and in the Clyde silty clay shows wider variations than in other profiles, but it is obvious that proportionate quantities of silica and alumina have not been eluviated with the clay (table 1). A greater response to fractionation and eluviation is shown by iron, but it is apparently as independent of the clay as silica and alumina. For the most part, greater quantities of iron occur in the B horizons of the well-drained soils and in some part of the subsoils of the poorly drained soils, but in the Miami, Wooster, and Fox soil colloids larger quantities are found in the C than in any other part of the profiles. The combined water content of the colloids of the Miami, Wooster, Hillsdale, and Fox soils (table 7) shows a tendency to decrease downward but less definitely so than does that of the colloids of the other soils shown. The averages of the combined water of the imperfectly and poorly drained soils are somewhat higher than those of the well-drained soils. The changes in the profiles apparently caused by differences in local drainage will be treated in the general discussion (see p. 45).

Organic Matter

As the organic matter has played a very important part in the development of the soils of the Miami family and of the Miami catena, it is desirable to bring together in a separate section the discussion of certain profile relationships concerning it. The percentages of organic matter recorded in tables 3, 4, and 6 indicate the usual vertical decrease in each profile. The quantities recorded as 0.0 by the hydrogen peroxide method, in table 3, indicate the limitations of the method for determining certain kinds of soil organic matter. A comparison of the quantities recorded in table 4 indicates that the organic matter in the lower horizons is not amenable to determination by the hydrogen-peroxide method. It also suggests that a certain amount of carbonization of the organic matter occurs in the deeper, wetter, and less aerated parts of the soils. This is indicated by the greatly enhanced percentages obtained by the combustion method for those samples. On the contrary, the hydrogen-peroxide method (table 3) indicates greater quantities of organic matter in the surface horizons of the Bethel, Brookston, and Clyde soils than the combustion method (table 4). This suggests that the carbon content of the organic matter is low in these samples, as the percentages found by the hydrogen-peroxide method are obtained by the weight lost and percentages found by the combustion method by multiplying the percentage of carbon dioxide obtained by a factor. It is obvious that close concordance of data obtained by the two methods cannot be expected.

If appreciable carbonization occurs or if the carbon content of the organic matter is low, it is obvious that the determination of organic matter by the combustion method is in error by the variation in its carbon content from 58 percent. In the calculation of organic matter in the samples determined by the combustion method it is assumed that the organic matter contains 58 percent carbon, although it is recognized that it may vary from this percentage.

Other variations in the organic matter that do not involve two methods of determination may be noted in tables 4 and 6. In most of the samples the organic matter of the soils is lower than in the colloids. In a few it is not. The A_1 horizon of the Wooster, the C_1 horizon of the Crosby, the U horizon of the Brookston, and the first three horizons of the Clyde apparently have more organic matter in the soil than in the colloid. It is not known if organic matter of the colloids of these samples has a lower carbon content than the organic matter of the soil, but it is reasonable to suspect that it has. This is more probable of the three black samples of the swampy Clyde soil. It appears certain that the carbon content of the organic matter of the soils and of the colloids is not identical. This may be caused by the manner of decomposition under various drainage conditions. Evidence of other differences in the composition of the organic matter may be noted in the carbon-nitrogen ratios.

The percentages of organic matter and nitrogen in the soils are given in table 4 and those of the colloids in table 6. From these data the carbon-nitrogen ratios of both soil and colloid have been calculated and placed in parallel columns in table 8.

TABLE 8.—*Carbon*[1]*-nitrogen ratios of some soils and colloids of the Miami family and of the Miami catena and part of the organic matter appearing in the colloid fraction*

MIAMI SILT LOAM

Sample No.	Horizon	Depth	C/N ratio of—		Part of organic matter appearing in colloidal fraction[2]
			Soil	Colloid	
		Inches			*Percent*
C4060	A_1	0-2	12.9	6.9	30
C4061	A_2	2-5	16.0	6.9	37
C4062	A_3	5-11	10.3	6.5	48
C4063	B_1	11-15	9.9	6.7	61
C4064	B_2	15-30	11.5	7.0	81
C4065	B_3	30-36	9.2	6.4	74
C4066	C_1	36+	10.1	7.3	29

See footnotes at end of table.

TABLE 8.—*Carbon*[1]*-nitrogen ratios of some soils and colloids of the Miami family and of the Miami catena and part of the organic matter appearing in the colloid fraction*—Continued

Sample No.	Horizon	Depth	C/N ratio of—		Part of organic matter appearing in colloidal fraction[2]
			Soil	Colloid	
WOOSTER SILT LOAM[3]					
		Inches			*Percent*
C4025	A_1	0-3	18.9	8.2	9
C4026	A_2	3-12	12.4	7.9	57
C4027	B_1	14-20	9.9	7.0	81
C4028	B_2	20-30	8.9	7.4	61
C4029	B_3	32-38	7.5	4.7	71
C4030	C_1	38-48	7.4	3.5	35
HILLSDALE FINE SANDY LOAM					
C4031	A_1	0-3	13.8	9.2	28
C4032	A_2	3-9	[4]10.4	6.9	73
C4033	A_3	9-13	8.3	7.4	58
C4034	B_2	13-28	8.7	6.5	68
C4035	B_3	28-50	4.3	5.6	68
C4036	C_1	51-72	7.2	4.0	50
FOX SILT LOAM					
C4048	A_1	0-2	18.2	8.5	16
C4049	A_2	2-10	8.4	7.4	44
C4050	A_3	10-18	8.5	7.3	58
C4051	B_2	18-32	5.1	5.7	[4]112
C4052	B_3	32-38	9.1	5.8	60
C4053	C_1	38-60	20.3	6.5	20
CROSBY SILT LOAM					
C4037	A_1	0-2	12.9	7.7	23
C4038	A_2	2-11	9.7	6.5	46
C4039	B_2	11-18	6.1	3.9	87
C4040	B_3	18-36	5.7	4.3	57
C4041	C_1	36-44	2.7	3.9	[4]112
C4042	C_2	44-60+	11.6	2.6	10
BETHEL SILT LOAM					
C4054	A_1	0-2	12.0	7.2	44
C4055	A_2	2-8	10.3	8.5	55
C4056	A_3	8-14	10.3	7.4	74
C4057	B_2	14-20	6.7	5.4	73
C4058	B_3	20-30	6.5	4.7	68
C4059	C_1	30-48+	15.3	3.3	18
BROOKSTON SILT LOAM					
C4043	[5] H_1	0-6	16.8	7.0	30
C4044	[5] H_2	6-20	9.7	8.6	52
C4045	[5] H_3	20-34	11.0	6.2	52
C4046	[5] M	34-44	6.6	4.8	52
C4047	[5] U	44-55	17.8	5.0	17
CLYDE SILTY CLAY					
C4067	[5] H_1	0-8	10.4	7.5	36
C4068	[5] H_2	8-20	10.5	7.4	40
C4069	[5] H_3	20-26	9.0	4.9	41
C4070	[5] M_1	26-38	9.1	5.7	60
C4071	[5] M_2	38-66	9.5	4.9	41
C4072	[5] U	66-75	23.8	6.0	31

[1] Organic matter×0.58.

[2] $\frac{\text{Percent organic matter in colloid} \times \text{percent clay}}{\text{Percent organic matter in the soil}}$. Further explanation in text, p. 41.

[3] Wooster soils only tentatively listed in the Miami family.

[4] Error presumably caused by the variation of the quantities of organic matter in the clay and colloid.

[5] Horizon designation used by the Indiana Soil Survey; see p. 11.

The carbon-nitrogen ratios of the soils range from 2.7 to 23.8 and in the colloids from 2.6 to 9.2. They range more widely and for the most part are higher in the soil than in the colloids. This trend has been shown by Brown and Byers (*6*). It is apparently caused by the greater quantities of incompletely decomposed cellulosic materials in the soils as compared to the quantities reduced to colloidal dimensions by more complete microbial decay.

The carbon-nitrogen ratios of the first few horizons of the soils are necessarily increased by the seasonal leaf fall and other additions of highly cellulosic materials of the vegetation. The effects of these additions diminish in the deeper parts of the profiles. This ratio in the parent material is surprisingly high. In some it is higher than in the surface horizon. Large quantities of carbonates in the parent material of certain soils cause the alkalinity to be higher than in other parts of their profiles. This change in environment may decrease the microbial destruction of cellulose, but it is even more probable that the high carbon-nitrogen ratios are caused by the quantities of relatively undecomposed organic matter furnished to this horizon by the dead roots of trees and plants. The feeder roots of trees in all but the poorly drained soils are most abundant in the A and in the lower part of the B and the upper part of the C horizons.

Reliance should not be placed on the carbon-nitrogen ratios where the quantities of organic matter and nitrogen are low, and especially is this so of horizons very high in carbonates. In the analyses the carbonates in the samples from the C horizons of all but the Wooster liberate more carbon dioxide than is liberated by the combustion of the organic matter. If the carbonates are high in the sample used in the determination of total carbon dioxide by combustion, the result obtained for organic matter is not so reliable, since the sample must be small. Nevertheless, checked determinations indicate that any errors of method introduced in the organic matter are much smaller than the percentages recorded in tables 4 and 6. The determination of nitrogen, however, is more precise because larger samples for its determination were used where the quantity of nitrogen in the sample was very small.

The errors introduced in the carbon-nitrogen ratio of the soil by large quantities of carbonates are negligible in the carbon-nitrogen ratios of the colloids, because only a few of the colloids contain appreciable quantities of carbonates. Because of this and because of the larger proportions of nitrogen to organic matter in the colloids, the ratios appear more certain. Furthermore, the colloids are comparatively free from the undecomposed cellulosic plant remains of the soil because of their very small particle size. Since it seems that greater reliance can be placed on the carbon-nitrogen ratio of the colloid than that of the soil, it is apparent that an increase of this ratio in the colloids of the bottom horizons indicates that the increase in the carbon-nitrogen ratios of the soil in the bottom horizons is not altogether illusory. The ratio approaches close to 20 in the bottom horizons of half of the soils. The carbon-nitrogen ratio of the colloids of these same soils is greater than in the horizon above. In the Miami silt loam it is greater than in other parts of the profile.

It is apparent that the organic matter has undergone as great, if not greater, change in the profile development of the soils as the inorganic portion of them.

The percentages of organic matter in table 8 indicate that the percentage of the organic matter of the whole soil that appears in the colloid fraction reaches a maximum in subsoil horizons above the parent material. These percentages were obtained by multiplying the percentage of colloid by the percentage of organic matter appearing in the colloid, and dividing by the percentage of total organic matter in the soil. Although these calculations involve errors caused by differences in quantity of clay and colloid in the soil as well as probable differences in organic content of each, it is not believed that the error is great in those not exceeding 100 percent. From the results obtained it is evident that more of the organic matter is of colloidal dimensions in the lower A. B. and M horizons than in the upper A and C horizons. The data strongly suggest eluviation and illuviation either in solution or as discrete colloidal particles of organic matter. The upper part of the parent material contains more or less organic matter in the form of partially decayed roots as well as in the form of more thoroughly altered organic matter which has filtered down from the B_3 horizon in the small cracks and root holes into the parent material. The fact that the greater part of the organic matter of the parent material consists of particles of noncolloidal dimensions suggests that it is largely the product of disintegration of tree roots in place. They are usually fairly abundant in the upper parts of the C horizon.

The determination of soil organic matter, whether by the hydrogen-peroxide method, the combustion method, or other methods, presents a problem that requires further study. The data presented in tables 3, 4, 6, and 8 indicate clearly that the composition of the organic matter of the soil and colloid varies in carbon and nitrogen content in various profiles and their parts. It is apparent that fractionation of the soil organic matter occurs during profile development. Such fractionation appears to be dependent largely on the environment of the microbial population of the soil. In various profile environments the organic compounds resulting from microbial decay of the soil organic matter apparently vary in carbon and nitrogen content. The compounds with low carbon-nitrogen ratios are more dispersable in distilled water. Consequently the carbon-nitrogen ratios of the soils are higher than the colloids extracted from them. All of the data concerning organic matter are confused by the inadequacy of the methods of determination as well as the possible presence of charcoal resulting from ancient or later fires.

Derived Data

More intimate relationships of the various inorganic constituents of the colloids than those shown in tables 6 and 7 may be shown by comparing their formula ratios. These together with the combined water of the soil acid have been calculated and presented in table 9. These derived data indicate that most of the chief constituents and bases of the colloids have not been greatly fractionated during the development of the soil profiles examined.

TABLE 9.—*Derived data of the colloids of the Miami family and of the Miami catena*

Sample No.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3 \cdot Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}}$ [1]	$\frac{SiO_2}{H_2O_2}$	$\frac{H_2O}{Fe_2O_3 \cdot Al_2O_3}$ [2]	$\frac{H_2O}{Fe_2O_3}$ [2]	$\frac{H_2O}{Al_2O_3}$ [2]	Combined water of the soil acid [3]
		Inches									*Percent*
MIAMI SILT LOAM COLLOID											
C4060	A_1	0-2	2.57	12.52	3.23	6.08	1.198	2.14	10.45	2.69	11.80
C4061	A_2	2-5	2.52	12.55	3.15	7.17	1.192	2.11	10.52	2.64	11.85
C4062	A_3	5-11	2.43	11.26	3.11	7.24	1.138	2.13	9.89	2.73	12.35
C4063	B_1	11-15	2.37	10.70	3.05	7.30	1.170	2.03	9.15	2.61	11.71
C4064	B_2	15-30	2.40	9.90	3.17	7.04	1.187	2.02	8.33	2.67	11.62
C4065	B_3	30-36	2.37	9.50	3.13	6.48	1.194	1.99	8.21	2.62	11.50
C4066	C_1	36+	2.42	9.93	3.21	6.18	1.315	1.84	7.55	2.44	10.46
WOOSTER SILT LOAM COLLOID [4]											
C4025	A_1	0-1	2.41	10.70	3.11	6.23	1.004	2.40	10.65	3.10	13.04
C4026	A_2	3-12	2.20	9.50	2.86	8.30	1.165	1.89	8.15	2.45	11.40
C4027	B_1	14-20	2.15	8.50	2.87	8.54	1.188	1.91	7.16	2.41	11.10
C4028	B_2	20-30	2.10	8.60	2.94	8.64	1.231	1.78	6.99	2.39	10.83
C4029	B_3	32-38	2.20	8.65	2.94	7.52	1.300	1.69	6.66	2.26	10.30
C4030	C_1	38-48	2.12	8.25	2.85	7.20	1.269	1.67	6.50	2.24	10.38
HILLSDALE FINE SANDY LOAM COLLOID											
C4031	A_1	0-3	2.41	12.00	3.02	7.74	1.187	2.03	10.12	2.51	11.65
C4032	A_2	3-9	2.16	11.35	2.74	9.45	1.272	1.70	8.92	2.15	11.80
C4033	A_3	9-13	2.22	9.56	2.89	8.29	1.279	1.73	7.97	2.26	10.59
C4034	B_2	13-28	2.18	8.48	2.94	7.66	1.220	1.79	6.95	2.41	10.90
C4035	B_3	28-50	2.25	7.94	3.14	6.95	1.235	1.82	6.43	2.54	10.88
C4036	C_1	54-72	2.27	8.66	3.07	5.98	1.175	1.93	7.37	2.61	11.46
FOX SILT LOAM COLLOID											
C4048	A_1	0-2	2.48	12.80	3.07	6.66	1.237	2.00	10.35	2.48	11.27
C4049	A_2	2-10	2.47	12.90	3.08	8.44	1.227	2.01	10.50	2.51	11.53
C4050	A_3	10-18	2.31	10.93	2.92	9.56	1.205	1.91	9.07	2.42	11.46
C4051	B_2	18-32	2.37	10.45	3.16	8.34	1.265	1.87	8.26	2.42	11.14
C4052	B_3	32-38	2.36	10.80	3.02	7.33	1.264	1.87	8.54	2.38	11.06
C4053	C_1	38-60	2.49	9.90	3.33	7.22	1.314	1.89	7.53	2.53	10.64
CROSBY SILT LOAM COLLOID											
C4037	A_1	0-2	2.80	15.30	3.42	7.10	1.156	2.42	13.23	2.96	12.80
C4038	A_2	2-11	2.81	15.21	3.45	7.57	1.236	2.27	12.33	2.79	12.10
C4039	B_2	11-18	2.83	11.40	3.42	8.56	1.271	2.07	8.97	2.69	11.51
C4040	B_3	18-36	2.52	10.43	3.32	6.60	1.305	1.93	7.99	2.55	10.88
C4041	C_1	36-44	2.70	10.30	3.30	5.76	1.345	1.86	7.06	2.45	10.50
C4042	C_2	44-60+	2.62	10.85	3.45	5.91	1.482	1.77	7.32	2.33	9.64
BETHEL SILT LOAM COLLOID											
C4054	A_1	0-2	3.04	18.64	3.63	10.30	1.341	2.26	13.90	2.71	11.64
C4055	A_2	2-8	2.96	13.76	3.77	10.50	1.613	1.89	8.38	2.29	10.91
C4056	A_3	8-14	2.71	13.72	3.37	10.23	1.385	1.96	9.91	2.43	10.86
C4057	B_2	14-20	2.42	12.18	3.40	8.68	1.320	2.05	9.23	2.57	11.21
C4058	B_3	20-30	2.68	11.35	3.51	8.35	1.341	2.00	8.46	2.62	10.06
C4059	C_1	30-48+	2.61	11.14	3.40	6.50	1.447	1.80	7.69	2.35	9.98

See footnotes at end of table.

TABLE 9.—*Derived data of the colloids of the Miami family and of the Miami catena*—Continued

BROOKSTON SILTY CLAY LOAM COLLOID

Sample No.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3.\ Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}^1}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O^2}{Fe_2O_3.\ Al_2O_3}$	$\frac{H_2O^2}{Fe_2O_3}$	$\frac{H_2O^2}{Al_2O_3}$	Combined water of the soil acid[3]
		Inches									*Percent*
C4043	[5] H_1	0–6	2.68	12.59	3.41	6.88	1.083	2.47	11.62	3.15	13.12
C4044	[5] H_2	6–20	2.73	11.87	3.54	6.43	1.302	2.10	9.12	2.72	11.25
C4045	[5] H_3	20–34	2.60	9.82	3.01	7.86	1.370	2.03	7.21	2.84	10.70
C4046	[5] M	34–44	2.50	9.77	3.30	5.82	1.396	1.79	7.00	2.41	10.06
C4047	[5] U	44–85	2.48	10.25	3.27	5.14	1.398	1.77	7.33	2.34	10.05

CLYDE SILTY CLAY COLLOID

Sample No.	Horizon	Depth	$\frac{SiO_2}{Fe_2O_3.\ Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{\text{Total bases}^1}$	$\frac{SiO_2}{H_2O}$	$\frac{H_2O^2}{Fe_2O_3.\ Al_2O_3}$	$\frac{H_2O^2}{Fe_2O_3}$	$\frac{H_2O^2}{Al_2O_3}$	Combined water of the soil acid[3]
C4067	[5] H_1	0–8	2.80	18.95	3.28	6.62	1.265	2.21	15.00	2.59	11.69
C4068	[5] H_2	8–20	2.82	17.00	3.38	6.77	1.303	2.14	13.05	2.50	11.50
C4069	[5] H_3	20–26	2.72	13.64	3.39	6.96	1.350	1.96	9.81	2.44	10.93
C4070	[5] M_1	26–38	2.55	13.06	3.32	6.86	1.337	1.91	9.77	2.48	10.95
C4071	[5] M_2	38–66	2.31	7.98	3.26	5.67	1.360	1.70	5.87	2.40	10.12
C4072	[5] U	66–75	2.48	9.77	3.32	5.67	1.420	1.75	6.88	2.34	9.81

[1] Oxides of magnesium, calcium, potassium, and sodium.
[2] Water of combination plus water equivalent of the bases.
[3] Water of combination plus water equivalent of the bases, corrected for organic matter and carbonate content.
[4] Wooster soils only tentatively listed in the Miami family.
[5] Horizon designation used by the Indiana Soil Survey; see 11.

The silica-sesquioxide ratios of the whole group of colloids range from 2.12 in the C_1 horizon of the Wooster to 3.04 in the A_1 horizon of the Bethel silt loam. A comparison of the silica-iron oxide ratio and the silica-alumina ratio shows that iron rather than aluminum is the cause of most of the variation of the silica-sesquioxide ratios. It appears certain that iron oxide has been fractionated in reference to silica but that alumina has not. This is not quite as clearly demonstrated in the Wooster as in the other profiles.

The silica-base ratios indicate a moderate amount of leaching, greatest in the first three horizons of the Bethel and least in the U horizon of the Brookston. These ratios also indicate the accumulation of bases in the surface layer by organic matter and the less complete removal of them from the colloids in the deeper parts of the profiles. The low numerical value of the silica-base ratios in most parts of the profiles suggests that the colloids are fairly well saturated with bases. This is expected as the soil profiles still contain large quantities of incompletely altered residual feldspar, mica, hornblende, and other primary minerals. Special attention is called to the depletion of bases in the A horizons of the Bethel (Planosol) that are in marked contrast to the high base content in the Brookston and Clyde (Half-Bog and Wiesenböden, respectively).

The water in the remaining ratios in table 9 is obtained by adding the water equivalent of the bases to the equivalents of combined water, the water loss between 110° C. and the ignition temperature. As the combined water is obtained by subtracting the organic matter and carbon dioxide (table 7) from the ignition loss, these values are affected by uncertainties involved in the calculation of the organic matter. Nevertheless, these ratios indicate in part the relative hydrolysis the colloids have undergone. The silica-water ratio is stated inversely to the other ratios involving water largely because of the acidic behavior of the silica and the generally basic character of iron and aluminum in the clay minerals of the colloids.

Although it cannot be stated precisely, the ratios involving water show certain trends with depth. For the most part, the silica-water ratios increase in the deeper parts of the various profiles, the water-alumina ratios are more nearly constant, and the decrease with depth of the water-sesquioxide ratios is largely caused by the greater abundance of iron oxide in the lower parts of the profile. The decrease with depth is, therefore, more marked in the silica-iron-oxide ratio.

Of this whole group of ratios, it is apparent that the silica-alumina and water-alumina ratios are more constant than the others. Within each profile they are still more constant. This constancy, as well as a small variation in the percentage of the combined water of the soil acid, suggests that the bond between these three major constituents of the colloid is closer than with the others. It also suggests that the colloid complex is largely composed of a complex silicate or mixture of silicates whose components do not vary widely from profile to profile and even less from horizon to horizon.

The Clay Minerals

Of the four major constituents—silica, alumina, water, and iron oxide—the first three form the framework of the colloids. A part of the iron is combined as a silicate, and a part apparently consists of free ferric oxides as the ocherous color of parts of the profiles suggests. In most of the colloids the amount of free iron oxide is apparently small. The average formula ratio of the 48 colloid samples is 2.49 $SiO_2.Fe_2O_3+Al_2O_3.1.92\ H_2O$, if all the iron is combined, and 3.22 $SiO_2Al_2O_3.2.53\ H_2O$, if it is not. If iron oxide is ignored, it is apparent that the simple average formula ratio approaches closely to the simplified formula of 3 $SiO_2.Al_2O_3 \times H_2O$. In these formula ratios, the combined water is that retained at 105° C. A part of this may not be water of constitution.

Many clay minerals, such as hydrous mica, illite (*1*, *15*), beidellite (*19*), and montmorillonite (*29*), have been identified in colloids. In these simple formula ratios the structural importance of potassium in hydrous mica (*15*) and certain relationships of other constituents in the various clay minerals are not considered. Possible structures have been discussed by Marshall (*21*), Hendricks and Alexander (*16*), and other investigators. No attempt will be made to discuss the possible substitutions and arrangements, but it is presumed that one of these clay minerals makes up a large part of the colloids of this group of soils.

A Miami colloid from Grant County, Ind., not far from where the samples of Crosby and Brookston were obtained, is reported by Alexander, Hendricks, and Nelson (*1*) to contain about 80 percent hydrous mica, 10 percent kaolin, and 7 percent free iron oxide. In the analysis of this colloid montmorillonite was not differentiated from hydrous mica.

In order to obtain an estimate concerning the quantities of clay minerals in the soil colloids, a representative group of colloids from the subsoils of the Miami, Hillsdale, Bethel, and Brookston soils were submitted to S. B. Hendricks and L. T. Alexander for approximate quantitative determination of the clay minerals in them. The determinations were made by the improved methods completely described by Hendricks and Alexander (*16*). Hendricks has reported that the colloids are closely similar in mineralogical composition. They contain about 10 percent kaolinite. They differ in thermal decomposition and in base exchange behavior. Montmorillonite varies from 10 to 25 percent, and the remainder consists of hydrous mica. The probable accuracy is not closer than several percent.

In view of the fact that these representative colloids from four of the profiles are so similar in mineralogical and chemical composition, it is quite possible that the fundamental differences in morphology between the Planosols and the Half-Bog soils on the one hand, and between the Planosols and the Gray-Brown Podzolic soils on the other, may be caused by the relative base saturation of their colloids as well as other conditions not disclosed by the data. It is recognized that organic matter plays a role of the first order in the morphology of the soil. The state of oxidation of the iron may also be of equal importance. Differences in pH reaction of different horizons, although caused by a variety of factors, within individual soil profiles and in corresponding horizons in different profiles suggest that more detailed information concerning the degree of base saturation of the colloids would explain more completely some of the differences in the morphology of the soils.

GENERAL DISCUSSION

The data discussed in the previous section show that in certain respects the various soils are similar in chemical properties in spite of the fact that some of the physical properties are strikingly different. Members of the Miami family are similar to each other in physical properties, but individual members of the Miami catena differ one from another in several respects.

Chemical similarity of the mineral part of the soil material is expected in a group of soils like the Miami family that have developed from essentially the same kind of parent rock under similar vegetation and climatic and drainage conditions, but it is not expected to the same extent in soils that are developed under different moisture conditions. Many of the differences between the soils are directly attributable to variations in drainage resulting largely from the local relief of the materials on which the soils have developed. The following factors each have a bearing on the morphology of the soils: (1) The parent rock, (2) climate and vegetation, (3) the lay of the land and natural drainage, and (4) the length of time the soil has been in formation. The last factor is probably nearly the same for all of the soils examined in this study.

THE PARENT ROCK

The parent rocks of all of the soils discussed have much in common with each other, but there are also certain important differences.

Although all of the soils developed are over unconsolidated glacial till or glacial outwash materials of Wisconsin age, there is some basis for supposing that part of the mineral portions of the soils consists of wind-blown silty loess, but it is not possible to say with certainty whether, or how much, loess is present, or how important it is. It appears certain, however, that both the glacial till and outwash deposits have been modified somewhat by frost heave and mixing effects of freezing and thawing, as well as by the activities of burrowing animals. Burrowing animals have caused more thorough mixing of the first few feet of the earth's crust than visual evidence discloses a few years after their operations. This factor is recognized as a continuous process. It was estimated by Darwin (*11*) that under favorable circumstances earthworms annually bring to the surface one-fifth inch of the earth. The quantities moved by larger animals too often escape detection or are ignored.

The glacial till of the Wooster soils is made up largely of rock flour and small fragments of fine-grained sandstone, siltstone, and shale. Although the soil was sampled to a depth of only 4 feet and, unlike the other soils, no appreciable quantities of carbonates were discovered to that depth, it is quite likely that there is an appreciable quantity of limestone in the unleached portion of the till at a depth somewhere between 6 and 10 feet. All of the other deposits are medium to strongly calcareous and have been leached to depths ranging from less than 3 feet to about 5 feet. The Hillsdale fine sandy loam is developed from a till that is high in sandstone and contains a moderate amount of fragmentary limestone. All of the rest of the soils are developed on strongly calcareous deposits, and the proportion of magnesium in the limestone fragments is often high enough to suggest that it is dolomitic.

Climate and Vegetation

As has already been mentioned, climatic conditions over the area covered by the soils sampled do not vary greatly. A vegetation of hardwoods originally covered practically all of the soils, but the type of hardwood cover varied considerably. On the well-drained soils the dominant cover consisted of oak, hickory, and maple. On the Planosols beech and elm were very abundant and the proportion of oak was somewhat less. On the Half-Bog soils the native swamp-forest association consisted of elm, basswood, and several other water-loving species. The original forest cover on the Clyde soils was sparse, and there were many spots where marsh vegetation was dominant.

Lay of the Land and Natural Drainage

For the most part the lay of the land, as this descriptive term suggests, largely controls the natural drainage conditions of soils, although there are many exceptions. Convex surfaces tend to shed water, and depressions and concave slopes tend to accumulate water if the soils and underlying materials are not excessively pervious. The well-drained Miami, Wooster, and Hillsdale soils owe a considerable share of their good natural drainage to the fact that they occur on convex slopes of sufficient gradient to encourage runoff following rains. Underlying materials are sufficiently pervious to permit at least a moderate rate of downward movement of water through them, although parent rocks of the Hillsdale fine sandy loam are the most permeable of the three. On the other hand, the Bethel silt loam occurs on level land and the Crosby silt loam on nearly level land. The surface runoff of both soils is very slow and the water stands on them for short periods following rains. The water runs off of the very gently sloping Crosby soil more rapidly than from the more level Bethel. The underlying glacial till is only moderately pervious in both soils so that downward movement of water through them is fairly slow. Furthermore, clay pans have developed in both of these soils, which still further retard the downward movement of water. Brookston and Clyde soils occur in depressions where the natural surface outlets are higher than the level of the soils, and the only time water drains from the surface is when a sufficient amount accumulates to overflow the high outlets. Movement of water through the underlying till of each soil is rather slow, so that they remain wet during a greater part of each year. This is in marked contrast to the Crosby and Bethel soils, which become very dry during the late summer when rainfall is low and the temperatures are high. Although the Brookston and Clyde soils have heavy subsoils, the structure of each is such that drainage is fairly rapid through the subsoils if outlets in the form of tile drains or ditches are provided.

The Fox soils are developed on glacial terraces whose surfaces may range from level to gently rolling. The soil analyzed in this study was taken from a level area. In spite of the lack of relief, Fox soils are always very thoroughly drained. On level areas the water penetrates the soil and is drained away through the underlying gravel, so that level areas of Fox soils are even more thoroughly drained than gently to moderately sloping areas of Miami soils. It may be mentioned, however, that all gravelly materials are not necessarily well drained. The very light-colored Homer soils, that have about the same drainage conditions as Bethel soils, as well as the dark-colored Westland and Abington soils that correspond in drainage to the Brookston and Clyde soils, are sometimes found on the same terraces with Fox soils. Such soils are poorly drained and almost permanently wet, in spite of their gravelly subsoils, because there is no outlet for drainage waters where they occur.

The structure (22) is an important feature modifying the permeability of many soils. In some of the soils internal drainage conditions are better than the texture of the soil material would suggest. The importance of the structure of a soil must not be underestimated. Structural aggregates function somewhat in the same way as sand, gravel, and larger rock fragments in the soil in that they permit water to pass through the crevices between them. Drainage through some rather clayey soils may be as rapid as through more sandy and gravelly deposits as long as the aggregates retain their form and the pore spaces between them.

The development of crumbs and granules in the A horizons of the well-drained soils of the Miami family permit easy penetration of percolating water. The removal of clay from the A horizons, either as a sol or in solution, leaves behind a light-colored soil beneath the dark A_1 horizon that is streaked by accumulated organic matter. This layer takes on a phylliform or very thin platy structure if the material is very silty, but the plates do not interfere materially with the downward movement of water. The B horizons generally have assumed a state of aggregation in which the individual aggregates are shaped somewhat like small hickory nuts and filberts. The aggregates of the B_2 horizons are more or less subangular in shape and each aggregate has a thin coat of colloid on the surface. The aggregates become more sharply angular with depth and have the form of small- and medium-sized blocks in the B_3 horizons. The vertical breakage in the B horizons is more pronounced than horizontal breakage, so that the individual aggregates appear to be heaped one upon the other in the form of irregular prisms or columns.

The averages of clay content in the A and B horizons of the Miami silt loam are 15.6 and 32.3 percent, respectively: of the Wooster silt loam, 13 and 22.1 percent; of the Hillsdale fine sandy loam, 7.3 and 16.4 percent: of the Fox silt loam, 4.5 and 37.7 percent; of the Crosby silt loam, 17.1 and 35.3 percent; and of the Bethel silt loam, 13.8 and 32.3 percent, respectively. The quantities of clay in the B horizons of each soil are 2.1, 1.7, 2.2, 2.6, 2.1, and 2.3 times as much as in the A horizons, respectively. The near uniformity of these numbers suggests that the transfer of clay in these five soil profiles is not dependent on texture. The structure of the soil may compensate for textural differences. The present permeability of the Crosby and Bethel is not as good as in the Miami, Wooster, Hillsdale, and Fox profiles. The clay pan developed in the Crosby and Bethel retard the movement of water. This is indicated by their waterlogged condition following rains.

Unlike the Crosby and Bethel soils the Brookston and Clyde have not developed clay pans. Poor drainage in the Brookston and Clyde is caused by their low drainage gradients. Water stands on them during much of the year unless drainage is improved by tiling or ditching. The water table of the Brookston profile examined has been lowered by tiling, and it is uncertain how much movement of clay has occurred since. The proportion of clay in the H horizons as compared to the M suggests that if translocation occurred, the profile was as permeable as the better drained soils. No translocation of clay apparently has occurred in the Clyde silty clay. Horizons H_2 and H_3 appear to contain a little more clay than other horizons, but if the clay content of the first three horizons is corrected for organic matter, the percentages are 47.3, 47.9, and 46.2, respectively, and the decrease in the quantities of clay is rapid below them.

The effect of drainage is reflected rather distinctly in the greater acidity in certain parts of all the soils. The lowest pH values found in the Miami, Wooster, Hillsdale, and Fox are 5.2, 4.4, 4.6, and 4.6, respectively. The lowest pH values found in the Miami, Crosby, Bethel, Brookston, and Clyde profiles are 5.2, 5.3, 5.3, 6.4, and 6.4, respectively.

It may be further noted in the last group that the acidity is greater where the drainage through the profile is more thorough. The alkalinity is greater in those profiles that receive the greater amount of drainage water from the surrounding slopes. It is apparent that the alkalinity is at least partially maintained in the lower members of the catena by bases dissolved from the soils of the surrounding higher land. It is noted that the lowest pH of the Brookston and Clyde profiles is approximately the same as the pH of the A_1 horizons of the Miami and Crosby that often occur on their borders.

It is apparent in table 4 that degree of removal of carbonates does not depend on the excellence of drainage in the soils. All but small quantities or traces are leached from the solums of all but the Clyde profile. The first four horizons of this swampy, poorly drained soil contain no carbonates and the quantity in the M_2 horizon is very small. The depth to abundant quantities of carbonates is 66 inches in the Clyde soil, 44 in the Brookston, 30 in the Bethel, and 36 in the Crosby and Miami. Traces remain in parts of the Wooster, although the parent material at the depth sampled is very low in carbonates as compared with the other soils. The surface horizons of the soils often contain more carbon dioxide than other parts of the solum.

Probably the decaying vegetation in the swampy Clyde soil supplies greater quantities of carbon dioxide for solution of the carbonates than in the better-aerated, better-drained soils. The subsurface drainage of water is slower and more continuous than at the surface of the soils. Very little surface water is drained from the Clyde soil. This assures a more continuous supply of water moving through the Clyde than in the soils farther up the slope. To this steady supply is added the surface wash from the adjacent slopes, so that the Clyde may receive several times as much water as falls on it in the form of rain. These conditions apparently have caused the complete removal of the carbonates from the first four horizons of the Clyde and an incomplete loss of them in the better drained soils.

It is necessary to turn to the colloids of the soils to note the effect of drainage on the more insoluble constituents (tables 6 and 7). No general trend with improvement in drainage is noted except in their content of silica. The colloids of the Miami family contain less silica than those of the imperfectly and poorly drained members of the Miami catena. This is more noticeable if the data are corrected for organic matter as in table 7. The profile averages of the Miami, Wooster, Hillsdale, and Fox are 46.31, 44.18, 44.42, and 46.61; of the Crosby, Bethel, Brookston, and Clyde, 48.33, 50.09, 47.92, and 48.22 percent, respectively. The same general decrease of the quantities of silica in the soils with better drainage is also noted in the Norfolk catena from the southeastern part of the United States (*78*).

It is impossible with the data at hand to correlate these data with the probable permeabilities of the profiles, but it may be noted that somewhat more silica is lost from the colloids of members of the Miami family than is lost by the imperfectly and poorly drained members of the Miami catena. It may be further noted (tables 3 and 7) that an increase in the quantities of iron oxide and alumina in members of each group roughly corresponds to an increase in the clay in the horizons of greatest accumulation. This is accompanied by a corresponding loss of silicate silica and accompanying bases. It appears probable that better drainage in the Miami family is a direct cause of the greater loss of silicate silica in the colloids of its members, as compared with the imperfectly and poorly drained members of the catena.

These changes as caused by differences in drainage are also noted in table 9. The silica-base ratios of the colloids of the Miami family, for the most part, are higher and the silica-water ratios are lower than those of the imperfectly and poorly drained members of the catena. This also indicates greater hydrolysis of the colloids, greater removal of silicate silica, greater permeation of the profiles by water, and more thorough, as well as more frequent, leaching of the colloids of members of the Miami family by percolating rainwater than has occurred in the imperfectly and poorly-drained members of the catena.

Living plants resist the leaching action of water and cause a circulation of essential plant constituents upward. Robinson et al. (*38*) have shown that the ash of trees, legumes, and grasses—some found growing on the Miami and associated soils—are high in calcium, potassium, phosphorus, and sulfur; the percentages of the oxides in these elements may be as high as 2.72, 4.22, 0.71, and 1.01, respectively. In table 4 it appears certain that a part at least has been retained by the incompletely decayed-plant remains in the upper horizons of the soil. This is even more evident in the analyses of the colloids recorded in table 6, as the colloids extracted from the soil are essentially uncontaminated by primary minerals and for the most part contain more organic matter than the soils.

The general tendency of manganese to be high where organic matter is high suggests the association in both soil and colloid. Nevertheless, this may be due largely to better aeration in the upper parts of the profile and in the deeper parts to calcium carbonate. According to Robinson (*36*) manganese, apparently, is precipitated through the agency of calcium carbonate. Aeration becomes less effective as drainage decreases, carbonates move downward during profile development, and other conditions modify the effectiveness of both to precipitate manganese—the first, in the first few horizons; the second, in the last few horizons of the profile.

Most of the soils show a striking increase in iron and phosphorus as well as an increase in alkalinity just above the carbonate layer. In a few soils, organic matter has accumulated in the C horizon. Presumably the phosphorus is precipitated with the iron, with the organic matter, or both, as iron compounds and calcium humate (*13*) become more insoluble near neutrality (*11*).

The data as a whole suggest that drainage must be very poor for eluviation of the clay to be prevented. It is also evident that the iron in the colloids has been fractionated and eluviated regardless of drainage conditions. All of the carbonates have been leached from the H and M horizons of the Clyde silty clay, and nearly all have been leached from the solums of the other soils. The activity is greater in the better-drained soils, but in the Clyde silty clay the H_1 horizon is only slightly acid, the H_2 is neutral, and the M horizons are slightly alkaline in reaction in spite of the fact that all but the M_3 horizon is completely free from carbonates. This, together with the strong state of aggregation of the soil in the various horizons, is a clear indication that the colloidal complexes are dominated and conditioned by the combined or the adsorbed calcium.

In Gray-Brown Podzolic soils generally the only marked chemical evidence of podzolization is the fractionation of iron and the leaching of divalent bases. This is shown by the analysis of these soils as well as by the large group of analyses of the Miami and the Chester profiles presented by Holmes and Edgington (*17*) and of the Chester and Manor profiles by Brown and Byers (*6*). If the analyses are corrected for organic matter it is still more evident that only iron has been fractionated and transferred to the deeper parts of the profiles during the formation of a Gray-Brown Podzolic profile.

In the Podzols and Brown Podzolic soils, however, the analyses of the Brassua, Hermon, and Gloucester presented by Brown and Byers (*6*), as well as those of the Caribou and Au Train presented by Byers, Alexander, and Holmes (*7*), indicate that aluminum as well as the iron is fractionated and eluviated. Marbut (*20*) notes that—

these soils occupy a region in which the rainfall is high and the temperature low, as compared with that of the rest of the United States, or areas where the soil material consists mainly of sand which is readily attacked by the forces of leaching.

He also notes that these soils—

have developed under forest cover, but for the most part under a cover containing a somewhat larger percentage of conifers and of plants which flourish on an acid soil than is the case with other members of the Pedalferic group.

It is, therefore, apparent that the high rainfall, good drainage, and thorough leaching in the permeable, acid sandy soils cause the fractionation of aluminum as well as iron in the Podzols. As a further consequence of rapid drainage in them, the bases are more thoroughly leached, less circulation of bases by the acid-loving plants takes place, and the aluminum and iron silicates approach more complete dissolution in the more acid parts of the Podzol profile.

In the few clayey Podzol profiles studied, the structure of the soil permits free drainage in the altered parts. In the last analysis the development of a soil profile depends on the quality of drainage; other factors define it.

In a climate where the temperature and rainfall are higher than in the more northerly areas of the Podzols and the Gray-Brown Podzolic soils, still greater destruction of the minerals and greater leaching of the profiles occur. This is evident in the Norfolk and associated soil series discussed by Holmes, Hearn, and Byers (*18*). The catena relationship of this group of soils, however, like the Miami catena, is owing largely to variations in topographic position and resultant drainage of each member. The Norfolk and associated soil series are, therefore, members of a soil catena. Soils of the Norfolk catena are developed from materials that originally contained smaller quantities of bases than soils of the Miami catena. Furthermore, the Norfolk and associated soils probably have been exposed to weathering much longer than the soils of the Miami catena.

In both the Miami and Norfolk catenas the loss of silica in the colloids with respect to the sesquioxides and the alumina is greater in the better-drained members of each, but the differential loss of silica is certainly more marked in the members of the Norfolk catena where rainfall is higher and the climate warmer. The mean annual rainfall on soils of the Miami catena is 35 to 40 inches and on soils of the Norfolk catena it is 50 to 55 inches. The mean annual temperatures are 50° and 60° F., respectively.

The remarkable variation of the silica-base ratio of the colloids with the depth of the profile of members of the Norfolk catena is caused by their relative position on an old undissected tableland. The drainage of the soils near the streams bordering the tableland is good; it becomes poorer in those along the gentle slope to the swampy central depressed part of the area. As the high rainfall in the hot summer months maintains the swampy condition, hydrolysis of the soil minerals is great. During seasonal abundance the water overflows the slightly elevated margins of the basin, taking with it the liberated bases and other soluble products somewhat in proportion to the duration of hydrolysis and continuous wetness of the profiles.

These conditions cause the acidity of the soils of the Norfolk catena, developed on well-weathered Coastal Plains material, to increase as the drainage becomes poorer. The lowest pH of the swampy soil of the Norfolk catena is 3.8. The soils of the Miami catena, unlike those of the Norfolk catena, are developed on comparatively unweathered Wisconsin glacial drift and the drainage water, therefore, carries a rich supply of bases to the swampy Clyde soil. Its lowest pH is 6.4. Better drained members of the Miami catena may have a pH as low as 5.2, but the pH is usually higher than in the Norfolk.

As a whole, it is obvious that the local drainage conditions of a soil, and the length of time they and the climate have operated, greatly influence the character of the soil profile. It is equally obvious that the character of the parent material is an important factor in governing the profile development of a soil, especially where the period of development is relatively short. Parent rock is too often ignored or minimized.

This study shows that the soils listed as belonging to the Miami family resemble each other in most important respects, but the Wooster silt loam differs from the other members of the family in so many minor respects that it may prove to be better classified in another family. A final decision will require further study.

As the conventional laboratory investigations followed in this study do not explain completely the causes of many of the important morphological features of the soils noted in the field studies, it would seem desirable to extend the study to other properties. The data presented suggest that the base exchange capacities, the degree of base saturation of the colloids, and the determination of the proportions of the principal soil-forming minerals may explain more fully the morphological features of the soils and their various relationships.

SUMMARY

The morphological, chemical, and physical characteristics of representative soils of the Miami family and of the Miami catena have been studied. The parent material of the soils is Wisconsin glacial drift. The climate and vegetation are essentially the same. The members of the Miami family have developed under similar local drainage conditions. Those of the Miami catena have not. A short discussion of the general system of soil classification is accompanied by tables and a figure of the relationships of the members of the Miami family and of the Miami catena. The description of each soil profile examined is preceded by a description of the landscape, the parent rock, and the drainage. The laboratory determinations include pH values, the mechanical and chemical analyses of the soils, and the chemical analyses of the extracted colloids, as well as the determination of the percentages of clay minerals of certain horizons of representative profiles of each group.

The analytical results and certain other data are arranged in tables and discussed in connection with the morphology of the soils and the influence of local conditions on their formation. This is followed by a general discussion of the consequence of local drainage on soil development.

It has been shown that the only inorganic constituent of the soils and their colloids that has been appreciably fractionated during profile development is iron. The illuviation of iron in the lower horizons does not vary greatly in the various profiles. Lateral subsurface drainage apparently has increased the iron content of the dark-colored swampy soils. It has been shown that the small quantities of carbon dioxide found in the leached acid portions of the soils are largely confined to discrete particles of dolomitic limestone.

It is apparent that the organic matter of the soils and colloids has been fractionated as much or more than the inorganic portion of the soils. This is indicated by the variation of the carbon-nitrogen ratios of the soils and colloids. The disagreement between the quantities of organic matter determined by hydrogen peroxide and by combustion either indicates clearly the inadequacy of both methods or remarkable fractionation of the organic matter.

It has been shown by the various derived data that the colloids of this group of soils are essentially alike. These data are supplemented by mineralogical analyses of representative samples which indicate that hydrous mica is the predominant clay mineral in the colloids. Associated with it are smaller amounts of montmorillonite and kaolinite.

It has been shown that the similarity of climate, vegetation, and parent material of the soils of the Miami family and of the Miami catena is the primary cause of their similarity of composition. The causes of certain morphological features of the soils are clearly indicated by the analytical data; the general classification of soils is not. It is suggested that the determination of the minerals of the soils and certain base exchange data may assist materially in determining the causes of the marked differences in the morphology of the soils of the Miami catena.

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