TONGUING, INTERFINGERING AND ARGILLANS IN THE MARLETTE AND MIAMI SOILS: THEIR GEOGRAPHIC DISTRIBUTION, GENESIS, MORPHOLOGY AND IMPLIED PRACTICAL DIFFERENCES

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ABSTRACT

TONGUING, INTERFINGERING AND ARGILLANS IN THE MARLETTE AND MIAMI SOILS: THEIR GEOGRAPHIC DISTRIBUTION, GENESIS, MORPHOLOGY AND IMPLIED PRACTICAL DIFFERENCES

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Field studies and laboratory determinations were conducted on a Typic Hapludalf (Miami) and a Glossoboric Hapludalf (Marlette), which are genetically related and commonly associated in southern Michigan.

The purposes of the study were to investigate the geographic distribution, properties and genesis of the two soils.

The distribution of these soils has been found to depend on local factors, among which the surface texture of the original glacial sediment seems to be the leading factor. A soil-plant relationship could have been involved as an additional factor, but this hypothesis could not be evaluated.

Field observations and fabric analyses have shown that tonguing and interfingering are created by a gradual destruction of a former B horizon by migration of the clay fraction from that horizon. This causes the silt and the fine sand fractions to become more exposed and free to migrate or collapse into interstitial openings created

by root activities and cracks due to freezing and thawing, or wetting and drying.

X-ray studies and fabric analyses have demonstrated that in spite of some possible formation of clay within the profile, the bulk of clay accumulation in the B is due to illuviation of the silicates minerals as discrete particles.

Fine clays are dominantly made of illite and montmorillonite and are thought to have accounted for a substantial proportion of the moved clays.

Over all, the Marlette appears to be a more deeply leached soil than the Miami. This is also shown by a general tendency for the Marlette to have a lower pH and lower percentage of exchangeable bases.

The tonguing and interfingering can be seen as a more advanced stage of profile development which links somehow the Marlette soils to some of the Intergrade soils transitional to the Spodosols. It is believed that, given enough time, the Miami soil will eventually reach a similar stage and will show most of the features commonly recognized in the Marlette series.

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By

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I. INTRODUCTION

The Miami and Marlette are two similar soil series from Michigan that are genetically closely related and commonly associated in the field.

The Miami series generally consists of well drained, medium textured soils that formed in calcareous loam and silt loam glacial till. Typical profiles of the Miami show a sequence of horizons consisting of an Ap (Al) horizon, an A2 and a Bt overlying a calcareous C horizon.

Like the Miami, the Marlette is a well drained, medium textured soil that has developed from calcareous loam till; it also has an A2 and a textural Bt horizon in which silicate clay minerals have decreased and accumulated, respectively. Unlike the Miami, however, the Marlette, in undisturbed areas historically possessed an upper sequum consisting of a sandy loam overlying a loam or sandy loam Bir (horizon of accumulation of organic matter, Al_2O_3 and iron oxides above the sequum). But as native vegetation was destroyed and the soil put under cultivation, the upper sequum was commonly incorporated into the plow layer. Associated with this soil is also the infiltration of the lower A2 horizon in the form of interfingering or tongues into cracks or between aggregates in the upper part of the B2t horizon.

In the new system of soil classification, the morphological differences between the two soils have been recognized at the subgroup level. The Miami soil is known as a Typic Hapludalf, a well drained soil series characterized basically by an accumulation of layer lattice silicate clays in the Bt horizon, while the Marlette is known as a Glossoboric Hapludalf--an Alfisol showing in addition to accumulation of silicate clays, in the Bt, extensive A2 materials in the Bt horizon as interfingerings and occasional tongues.

Accumulation of clay minerals has itself been diversely interpreted. It is possible that this accumulation is caused by active neoformation of colloidal minerals inside the B or it may be due to accumulation of the clay by migration of these materials from the upper part of the profile.

The objectives of this study were to:

1. Investigate soil formation factors associated with the differences in these two soils, Miami and Marlette; i.e., the formation of the tonguing or interfingering of the A2 into the Bt.

2. Study the pattern of geographic distribution of the two soils in Southern Michigan.

3. Conduct appropriate field and laboratory investigations to establish the morphology and genesis of the diagnostic characteristics of these two series.

4. Summarize the practical significance of these soil differences in land use and management.

II. LITERATURE REVIEW

1. Gray Brown Podzolic Soils and Podzol Intergrades

Within the North Central and the Northeastern United States extends a group of soils that have been developed in a humid, temperate environment, under a forest cover consisting chiefly of oak-hickory and beech-maple associations. These soils have been formed predominantly from glacial drifts of mixed lithology and well supplied with clay forming materials.

The profiles of these soils from loamy till exhibit a specific morphology consisting essentially of the following sequence of horizons: an A2 (Ap), 8 to 20 cm. thick, of loamy texture; a grayish A2, 7 to 12 cm. thick; a transitional A3/B1 layer; a Bt horizon, dark brown in color and significantly finer in texture than the overlying horizons; a B3 horizon, coarser in texture than the Bt and transitional to the C horizon which is essentially a calcareous loam.

The A2 is a mineral horizon from which clay, iron and aluminium have been removed with subsequent concentration of quartz or other resistant minerals of sand and silt sizes. The Bt horizon is an illuvial horizon characterized by concentration of silicate colloidal materials removed from the upper part of the solum (Soil Survey Staff, 1960). This B2t horizon has a characteristic reddish-brown color and a well defined structural development enhanced by the presence of coatings on most of the peds by colloidal mineral particles.

Since these soils occupy a very large portion of the landscape in Southern Michigan, Northern Indiana, Northern Illinois and Northern Ohio, they have been, in these states, the subject of intensive field studies and laboratory characterizations (Baldwin, 1937; Thorp et al., 1959).

Prior to 1950, these soils had been known as Gray-Brown Podzolic soils, an intermediary group of zonal soils between the Podzols to the north, and to the Red Yellow Podzolic soils to the south.

In Michigan, these soils occupy an extensive area that coincides with the boundary of the fine to medium textured till plains and moraines deposited during the Wisconsinan glaciation--extending from the Ohio-Indiana border to the South, to the Podzols or Gray Wooded soils on the North. The Podzols and Gray Wooded soils have developed in a colder, more humid environment, under a vegetation of mixed hardwoods and/or conifers.

The boundary between these soils and the Podzols is not sharp; rather, it is transitional, with the development of intergrade soils showing some profile characteristics similar to both those of a Podzol and a Gray-Brown Podzolic Soil. Gardner and Whiteside (1952) have studied these intergrade soils, and have suggested an outline showing their spatial distribution throughout central Michigan. Profiles studied by those authors on a lithosequence succession from medium sand to silty clay loam have shown a more pronounced development of podzol features as the texture of the parent materials becomes coarser.

Frei and Cline (1949) have similarly studied and described sequences of soil groups and intergrades developed from glacial till deposits in New York State; they presented evidence that with time, a Brown Podzolic solum will develop in a former Gray-Brown Podzolic soil in Central and Western New York.

Soil bodies are continuums which vary with soil formation factors (Jenny, 1941). Along the continuums, there are places where the characteristics of these bodies are expressed to the maximum level established for the typical model, while in other places, these bodies are similar to "hybrids" with less contrasting characteristics and with features belonging to the adjacent typical models.

Soil profiles have been visualized as complex bodies made up of single components acting as microprofiles and whose morphology is diagnostic of the genetic orientation within the profile (Heil and Buntley, 1965). On typical zonal soils, an analysis of the distribution of the single features is likely to show that each feature reinforces the final characteristics of the composite body. But in other cases, the observations of selected features show evidence of conflicting processes within a very short distance (Remezov, 1932). These cases, rather than leading to confusion, illustrate the dynamism of the processes that take place in the formation of soils and, as suggested by Heil and Buntley (1965), some of these features represent higher stages in the known development sequence of these soils and appear to be diagnostic of the direction of genetic intergradation within the macroprofile.

Intergrade soils of the North Central and Northeastern U.S. have been recognized and described (Marbut, 1935; Lyford, 1946; Cline, 1949; Frei and Cline, 1949; McCaleb and Cline, 1950; Gardner and Whiteside, 1952), but because the soil systematics and terminology then in use were not adequately developed, these soils have been mentioned in descriptive terms such as "immature" or "incipent" soils to differentiate them from the mature or true zonal soils recognized at that time.

The deficiencies in the nomenclature at the lower levels of classification have been corrected with the adoption of the new system of soil classification (Soil Survey Staff, 1960; Soil Conservation Service, 1975) which is based essentially on identification of quantitative genetic features of soil profiles and their recognition at all levels of classification.

The following case, which is of immediate interest herein, since it constitutes the basis of this research work, is used as an example to show how specific features can be recognized at different levels of the taxonomy.

Gray Brown Podzolic soils of the North Central and the Northeastern United States have been recognized as Alfisols in the new classification. The well drained soil series that show no other diagnostic genetic features than the presence of an argillic horizon are known as Typic Hapludalfs.

For the other members that show development of tonguing and interfingering (see definition later), the prefix "gloss-", meaning tongue, is used. This addition can be done either at the great group level--Glossudalfs (members in which the tongues commonly extend throughout the argillic horizon)--or at the subgroup level--Glossoboric Hapludalfs (members in which there is some evidence of destruction of the argillic horizon in the form of albic materials interfingering into the argillic horizon).

All these soils and some others were similarly recognized as Gray Brown Podzolic soils or Gray Wooded soils in the old system of classification (1949), while they have been recognized separately in the new soil taxonomy (Soil Conservation Service, 1975).

2. Tonguing and Interfingering

a. Definition of terms

The Soil Conservation Service (1975) has given the following instructions for recognition and identification of tongues and interfingering.

> Tongues of *albic* materials consist of penetration of bleached materials that have the color of an albic horizon in an argillic horizon or a natric horizon along ped surfaces, if peds are present....The penetrations have a vertical and horizontal dimension in any argillic or natric horizon. Their horizontal dimension is 5mm or more in a fine textured argillic or natric horizon and 10mm or more in a moderately fine textured argillic or natric horizon and 15mm or more in medium or coarser textured argillic or natric horizon. The penetration must occupy more than 15 percent of the matrix of some part of the argillic or natric horizon before they are considered *tongues*.

> The following are the requirements for interfingering:

> Interfingering of albic materials consists of penetration of albic materials into an underlying argillic or natric horizon along faces of peds, primarily along vertical faces, but to a lesser degree along horizontal

> faces. The penetrations are not wide enough to constitute tonguing, but they form continuous skeletons more than 1mm thick on the vertical ped faces which means a total width of more than 2mm between abutting peds....

To be recognized as interfingering, all of the following must be met.

1) The horizon must be 5 cm or more thick.

2) Half or more of the matrix must consist of peds of the argillic or natric horizon.

3) Clay skins must be present in the peds or at least in the pores.

The following are the requirements for colors.

> If value dry is 7 or more or value moist is 6 or more, the chroma is 3 or less. If the value dry is 5 or 6 and the value moist is 4 or 5, the chroma is closer to 2 than 3.

Albic materials are materials originated from an albic horizon which may itself be defined as

> an horizon from which clay and free iron oxides have been removed or in which the oxides have been segregated to the extent that the color of the horizon is determined by the color of the primary sand and silt particles rather than by coatings on these particles....There may be coatings on the particles, but they are so thin and discontinuous that the hue and chroma are determined chiefly by the color of the sand and silt particles. Color requirements are as described under tonguing and interfingering.

b. <u>Origin and formation of tongues</u>

Many theories have been proposed to explain formation of tongues in soil profiles.

Ranney and Beatty (1960) have presented evidence that the upper albic tongues were formed primarily by clay removal followed by physical movements of materials low in clay, into cavities within the soil; such cavities could be created by desiccation cracks, root channels or animal burrows.

Suita and Terelac (1963) have studied pockets and veins of albic materials distributed in the illuvial horizon of certain loess soils of the Antopol area; they interpreted the sharp boundary between the peds of the A2 and of the B in a single horizon as a sign of absence of genetic association between these features. They concluded that the deformations and transportation of the mass are made by upward pressure of gases from the soil to the atmosphere. They cited evidence of marked pressure increases that develop as dry soil masses containing some amount of fine materials are subjected to wetting. They further studied the different factors more likely to be responsible for these deformations, and found that texture is the primary element. Through model experiments they found that the pressure developed on wetting of a soil mass is dependent mostly on mechanical composition and profile texture of the solum; maximum development seems to occur in medium textured deposits. Those features are not likely to develop easily on coarse textured soil masses because the presence of large pores assures a direct contact between soil mass and the atmosphere and thus prevents any pressure buildup. On the other side in fine textured soils, there is a lack of uniform network of capillary pores and consequently in such materials the compression of gases is of a local character and does not affect large soil masses.

Gaseous activities have been mentioned by others (Brewer, 1964; Buol et al., 1973) to be responsible agents in the development of vesicular structure in soil. Springer (1958) has proposed a theory describing the possible formation of vesicles of trapped air upon alternate wetting and drying of the surface soils in arid areas.

Soil features with morphology related to tongues and interfingering have been described in studies related to frozen ground phenomena (Emblenton and King, 1968). Most of those features have been found to be associated with ice segregation in supersaturated materials with texture approaching silt size. Taber (*ibid.*) mentioned that ice segregation activities were absent in materials with particle size greater than .07 mm but were easily induced in materials of grain size .01 mm or less. But in clayey materials, segregation was found to be restricted by the fine size of the pores reducing the rate of water flow to growing ice crystals.

Theoretical studies of ice segregation in soil have been conducted by Arakawa (1966), who has proposed mathematical equations for the dynamics of ice segregation; he has concluded that segregation efficiency is a function of size of soil particles, amount of water available, size and percentage of voids, and rate of cooling.

The growth of the ice masses can provide expansive forces for cracking the ground. With the approach of spring thaw, the solid crystals melt, and loose materials and debris can be washed and slump into the wedge molds whose form will be preserved in various degree. While these features have been observed to be well preserved in silts and clays, they are easily destroyed in sand and gravel. Final shape of cavities and fillings will normally depend on the general process of their formation; while wedges stand more or less vertically with sides converging with depth, round cavities will be filled by general slumping of sediments coming from above and the side (Embleton and King, 1968). Many of these frozen ground phenomena may induce development of large tongues through mixing of materials of contrasting textures.

White (1971) has described tongues of A materials in both the B and C horizons of some soils in Western Montana. He concluded that these tongues form when the surface soil slumps dry or is moistened and swells downward into natural desiccation cracks between prisms. Narrow tongues were found to be most common in clay soils while the widest tongues were more frequent in coarser textured soils. In this landscape, he thought that some of the commonly adopted theories linking formation of tongues with ice segregation phenomena were not applicable; rather, genesis of wedges was attributed to crack formation through cycles of shrinking and swelling of the soils.

Daniel et al. (1968) have observed bodies of eluvial materials enclosed in the B horizon of some Ultisols of the Atlantic and Gulf Coastal Plains. In spite of the very sharp contrast and irregular boundary between the bleached, eluvial bodies and the dark brown illuvial matrix of the B horizon, these authors theorized that these bodies are formed in place, independently of the A2 of the solum. They concluded that the illuvial portions of the solum are being destroyed by eluviation, without any other important movements.

The geographic distribution of soils showing extensive development of tonguing and related features suggests that these features are likely to be formed under a wide range of both moisture and temperature regimes (Soil Conservation Service, 1975). *Glossoboralfs* are the well drained Alfisols of the Northern regions, developed under a frigid temperature regime (mean annual temperature lower than 8 C), *Glossoboric Hapludalfs* are developed under a mesic temperature regime (mean annual temperature between 8 and 15 C), and many *Glossudalfs* developed under a thermic temperature regime (mean annual temperature between 15 and 22 C) have been described in the Southern part of the United States.

c. Summary

On the basis of the conclusions drawn by the soil scientists and geographers cited above, the following may be suggested as a summary of the genesis of tongues and related features in soils.

The eluvial albic bodies are formed primarily by discrete removal of clay materials from the upper part of the solum by percolating water. As more and more clay is removed, the coarser particles (silt and sand) left behind become loosely packed, cohesionless and more susceptible to movement or concentrate on the ped faces. Upon entering of additional water into the profile, these loose individual coarse materials become free to move downward through the interstitial openings of the profile. The distance they travel will normally depend on the flow of water, the size of individual grains and the makeup of the network of the openings or voids present in the soil. Due to their smaller size, silt particles are likely to move most. They are probably transported in a state of suspension. As the flow or film of water decreases through moisture equalization, the particles are gradually deposited on the surfaces of the peds as skeletan-coatings that are easily identifiable because of their color strongly contrasting against the basic darker tone of illuvial B horizons.

Unlike the silt particles, sand grains are difficult to be picked up and transported by water in a soil profile. A simple analysis of the Stoke's law (Tanner and Jackson, 1947) shows that particles of this size cannot remain in suspension for an appreciable length of time; consequently, their migration is probably due to gravity fall in the larger voids (cracks, cavities, wedges) mentioned above.

3. Argillic horizons

Since the formation of the tongues implies, as a beginning step, the removal of clay particles from the upper part of the solum, it becomes logical to discuss the accumulation of these fine particles in the lower part of the profile.

The formation of an horizon in which silicate clays have accumulated by illuviation has been recognized at the highest level of soil classification. Such a diagnostic horizon designated as an argillic horizon is the major requirement for the Alfisols and a large number of suborders and great groups of soils (Soil Survey Staff, 1960; Soil Conservation Service, 1975).

The current theories related to the genesis, morphology and identification of argillic horizons have been extensively reviewed (Laurin, 1973). The theory endorsed by the Soil Conservation Service (1975) is that the bulk of the silicate accumulation in these horizons is due to physical migration, although some clay may be formed in place. The continuous removal of colloidal minerals from the A horizon and the upper part of the B is expected normally to deplete completely these portions of the solum, of the fine colloidal minerals, unless more clay is released in such a way as to compensate for that loss. If removal is rapid, albic bodies will be formed intensively.

Consequently, every factor that contributes to the removal of clays must be considered as a contributing factor for the formation of the eluvial materials.

Jackson (1959), reviewing the parent material factors influencing the dynamics of soil clay mineralogy, puts a major emphasis on rate of leaching. Leaching itself is a process that is a function of other factors such as permeability of the parent material, slope, climatic factors, biotic factors and age.

The study of the combined effects of all the primary and secondary factors on soil morphology is the basic object of investigation of profile development. This is the first step in characterizing newly recognized soil series and making comparative studies of selected soils in a landscape or in a broader geographical area.

4. Study of profile development

The study of profile development refers to the study of changes relative to the original material from which the soil has been formed. There is no single, standard, unique method to study soil profile development; nevertheless, both field and laboratory determinations are involved.

Smith (1941) has pointed out all the advantages and problems in field study of profile development. Those problems stem from the importance of selection of suitable sites in such a way that actually the most important soil forming factors can be singled out and studied. The selection must be done so that one can recognize and locate those areas where the influence of change in one soil forming factor can be studied while all other factors are relatively constant. In the field, single factors are difficult to separate individually since changes in any one soil forming factor are usually associated with changes in other factors or with possible unknown changes.

Ideal situations (Smith, *ibid.*) would be to select and sample profiles which have developed with differences in only one variable, but these situations are rather rare.

In contrast to the field man, the laboratory worker in studying soil profile development is able to make quantitative evaluation by measuring selected properties of the products of alterations.

Any soil product or property that can be accurately measured in the laboratory may be used to some extent to evaluate stages of profile development. In fact, a wide array of methods have been developed for this purpose from the classical elemental sample analysis widely favored in the early days of soil classification (Jackson, 1958) to more selective differential extraction and determination more commonly used nowadays.

Marshall and Haseman (1942), theorizing that the soil profile normally displays clear internal evidence of their origin in the resistant heavy minerals that they contain, suggest that these latter may normally be used to measure soil development. They used the percentage of zircon to estimate the uniformity of the original material and the possible changes that may have occurred during the process of profile development.

Quartz has been found as a suitable resistant index mineral for conducting pedogenetic study. Quantitative determination of this mineral has therefore been performed either on whole soil samples (Phillipe and White, 1950) or in selected fractions of the soil (Cann and Whiteside, 1955).

Brewer (1964) and Barshad (1965) have extensively reviewed the different index minerals and the methods most commonly used in quantitative pedogenesis.

Differential extraction of iron, aluminium and the colloidal fraction has been found a useful tool to identify some genetic horizon and important classes of soils (McKeague and Day, 1966).

Micromorphology has been found a useful tool to observe basic changes that have occurred in soils (Brewer, 1964; Kubiena, 1934) and attempts have been made to quantify pedogenetic processes through examination of thin sections of soil (Grossman, 1964).

III. GEOLOGY AND SOILS

1. Geology and soils

The study of soil profile development becomes more meaningful when it is substantiated with a review of the geological conditions of the area. A knowledge of the stratigraphy and history of the locality may clarify many elements of soil forming factors and help establish patterns for a better field investigation.

In Southern Michigan, most of the surficial sediments are glacial deposits of Wisconsinan age (Wayne and Zumberge, 1965). These materials were deposited by the nearly simultaneous advances of several major glacial lobes affected by the trends of Lakes Michigan, Huron and Erie. Within Michigan the Wisconsinan drifts may be assigned to Cary, Mankato (Port Huron) and Valders substages according to Leighton's chronology (1960). The time stratigraphic nomenclature has been modified by Frye and Willman as shown in the following diagram.

Stratigraphic terminology in the Great Lakes is still in a state of flux and in Michigan correlation is sometimes being made by means of informal morphostratigraphic units (Farrand and Eschman, 1974).

CLASSICAL WISCONSINAN TIME STRATIGRAPHIC NOMENCLATURE

Frye and Willman, 1960		Leighton, 1960	
Valderan		Valders	
	*Two Creekan		*Two Creeks
		Mankato	
			*Bownanville
Woodfordian		Cary	
			*St. Charles
		Tazewell	

---

*Interstadial

The earliest part of Michigan to become free from ice lies just west of the line where the St. Joseph river passes into Indiana east of Cassopolis. The deglaciation of that area took place approximately 15,000 years B.P.

The ice margin then retreated to an unknown extent to eventually form two of the most conspicuous moraines in the state: the Kalamazoo-Mississinawa Morainic System (14,800 B.P.).

Through a subsequent series of retreats and advances of the ice margin, a network of morainic systems was built. The most important of these are shown in the following diagram.

All of Michigan has been free from ice for about 10,000 years. A familiarization with the chronology of the events of glaciation in Michigan should be of great help to soil scientists whenever time-related factors of soil formation have to be studied. As a

NAMES AND APPROXIMATE RELATIONSHIPS OF THE DIFFERENT MORAINIC SYSTEMS IN SOUTHERN MICHIGAN (After Martin, 1955). See also Figure 1-a.

Lake Michigan Lobe	Saginaw Lobe	Huron-Erie Lobe
Port Huron	Port Huron	Port Huron
		Yale - Adair
	Owosso	Emmet
	Flint	Grosse Ile
	Fowler	Mt. Clemens
		Detroit
Lake Border		Birmingham
	Lyons	Defiance
	Portland	
	Ionia	
	Grand Ledge	
	Lansing	
Valparaiso	Charlotte	Fort Wayne
Kalamazoo	Kalamazoo	Mississinewa
Tekonsha	Tekonsha	Tekonsha
Sturgis	Sturgis	Sturgis
LaGrange	LaGrange	

whole the surface is older in Southern Michigan and gets younger and younger towards the North.

The study of the morainic systems of Michigan may also help soil scientists recognize patterns of distribution of parent materials. In fact, tills from a given lobe or sublobe have been found to have specific ranges of properties different from those of tills from other lobes (Wayne and Zumberge, 1965; Rieck, 1976).

In general, tills from the Michigan and Erie Lobes have been found to be more clayey and silty than those from the Saginaw Lobe.

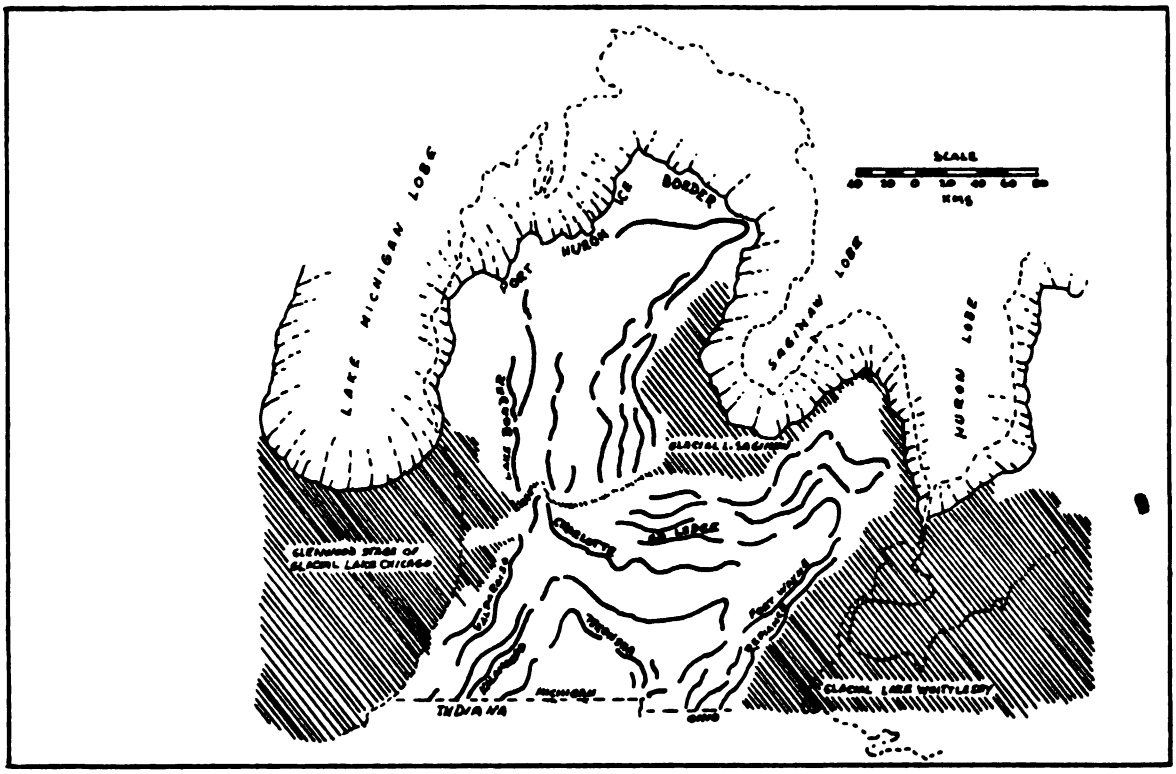

Fig. 1-a. Paleogeographic map of the Southern Peninsula of Michigan during the Port Huron (Mankato) maximum. After Wayne and Zumberge (1965).

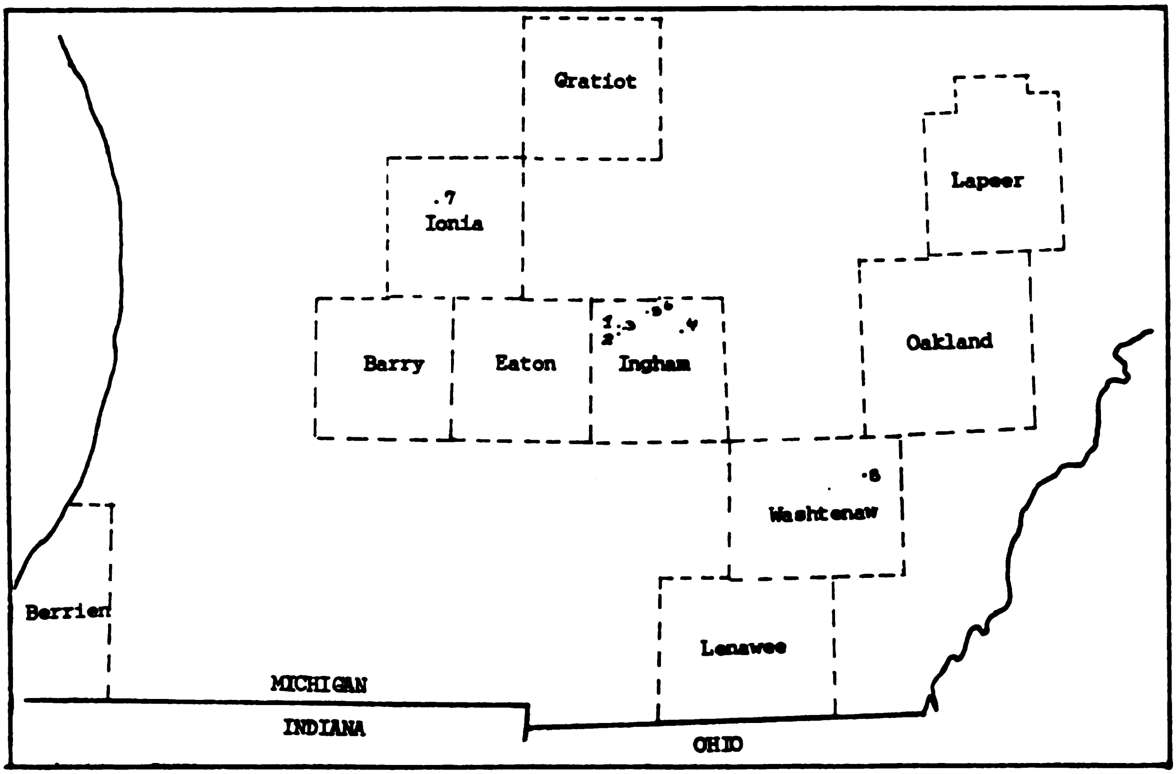

Fig. 1-b. Sketch showing the Counties in which soil investigations were conducted in connection with this study. Numbers refer to approximate location of profiles sampled.

Typical tills from individual lobes may be distinguished without difficulty by their geographic location; but in interlobate areas, where they intermingle with each other, their identification can become increasingly difficult (Wayne and Zumberge, 1965). Methods have been proposed to recognize them in those complex areas (Rieck, 1976).

The map of the surface formations of the Southern Peninsula of Michigan by Martin (1955) shows the pattern of the morainic system for this part of the state. In places, this pattern is well defined and relatively simple, but in other places it is rather complex.

In the central portion of Southern Michigan (eastern part of Montcalm County, Gratiot and Ionia Counties) the pattern consists of a succession of nearly parallel and concentric moraines in a pattern concave to the southwest (Figure 1). With little doubt, these systems can be assigned to the Saginaw Lobe.

In the Southwestern part of the state (Allegan, Van Buren, Berrien, Kalamazoo, and Cass Counties), most of the moraines are oriented in a north-east, south-west direction. These features have been formed by the activities of the Michigan Lobe.

The Moraines that exist in the Southeastern part of the state are preferentially oriented according to a Northeast-Southwest direction; their location and general orientation suggest that they have been formed, at least in part, by the activities of the Erie Lobe.

By contrast, the pattern of the morainic systems that cover a large portion of the lower part of Southern Michigan (Northwest of Oakland and Washtenaw Counties, Livingston, Jackson, Ingham Counties) is rather complex. Consequently, soil investigations in which the nature of parent material is an important factor will be more difficult in these areas.

2. The Miami and Marlette series

The Miami series is the best known of the Gray Brown Podzolic soils. Baldwin (1937) has outlined its history since it was first recognized in 1900 on the banks of the Big Miami River in Ohio. Until about 1950 in Michigan the Miami soil had been mapped, undifferentiated from other competing series such as Marlette and Morley. The Marlette soil definitely exhibits morphologic features nonexistent in the Miami. These features are spelled out in the official profile descriptions (see Appendix I). The differences between the two soils are at the subgroup level.

In the northern undisturbed areas, the Marlette soils show a bisequal layout of horizons. The upper sequum consists of a weak Podzol (incipient) overlying the Gray-Brown Podzolic like lower sequum. But in most areas where the land has been cleared, and cultivated, the upper sequum of the Marlette has been mixed by plowing and destroyed. The sequence of horizons is then fairly similar to that of a Miami except for the presence of extensive development of interfingering and some tonguing in the Bt horizon of the lower sequum.

A comparative field study of these two soils will therefore call for specific recognition of the tonguing and interfingering features as they are previously described in the "Literature Review."

IV. METHODS AND PROCEDURES

1. Field investigation

The field investigation was carried out in counties of Michigan where either Miami soils or Marlette soils (or both) have been described and mapped. Stops were selected in the office from available general soil association maps, published soil survey reports, or the advanced detailed field sheets. Those stops were recorded on county road maps and on the detailed soil map.

Field work involved on-site examination of the area with the soil auger or spade. The general features of the profile were examined and summarized in a log that is reproduced in Appendix B. The features considered to be more important dealt with texture of the surface horizon, identification of an A2 horizon, presence and extent of tonguing and interfingering features, close examination of albic features and general morphology of peds of the B2 horizon.

In addition, landform, slope and position in the landscape were recorded. In several cases, isolated bag samples were collected in case further needs might arise for complementary laboratory observations.

Finally, eight pits were dug (see Figure 1-b). The soil profiles were described at these sites and soil samples were collected (Appendix C). These soil samples were collected in plastic bags and prepared according to the standard method described by the Soil Conservation Service (1972).

2. Chemical determinations

Cation exchange capacity, pH, and exchangeable cations were determined according to methods described by Soil Conservation Service (1972).

Total carbon was determined by the dry combustion method using a Leco Carbon Analyzer equipped with an induction furnace.

Calcium carbonate was measured according to the method developed by Bundy and Bremmer (1972).

3. Physical determinations

Mechanical analysis was performed using the Kilmer and Alexander method (1949).

Fine clays were separated by centrifugation according to nomographs developed by Tanner and Jackson (1947). Bulk density values were obtained according to methods described by Soil Conservation Service (1972).

4. Mineralogical observations

Clay fractions were separated by sedimentation, concentrated by flocculation and centrifugation, and cleaned with Sodium-Diothionite-Bicarbonate to remove iron oxides. Samples were then oriented on ceramic tiles after being washed with a Mg-glycerol solution. The tiles were dried over $CaCl_2$ and x-rayed using $CuK\alpha$ radiation while being scanned between 2 and 30° 2θ.

The clays were later saturated with 1 N KCl, air dried and heated at 300° and 550° C. They were scanned again over the same angular range after each heating treatment (Mortland, 1974).[1]

5. Fabric analysis, micromorphology

The split and debris observations were conducted with the aid of a binocular microscope under direct illumination. Peds were separated and broken open with a dissecting needle; primary peds were examined under magnifications ranging from 9 to 54X.

Thin sections were prepared from natural peds. The peds were overdried, impregnated, cut in small sections and mounted on a petrographic glass slide (Batten, 1973). Morphological features were first described under a binocular microscope equipped with a special stand and polarizing filters allowing observation of optical patterns. The advantage of using this type of microscope is that it allows examination of a much broader field than that commonly observed under the regular polarizing microscope. Later, selected specific features were observed under a Spencer polarizing microscope under magnifications ranging from 30 to 200X.

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[1]Unpublished clay mineralogy notes.

V. RESULTS AND DISCUSSION - GEOGRAPHIC DISTRIBUTION

1. Geographic distribution

The results of the field investigations are summarized in Table 1.

There is no evidence of a clear cut pattern of geographic distribution for the Marlette and Miami soils. However, there are definite trends. The following is a review of the distributional pattern county by county.

In *Lenawee* County, the Miami soil was found to be largely dominant, accounting for 80 per cent of the observations, with no preferential distribution of the Marlette soil.

In *Washtenaw* County, the Miami soil still predominates, but the percentage of the Marlette greatly increases. Furthermore, there is a trend in the distribution of the two soils. In the western and central portion of the county, the observations are almost equally distributed between these two soils. But along the morainic edge crossing the county in a north-east, south-west direction from Salem to Bridgewater and Benson, the Miami strongly predominates with the Marlette accounting for less than 20 per cent of the observations. This strip of moraine extends from the north-east corner of Macomb County South, into Lenawee County. In the portion of Macomb County covered by this moraine, the soil series

Table 1. Summary of field observations[1]

Stop No.	Soil Series	Ap Texture	Slope %	Thickness in.
		Lenawee County		
1	Celina	loam	-	48
1b	Miami	-	-	-
2	Miami	s.loam	-	40
3	Mi-Owosso	s.loam	-	41
4	Marlette	loam	-	38
6	Owosso	s.loam	-	32
7	Marlette	loam	16	30
8	Miami	loam	6	30
9	Metea	lo.sand	4	-
		Washtenaw County		
1	Sisson	silt loam	5	40
2	Miami	loam	5	58
3	Miami	loam	2-5	19
4	Marlette	s.loam	steep	36
5	Miami	loam	4	36
6	Marlette	s.loam	10	42
7	Marlette	s.loam	14	35
8	Ma-Mi	loam	8	30
9	Marlette	loam	4	26
11	Miami	loam	8	29
12	Miami	loam	5	21
13	Miami	loam	25	34
13a	Miami	loam	10	30
15	Celina	loam	2	30
16	Morley	loam	7	25
17	Celina	loam	2	30
18	Marlette	s.loam	2	-
19	Miami	loam	3	-
20	Miami	loam	5	-
21	Mi-Ma	c.loam	3	-
22	Miami	loam	8-10	-

[1] s.loam = sandy loam
c.loam = coarse loam
lo.sand = loamy sand

Table 1 (continued)

Stop No.	Soil Series	Ap Texture	Slope %	Thickness in.
		Eaton County		
1	Miami	loam	5	32
2	Marlette		3	31
10	Marlette	c.loam	7	31
11	Marlette	s.loam	20	26
12	Marlette	loam	4	
13	Marlette	loam(wet)	3	40
14	Marlette	loam	14	36
15	Marlette		6	36
15b	Marlette	eroded	4	20
16	Marlette	s.loam	5	
16b	Marlette	loam		variable
17	Marlette			
18	Marlette		12	30
19	Marlette	loam	28	32
20	Marlette	loam	5	35
21	Marlette	loam	3	36
22	Marlette	s.loam		50
23	Ma-Mi	s.loam	4	34
24	Marlette	s.loam	5	
25	Owosso			
26	Marlette	s.loam		
27	Miami	loam		
28	Marlette	c.loam	6	42
		Ionia County		
1	Marlette	s.loam	2	40
2	Marlette	s.loam	3	38
3	Marlette	c.loam	3	53
4	Marlette			
5	Marlette	s.loam	3	37
6	Miami	loam	5	
8	Marlette	s.loam		46
9	Marlette	s.loam		50
11	Marlette	loam	15	32
12	Miami	s.loam	3	36
13	Miami	loam	5	
14	Miami	loam	4	
17	Miami	loam	steep	
19	Marlette	s.loam	2	36
22a	Marlette	s.loam		
22b	Miami	loam		
23	Miami	loam	7	36
26	Marlette	loam	2	

Table 1 (continued)

Stop No.	Soil Series	Ap Texture	Slope %	Thickness in.
		Lapeer County		
1	Marlette	s.loam	3	60
3	Marlette	c.loam	3	
6	Marlette	s.loam		
7	Miami	loam	3	28
		Barry County		
1	Marlette	c.loam	3	36
1a	Miami	loam	6	30
1b	Marlette	loam	7	
2	Marlette	c.loam	8	45

[1]The present list summarizes the field logs presented in Appendix B. These logs contain a description of the sites where the pedons were found to be related to the Marlette or the Miami soils. Description of other sites where the pedon was not related to these soils has not been recorded.

- = not recorded.

that have been recognized and mapped consist mostly of an association of Lapeer-Miami-Celina soils (Larson, 1971).

In *Eaton* County, the Marlette soils strongly predominate, accounting for 78 per cent of the observations. There is no evident geographic pattern of the distribution of the Miami soils in that county, and the few sites where the Miami has been observed are scattered throughout the county.

Both the Miami and the Marlette have been recognized in *Ionia* County (Threlkeld and Alfred, 1967). The common theory that, in this county, the Marlette soil occurs north of the Grand River and the Miami south of the Grand River could not be verified. Originally, the Marlette soil was described as having a sandy loam surface, but extensive areas are covered by Marlette loam and clay loam types; these places correspond to eroded phases where the original soil surface has been removed, leaving the subsurface horizons exposed.

In *Lapeer* County, the Marlette soils seem to predominate. However, the published soil survey (Earle, 1972) has recognized a widely spread association of Marlette-Miami throughout the area. But unlike the cases of the counties mentioned above, the Marlette sandy loam soil has been mapped exclusively. As far as the Miami soil is concerned, the loam and the clay loam types (not the sandy loam) have been recognized and mapped.

From the 5 observations in *Barry* County, only one turned out to be a Miami soil, although this soil series had been formerly widely mapped in individual farm plan maps throughout the county.

A summary of point transect observations in *Ingham* County shows that the Marlette soils are largely dominant in this county. There is no geographical trend for the separation of the Miami from the Marlette in this county. Both the sandy loam and loam types of the Marlette have been recognized. It seems that the original sandy loam surface has commonly been removed by erosion, leaving the loamy subsoil exposed at the surface.

In *Oakland* County, point transect observations have shown that the Miami and Marlette soils are present in that county, approximately in equal proportion.

A soil profile was observed in *Berrien* County. The pedon has shown the presence of extensive tonguing.

A wooded area was found northeast of the City of East Lansing where a Marlette-like soil was observed and sampled. On this particular site the pedon shows a bisequal pattern with the predominance of a coarser texture (sandy loam) in the upper part of the profile and a finer textural material in the lower part.

This county-by-county review of the preferential distribution of the Marlette and Miami shows that the pattern of occurrence of the two soils is complex and rather difficult to establish. Nevertheless, some hypotheses can be tested.

The original hypothesis of an exclusively latitudinal occurrence of the two soils no longer stands: Marlette-like soils have been described in Ohio, and it does not seem that in Michigan there is a consistent phasing out of the Miami as one progresses northward. In Eaton County, for example, the percentage of Marlette observations is much higher than in Ionia County, which is located further north.

The testing of a latitudinal occurrence is further complicated due to the difficulty of testing such an important independent factor of soil formation as vegetation. The original forest population of Michigan has been removed and the map of presettlement distribution of forest vegetation prepared by Veatch (1959) is too general for investigation of soils-plant relationship at a local level.

The scheme of distribution of the two soils in Washtenaw is of a special interest because of the existence of the dual pattern. As mentioned earlier in the western and middle part of the county, the proportional occurrence of both soils is approximately equal, while the Miami is almost the exclusive soil along the eastern part of the county. This strip of sediments corresponds to the location of the Defiance moraine, a well defined moraine deposited by the advance of the Erie Lobe.

Field investigations dealing with spatial distribution of soils are strongly facilitated when the origin of the parent materials can be unequivocally identified. The identification of the origin of the parent materials from which the soils have been developed is rather difficult in most of central Michigan, including most of Washtenaw County. The layout of the morainic system, as shown on the map of the surface geology of the southern part of Michigan (Martin, 1955), is complex and shows no well defined pattern of orientation. This lack of a patterned orientation is due to interlobation of the sediments originally deposited by two different lobes. Methods have been developed to identify the individual tills (Dreimanis and Vagners, 1971; Reick, 1976). There is no doubt that these methods should be of special interest to soil scientists in field investigations.

The relationship between tonguing occurrence and texture of soil profiles seems to support the hypothesis that the latter may condition the formation of the former. Sixty per cent of the pedons classified as Marlette occur on sites in which the A horizon is a sandy loam; on the remaining sites with loam texture, a number of pedons, accounting for 15 per cent of the total Marlette observed, have shown signs of significant erosion, bringing a strong possibility that pre-existing coarser surface materials could have been removed.

On the other hand, 80 per cent of the sites on which the Miami soil has been identified reveal the texture of the A horizon to be loam. Furthermore, in most of these pedons, the texture of the solum has been found to be overall finer than that of the Marlette.

Some Morley and Morley-like soils, having a finer texture, were occasionally encountered. But no substantial tonguing or interfingering was observed on those sites. The predominance of fine texture does not necessarily preclude formation of tongues in soils. The Nester, Perrinton and Ithaca soil series are all characterized by a fine textured solum (averaging more than 35 per cent clay). Nevertheless, these soils have been classified as Glossoboric or Glossaquic Hapludalfs. In all 3 cases, descriptive comments following the profile descriptions commonly mention that the original surface of these soils has been removed by erosion. This suggests the former existence of coarser materials at the land surface.

It seems logical, therefore, to conclude that on most sites where the Marlette soil occurs, there was at the beginning a thin cap of sandy materials at the surface, and this could enhance substantially formation of eluvial bodies of coarser materials and their deeper penetration upon cracking and fissuring of the lower part of the solum.

2. Relation of tonguing with drainage

Since both Miami and Marlette series are well drained soils, selection of sites for the field investigation was intentionally limited to well drained areas. However, unavoidably, some sites turned out to be located in moderately well and somewhat poorly drained portions of the landscapes. In several of these sites, the "bleached materials" were found in proportions substantial enough to qualify these soils as Glossaquic Hapludalfs.

The Soil Taxonomy (1975) has in fact recognized existence of tongues on drainage classes ranging from well to poorly drained. However, there is no established evidence that these features occur on poorly drained soils in the areas investigated here.

VI. RESULTS AND DISCUSSION - MORPHOLOGY OF THE MIAMI AND MARLETTE SOILS

Morphological studies of soils refer to an analytical description of the basic features, as they set the scheme for the identification of the horizons involved and subsequently for the classification of the pedon. These studies have been conducted both in the field and in the laboratory.

1. The field investigation consisted of the close examination of the profiles with the naked eye or occasionally with hand lenses. The object of such examinations was to investigate the basic makeup of the peds and the pattern of distribution of the individual soil features and pedons.

This portion of the study was conducted throughout the field investigations and the work is recorded in Appendices B and C, the stops and sites observed.

2. Micromorphology

Buol et al. (1973) define soil micromorphology as "the study of soil morphology in the range where optical aid is needed for the naked eye." The main difference between field observation and micromorphology studies is the level of the units involved. In the field, emphasis is put on relationships among the peds and the external configuration of the peds by horizons as well as continuous pedological features. In the laboratory the observations are centered around arrangements at the lower level of single peds or the soil matrix.

Micromorphological studies are further subdivided into split sample examination and thin section observations.

The scheme and vocabulary used in the following discussion have been adopted from Brewer (1964).

a. Split and debris examinations

Miami Profile

A horizon: The peds are well defined and subrounded in shape. The tertiary units average 30 mm in size and the primary peds measure approximately 8 mm. The fabric is intertextic (skeleton grains being embedded in the porous ground mass). The individual skeletal grains are dominantly small in size. The voids are irregular, medium in size, fairly continuous and often exhibit a composite configuration (small system developing within larger units). The plasma consists of organic matter, silt and clay exhibiting an amorphous configuration without any specific pattern of concentration. Relics consist of broken pieces of roots. Under pressure, the peds break easily into single grains.

A2: The fabric is agglomeroplasmic (showing incomplete fillings in the intergranular spaces between skeleton grains). Their whitish color suggests that a large portion of the colloidal plasma has been removed.

The voids are irregular; the surface of their walls is rough and very irregular because of skeletal grains protruding.

There are isolated traces of plasma concentration consisting of light brown coatings on the wall of some elongated pores.

B2t: The peds are strongly expressed and most of them are angular, with the angles being sharper on the secondary and primary peds. The tertiary peds average 35 mm and the primary peds 10 mm in diameter. The fabric is intertextic with much porphyroskelic fabric in isolated spots.

Plasma concentration is clearly evident and consists of continuous shiny coatings of brown clay (argillans). These argillans have a referred orientation pattern, basically parallel to such reference features as ped surfaces, walls of voids and surface of individual skeletal grains. It is possible to see that the thickness of these clay cutans is not uniform: along the surface of many peds as well as along the walls of few pores, the cutans show a festooned pattern. This is probably due to the fact that they are composites of layered coatings deposited individually. When the recent coatings do not completely cover the older ones, the festooned patterns are created.

The coatings often show signs of crackings. There is no preferential pattern of orientation of these cracks.

In other peds, the fabric is porphyroskelic due to greater concentration of the plasma. In other places, the color is very dark brown, probably due to admixture of organic matter.

Some ped surfaces have a lighter color in spite of the presence of shiny coatings. It is possible that those are areas where the coatings are thinner because deposition is still at an early stage or because the original coatings are being destroyed by removal. Relics consist of fragments of roots partially embedded in the mass of coatings.

B3: The size of the peds is larger, reaching 45 mm for some tertiary elements.

The shape of the units is strongly defined and is dominantly subangular breaking to angular.

The fabric plasma is intertextic, grading occasionally to agglomeroplasmic. The topography of the ped surfaces is rougher than that of the B2t and the coatings (basically argillans) are clearly discontinuous. The walls of the elongated pores (old root channels) are dominantly smooth and uniformly coated. Cracks are also present along the coatings, but they are fewer than in the B2t.

Relics of fine roots are common.

C horizon: Again, the size of the peds has increased, becoming large masses, difficult to break. Tertiary peds are subangular and average 35 mm in size. Primary peds are angular and subangular. The fabric is basically porphyroskelic, with the matrix densely packed.

The pores consist of small, usually isolated voids. The topography of the ped surface is rougher than that of the B3.

Relics consist of fragments of calcite (whitish in color) and traces of organic materials.

There are traces of broken argillans.

Marlette Profile

Ap: The peds are dominantly rounded to subrounded with no evidence of presence of flat surfaces. The boundaries among peds are irregular basically because of the dominance of the coarse grained materials. The fabric is agglomeroplasmic with the smaller individual skeletal grains clustered around the larger grains that serve as nuclei. No pattern of orientation or preferential distribution is visible. The size of individual peds ranges from 1 mm to 6 mm (dominantly 4 mm).

The voids are the macrovoid types, irregular and more or less continuous.

Signs of general plasma concentration are absent, but there is evidence of free grain cutans of organic materials around the coarse grains. Relics of organic materials are visible; they consist mostly of small roots in tubular voids.

Under pressure, these peds are easily crushed, breaking to single fragments dominantly rounded in shape.

A2 horizon: The level of organization is not well defined. The larger peds (8 to 15 mm in size) are predominantly subangular blocky, breaking to fine (2 to 5 mm) angular.

The fabric approaches closely the granular type with very little plasma embedding part of the individual skeletal grains which are larger in size than that of the Miami. The network of voids consists of many irregular pores, some of them showing a smooth configuration. There is evidence of some whitish coatings on some of these smooth surfaces; possibly they are siltans deposited by water or eluviated surfaces.

B and A: As the name suggests, this is a genetically mixed horizon in which some characteristics of both the A2 and the B2t are expressed. This pattern is very apparent at first glance at the peds. The color pattern is mixed with predominance of brown color over the light brown and tan.

The fabric type varies from one place to another. In the portions corresponding to the B horizon part, the fabric is of the intertextic type with evidence of substantial amounts of red-brown ground mass embedding the skeletal grains. The "patchy" appearance of this plasma suggests that it has been partially destroyed.

The voids are very irregularly shaped, but many of them are mammilated and partially lined with shiny, light coatings (thin argillans or silica). As for the horizon above, the individual peds are difficult to recognize.

The morphology of the portions corresponding to the A2 part is drastically different. There, the fabric ranges from granular to agglomeroplasmic; the network of the voids is more strongly developed but poorly organized than in the B portions. These voids are very irregular and their walls are partially coated with silans. Under pressure, they almost completely break into individual skeletal grains. Several elongated channels are observable; they probably come from old root channels; their walls are dominantly smooth and there are signs of relics of old organic materials.

Many pores are partially coated or even filled with fine silt grains easily recognizable by their particle size distribution, their darker color and the lack of cohesion among the individual grains. Very likely they consist of materials that have been brought from the upper part of the profile. The lack of organized pattern and the uneven distribution of these granular coatings or fillings suggests that they have been deposited by slumping either in a dry or a wet state.

Some other peds are characterized by a larger-than-normal number of spherical pores; this pattern gives them a porous appearance under observation at low magnification.

The morphology of the B2, B3 and C horizons is generally similar to the one of the corresponding horizons of the Miami except that some of the granular coatings and fillings described above (under B and A) are evident, although to a much lesser extent.

b. Thin section observations

The Miami Profile

Ap: The fabric is porphyroskelic with a dense plasma consisting of an amorphous mixture of clay, organic matter and silt.[1] On many occasions, the peds are not easily recognizable, possibly because of the fact that the pores are completely filled with organic matter. In those cases, only very careful observation allows recognition of individual units, on the basis of a slight difference in color of the adjacent peds.

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[1]Although by definition, silt particles are normally considered a part of the skeletan, fine silt when intimately mixed with organic matter or clay has been sometimes considered as a part of the plasma.

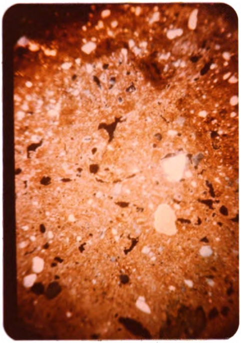
Figure 2. Thin sections of representative samples:

(a) C horizon of a Miami soil: fabric is dense with few or no pores. Under crossed nichols.

(b) B3 of a Miami soil: fabric is still dense, but the pores are at an early stage of development. Under plain light.

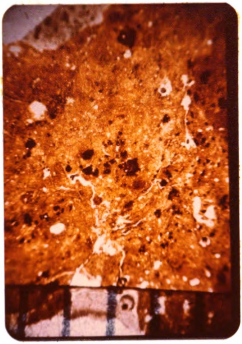
(c) B horizon of a Marlette soil: poorly oriented clay, mixed with silt, between well oriented clay skins (top and bottom of photo). Under crossed nichols.

(d) Very large pore with partly disturbed wall from a sample of B and A of a Marlette soil. Possible part of a vesicle. Under crossed nichols.



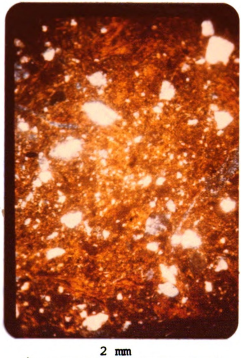
1 mm

(a)



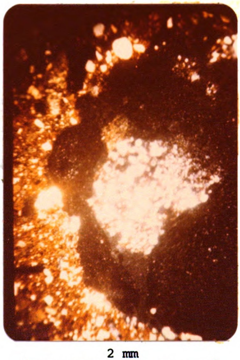
3 mm

(b)



2 mm

(c)



2 mm

(d)

In some cases, the voids consist of a network of small but well organized pores. The size of the primary peds ranges from 8 to 15 mm.

The size of individual sand grains varies from fine to medium; larger sand grains are present, but not dominant.

Organic matter is the principal cementing agent; it is easily identified by its dark brown color and its amorphous appearance. A sample collected at the bottom of this horizon shows evidence of poorly oriented clay mixed within the mass of the organic matter. Another sample, collected from the surface of a pedon that has been subjected to severe erosion, shows a less amorphous plasma. The mixture of clay and organic matter exhibits some birefringence. For this particular layer, the size of the individual skeletal grains is larger.

Relics consist of remnants of roots. A cross section is nicely illustrated in Figure 3-c.

A2: The fabric is agglomeroplasmic. The plasma occurs as loose fillings in the intergranular spaces between the skeletal grains. The primary peds are well expressed and are defined by small, but well developed, pores that are continuous. A few single, angular, medium pores are present. The skeletal grains contain a greater proportion of the larger sand grains than the Ap. The fabric grades toward a granular type in places where the plasma (mostly organic matter and clay) is less dense. The color of the sample is much lighter in these areas.

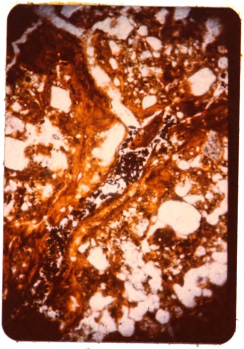
There is evidence of remnants of argillans in places. They appear as broken, discontinuous, isolated strips of well or

Figure 3. Thin sections of representative samples (cont'd.).

(a) Well developed argillans in a B2 horizon of a Miami soil. Under plain light.

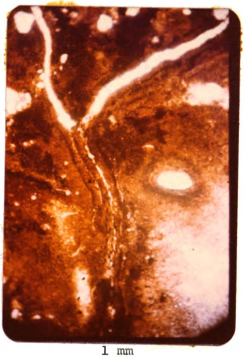
(b) Cracks in an argillan. Under plain light.

(c) and (d) B2 of a Marlette soil being destroyed. Under crossed nichols.



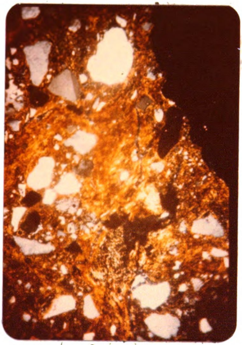
1 mm

(a)



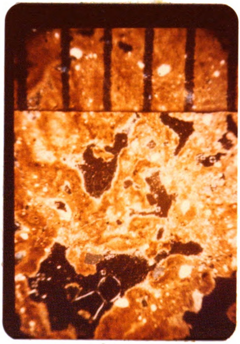
1 mm

(b)



2 mm

(c)



3 mm

(d)

not-so-well oriented argillans (clay skins). A few individual sand grain clay-cutans are present. These coatings do not have a sharp boundary; rather, their edges are diffuse.

B21t: The fabric is intertextic but grades to porphyroskelic in places. The plasma is more abundant than in the A2 and consists of mostly amorphous clay mixed with some organic matter and silt.[1] The peds are larger, well defined, and separated by continuous, medium pores. There is some evidence of segregation of skeletans, with fine sand grains and silt concentrated in some areas. Plasma concentration is obvious; it consists of clay substance distributed around individual large skeletal grains or spread throughout the mass without preferential orientation. This "separated" clay differs from the amorphous clay already mentioned; it is optically oriented and exhibits extinction phenomena under crossed nichols, upon rotation of the stage. Relics consist of fragments of roots and unidentified animal droppings. One thin section made from a sample collected at the top of this B21t shows the contrast of fabric between this horizon and the A2 horizon right above.

B22t: The fabric is much denser than that of the B21t, and is dominantly porphyroskelic with the clay plasma appearing as a dense ground mass in which the skeletal grains are set like phenocrysts in a porphyritic rock. The size of the peds is relatively large and each primary ped is well defined. The pore system is well developed with the presence of voids of all shapes and sizes.

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[1]See footnote on page 41.

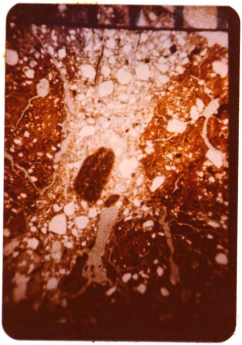
Figure 4. Thin sections of representative samples (cont'd.).

(a) Tongues in a B and A of a Marlette soil. Note the contrasting colors and fabric. Under plain light.

(b) Contrasting colors and fabric in an A and B of a Marlette soil. The contrast is less obvious than in (a). Under crossed nichols.

(c) Root remnant in the Ap of a Miami soil. Under plain light.

(d) Concentration of skeletal grains (fine sand and silt) in a Marlette soil. Under crossed nichols.

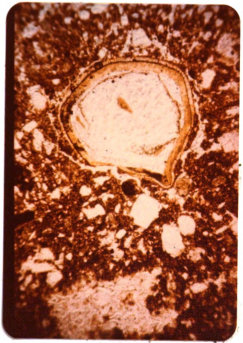


3 mm

(a)

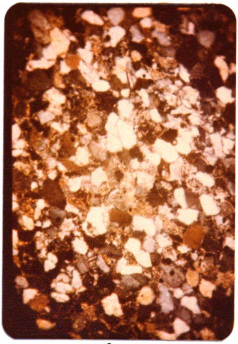
1 mm

(b)



1 mm

(c)



1 mm

(d)

The majority of the voids are, however, interpedal. The primary interpedal pores are the more regular voids; they are elongated, narrow and continuous. Secondary pores are also very common; they exhibit all types of branching patterns (single, dendroid). The intrapedal pores are irregular in shape; they are basically single packing voids inside the peds and are of all sizes. Transpedal voids are also present but are not very common. They traverse the individual peds and are probably created by recent stresses throughout the soil mass.

Plasma separations and concentrations are essentially expressed as clay masses and clay bodies. The clay masses are confined within the peds; they make up the dominant part of the matrix and appear as dense ground mass mixed with silt material and occasionally some organic matter. The clay masses are basically optically amorphous and relatively opaque. Spatially they are diffuse.

By contrast with the clay masses, the clay bodies are spatially more sharply defined; they occur dominantly as argillans or clay coatings. The main features of these coatings are their related distribution and their optical properties. All of the cutans are distributed around interpedal pore spaces or around individual skeletal grains or in root channels. These argillans are of various thicknesses and under reflected light they have either a smooth, glazed surface or an uneven ropy appearance with waxy luster, like the models described by Brewer (1964) (see Figure 2-a).

The argillans have a characteristic golden color (under polarized light) and under larger magnification they show a pattern of lamination parallel to the related surface of deposition (individual grains, pores, root channels). These laminations consist of bands of the golden clay separated by dark lines of organic matter. The lamination pattern suggests that these cutans are made of many single layers, deposited individually. In several instances, the association of the organic matter with the clay cutans is less well organized, and the organic matter appears as dark masses mixed with the clay on the surface of the peds.

Quite often the cutans (mostly the thicker ones) show extensive cracks with a random pattern. These cracks are probably created by shrinking of the clay materials upon drying (see Figure 2-b).

There are a few instances where the clay skins seem to have been destroyed. In those areas, the cutans appear as thin, elongated fragments of oriented bodies incorporated within the mass of the peds.

Relics are not widespread but in places there are signs of fossil remnants appearing as well preserved minute black granules inside pores between adjacent clay skins.

B3: The fabric approaches the porphyroskelic with the plasma occurring as a dense amorphous ground mass in which are set the skeletal grains (see Figure 1-b). The fabric shows fewer pores than above. This plasma is dominantly clay which is optically amorphous. The plasma is largely mixed with relatively large amounts of organic matter easily identifiable by its black color and its dull appearance. In several instances, the organic matter shows some pattern of concentration along the pores and on ped faces. The primary peds are large but not easily recognizable because of lack of contrast between the dark or very dark brown color of the plasma and the black color of the organic matter which often accumulates at the surface of the peds. In other cases, the fabric appears as a very dense mass with very few skeletal grains and little or no evidence of ped differentiation. The few pores present are very narrow, elongated, and continuous, suggesting that they may be crack related. Oriented clay bodies are noticeable; they are few in number and appear to be "buried" in the mass instead of being nicely deposited on the natural surfaces.

Plasma separation consists also of isolated black spots of organic matter.

A sample collected from the B3 of Miami site 1 shows a network of small, parallel, elongated cracks or voids that are believed to be stress-related. Another sample from the same horizon shows, in the middle of a mass of amorphous plasma, a well developed, continuous set of cutans with their golden color strongly contrasting with the gray brown of the adjacent peds.

C: The fabric is dominantly porphyroskelic with a plasma denser than that of the B3 (see Figure 1-a). In isolated places the fabric grades toward the intertextic showing a plasma more loosely packed. There is little sign of plasma separation, but the whole matrix is dominated by the amorphous ground mass consisting of a mixture of silt, clay and a small amount of organic material. The color of the plasma ranges from a light yellow brown where the amount of organic matter is small to dark brown and more opaque where a larger proportion of organic matter is incorporated into the ground mass.

The number of voids is relatively small, and the individual voids are dominantly either isolated large individual voids, irregular in shape, or more often long, narrow, continuous voids--very likely crack-related. Occasionally there is some concentration of dark organic matter at the boundary of these elongated pores.

In places, there is evidence of small black or dark reddish brown pellets; they are scattered throughout the mass of the plasma and are believed to be segregation of iron and/or manganese. Some cracks are filled with a light brown mixture, probably clay and silt with occasional dark spots of organic matter.

The skeletal grains are mostly of medium size (.5 to 1 mm) with a few very coarse grains (± 2-3 mm) scattered throughout.

Relics are mostly pedorelics; they consist of "ghost lime" appearing as amorphous masses with some highly birefringent calcite remnants.

<u>C2</u>: In the field, the C2 when present was recognized on the basis of the size of the peds and their firmness. Peds from the C2 horizon were found to be larger and firmer.

The thin sections from the C2 have a general morphology quite similar to the C, but the peds (when they are identifiable) are larger (more than 12 mm).

The Marlette Profile

<u>Ap</u>: The fabric is agglomeroskelic with a loose plasma filling the intergranular spaces. The plasma is light brown and consists of a mixture of organic matter, silt and clay. The peds are not easily recognizable because of the general irregularities

of the interpedal voids. The boundary of these voids is very irregular, probably because they are fairly recent.

The size of the individual skeletal grains varies greatly, but the coarser grains (>1 mm) represent a very large proportion of the total grains.

Quite a few voids show a general pattern of parallel distribution; this is probably caused by lateral shearing from surface stresses. Remnants of roots are common; they are embedded in the mass of the amorphous ground mass.

A2: The fabric ranges from granular to agglomeroplasmic. The plasma has a much lower proportion of organic matter and clay, and a higher proportion of silt. This accounts for the general granular appearance of the plasma. There is evidence of some particle segregation. It appears that many old voids are filled with very fine sand material mixed with silt and very little clay and/or organic matter. In other areas where the fabric grades toward the agglomeroplasmic type, the plasma is denser with a greater proportion of clay. The clay appears either as partially optically oriented, bracing individual grains, or as isolated masses showing some birefringence. Broken isolated small strips of oriented clays are present here and there. Many of them present evidence of association with organic matter as alternate, parallel, dark bands.

Several voids seem to be associated with animal activities. They are filled with a black, amorphous plasma containing birefringent granules.

The size of skeletal grains ranges from fine to coarse sand with some predominance of the larger grains.

A and B: The mixed nature of this horizon (as described under split preparations) is shown by the heterogeneous appearance of the sample. The A portion appears lighter in color and has most of the characteristics of the A2 horizon. The B part is browner and is more related to the morphology of the textural B.

The fabric observed in the A portion grades toward a granular with a small amount of plasma embedding the skeletal grains. The plasma is made mostly of fine silt mixed with little organic matter and clay; it is essentially optically amorphous.

The void system does not have any dominant pattern of arrangement; in places, there are hardly any voids except very small single packing voids created by incomplete fillings of the inter-skeletal spaces by the plasma. In other places there are large interconnected or isolated voids partly filled with loose incoherent small and large skeletal grains. Many large circular voids are present.

There is clear evidence of migration and concentration of silt materials as coating either between the walls of the pores or around single grains. Within the large voids these silty materials along with a mixture of organic matter and clay embed the medium sand grains.

There are remnants of clay skins. They appear as isolated bodies but have maintained their thickness and their birefringent properties.

The B part has an agglomeroplasmic fabric that often grades toward the intertextic. The plasma is abundant, thus causing the fabric to be densely packed.

The plasma is dominantly made of clay with an admixture of organic matter and silt in various proportions. The relative content of these individual components in the mixture can be easily evaluated by the general appearance of the plasma: as the proportion of the clay increases, the color of the mass is more yellow (honey like) and shows a stronger birefringence; the maximum birefringence is observed when the clay appears as cutans either on the surface of the individual grain or along other natural surfaces as pores, cracks, or channels. But, as the proportion of organic matter increases in the mixture, the mass loses its golden color and appears darker and more amorphous. On many occasions these cutans appear as discrete bodies with sharp boundaries on either side, but in other cases the face that is in contact with the peds is diffuse, showing gradual addition of silt and organic matter.

The contact between the A with the B portion exhibits various patterns. In the majority of the cases, the contact is sharp. The eluvial bodies usually penetrate the B2t as conical intrusions pointing downward (see Figure 3-a); their grayish granular fabric mostly is composed of silt grains and little organic matter, strongly contrasting with the golden or yellowish brown color of the adjacent argillans. The size of these A2 intrusions varies widely, from the 2 mm interfingerings to wide tongues (several inches) observed with the naked eye in the field. In other cases, these eluvial bodies blend with the argillans to actually form new peds in which the remnants of old cutans still persist as narrow strips parallel to the original direction of the walls (see Figures 2-c and 2-d).

The pattern of the voids is very variable, and consists of small single packing voids, narrow elongated voids (possibly crack-related) and large to very large irregular voids.

This last group is of special interest. The large size of these pores, their irregular shape and the absence of coating on their walls suggest that they are being created by some strong processes. They are often interconnected through a narrow opening. The larger ones may have in their center small islands characterized by a granular or agglomeroplasmic fabric (see Figure 1-d). It is possible that these features are created by the bulging of these materials through displacement by air. This process has been recognized by several authors (Brewer, 1964; Embleton and King, 1968; Suita and Terelak, 1966). A distinctive type of pores (vesicles) is associated with air bubbles in soils.

The absence of coatings on the walls of the pores and the broken appearance of their periphery suggest that they are being subjected to some destructive, eluvial process. This eluvial process has been recognized and described by Heil and Buntley (1965); during this process the fine particles, clay, are being removed first, leaving the coarser grained silt and sand exposed to the surface. Hence the characteristic whitish color commonly observed on the surface of these peds.

There are many examples of the presence of a very dense granular fabric (see Figure 3-d). In those cases, the individual skeletal grains are arranged in a very compact arrangement; they tend to accommodate each other's shape with very little plasma in between. This type of arrangement is believed to be created by great pressure. It is possible that these densely packed horizons can represent the beginning of a fragipan in these soils: such features were recognized during the sampling and the survey works conducted in Ingham County during the summer of 1974 and 1975 both by the author and R. Engel (1975).

B and A: Like the A and B, this horizon shows the features of both the eluvial A2 and the textural B. But, unlike the A and B, a larger proportion of the horizon exhibits the properties of the B. The fabric is dominantly intertextic with some "islands" (about 20 to 25 per cent) of the characteristic eluvial A2.

B2t: The fabric, pedal arrangements and the majority of the pedological features are similar to those of the B2t of the Miami, except that some isolated interfingering features are still observable. In those cases, the skeletal grains are partly incorporated into the mass of the argillans.

B3 and C: There are no signs of great morphological differences between these horizons and the corresponding horizons of the Miami. The fabric is similarly densely packed.

The void system occasionally shows small rounded or oval voids with a smooth edge. They seem to be distributed along a straight or nearly straight line. It is possible that they may be caused by dissolution of some components of the original parent materials.

3. General interpretations

The commonly denser fabric along with the more abundant plasma observed in the A horizon of the Miami suggest that the Marlette soils have been depleted of some finer materials. This could have happened as early as at the time of the deposition of the original material.

The general continuous pattern exhibited by the clay cutans either as continuous bodies with distinct boundaries or as clear coatings around individual single skeletal grains suggests that they are made of clay particles that have migrated as discrete crystals and later have redeposited as oriented coatings at the surface of the voids or the grains. The significance of the presence of optically oriented clays has already been discussed (Brewer, 1964; Stephens, 1960; Cady, 1965; Laurin, 1973). This hypothesis is reinforced by the fact that most of the clay making up the matrix of the peds shows little or no birefringence.

The preferential distribution of cutans along the pores shows that their deposition must have occurred after these pores (or cracks) have been formed. Their absence, or relatively small number, both in the C and B3 horizon shows that some factors present in these horizons must prevent their migration further down. The factors most widely recognized as flocculation agents are the calcium and magnesium ions that are the dominant ions in the calcareous tills.

Since the organic matter is commonly associated with the clay skins, there is a strong possibility that they may have some inducing action on the clay movement by shifting the flocculation values of the soil electrolytes to a higher value as suggested by Smith (1934).

The A and B and B and A horizons of the Marlette soils are possibly former B horizons that are being depleted of their finer materials. The packing of the grains shows that they are deposited not by water but possibly through slumping into relatively large voids. The V-shape of many of these voids led to the conclusion that they are formed by cracks extending from the surface, down. Such cracks may have been created by freezing and thawing action or wetting and drying cycles as proposed by Embleton and King (1963) and Heil and Buntley (1965).

There is also evidence that densely packed, indurated horizon is being formed at the bottom of the A or A and B horizon. Such a horizon has some similarity to the fragipan recognized in many Alfisols (Fragiudalfs, etc.). Yassoglou (1959) has studied the fragipan present in some soils of Northern Michigan and has suggested that they are formed by a sequence of events including removal of the clay mineral, followed by contraction of the soil mass and by slumping of loose fine sand and silt into the voids. Following this slumping, these materials are compacted and later cemented with clay or Al.

The presence of vesicles in some of the thin sections is valid testimony that gaseous activity may have been a factor in their formation. Such processes have been recognized by Brewer (1964), Springer (1958), and many other researchers.

There is plenty of evidence that the tongues do not persist indefinitely as separate entities. After a certain time, they become mixed with the clay skin and later incorporated in the mass of the peds or become the skeletal grains of new peds, by mixing with the clay and organic matter.

The etching observed on the edge of the voids and on the surface of the peds suggests that finer materials (clay and, later, silt) are removed gradually from these surfaces leaving behind the coarser materials.

The formation of the tongues thus appears to be made by a dual process. On one hand, it is an illuvial process in which very fine sand and silt slumps into cracks at the surface of the peds or along the walls of the pores. On the other hand, it may be seen as an eluvial process during which the fine sand and silt concentrated at the surface after the removal of the clay become cohesionless and fall into any available openings. Detachment of these sand grains by plucking during ice crystal formation is also a possibility that has been raised by Heil and Buntley (1965).

There seems to be an ideal particle size distribution for the cracks and vesicles to be formed. The imporance of such parameters has been mentioned by Suita and Terelak (1963), Arakawa (1966), and Embleton and King (1968). The significance of the particle size, as seen by these authors, has been reviewed earlier in this study (Literature Review).

It is possible that the coarser texture commonly observed on the surface Marlette soils has provided ideal conditions for the formation of the tongues characteristic to these soils. The texture of the surface may be seen as more critical than the texture of the B. In fact, as mentioned earlier (Geography and Soils), tongues have been recognized in soils (Perrington, Ithaca) with much finer texture than that of the Marlette and even the Miami; but in all cases it has been mentioned that the original surface was sandier and has been strongly altered by surface erosion.

VII. RESULTS AND DISCUSSION - PHYSICAL AND CHEMICAL CHARACTERISTICS

1. Particle size

The particle size distribution data are shown in Table 2. The most striking pattern is the lower percentage of *clay* and higher percentage of *sand* of the Marlette soils in the Ap(Al) horizon. When the data are arranged by increasing values of the total sand or decreasing values of total clay, the first three values correspond to the Marlette profiles and the last four figures to Miami soils.

For a given profile (Miami or Marlette), a large portion of the sand is in the fine size fraction (.25 to .1 mm). This fraction accounts for about 50 per cent or slightly less of the total sand.

Except for two pedons (Sites 1 and 4), the Ap has a higher percentage of sand than the remaining horizons of the profile.

The results of the mechanical analyses tend to reinforce the general trend observed in the field where a large majority of Marlette pedons were found to have a sandy loam surface.

The texture of a till is also greatly influenced by the nature of the underlying bedrock, mostly when the surface of the bedrock is fairly close to the surface. In a recent study conducted in an interlobate area in Southeast Michigan, Rieck (1976) has concluded that the sandy nature of the till could be due at least in part to presence of sandstone both beneath and proximal to the moraine. The same author has plotted on a textural triangle the results of

Table 2. Particle size distributions of the soils sampled (% on oven dry, carbonate free basis)

Site No., Soil Series & Location	Horizon	Depth cm.	Particle Size in mm 2-1	1-.5	.5-.25	.25-.1	.1-.05	Total Sands	.05-.02	.02-.002	<.002
							%				
1	Ap	0-18	-	6.5	7.9	14.2	7.2	34.8	14.4	29.4	20.4
Miami	A2	18-25	-	0.4	10.1	19.8	11.3	59.8	11.1	15.5	13.6
Ingham Co.	B2t	25-38	-	3.3	9.9	19.4	11.5	44.1	11.2	17.9	26.8
MSU Campus	B3	38-65	-	2.9	6.9	14.7	10.7	35.2	17.2	26.1	21.5
	C	65-100	2.7	3.1	8.1	10.7	7.2	31.8	15.3	27.1	25.8
7	Ap	0-20	-	3.3	9.3	15.8	10.3	38.7	16.6	28.9	15.8
Miami	B1	20-30	.8	1.3	5.1	8.6	6.9	22.7	16.6	32.1	28.6
Ionia Co.	B21t	30-45	-	3.0	4.4	7.5	6.8	21.7	18.9	33.8	25.6
Wheat Plots	B22t	45-58	-	2.6	5.0	9.5	6.0	23.1	16.7	36.5	25.3
	B3	58-75	-	1.4	4.6	7.4	4.3	17.7	10.8	44.8	26.7
	C	75-125	-	3.2	11.3	20.7	10.5	45.7	11.9	23.7	13.7
8	Ap	0-18	1.5	1.7	8.0	19.5	12.6	43.3	15.7	24.2	16.8
Miami	B1	18-30	-	2.7	9.0	17.9	11.8	41.4	12.4	26.6	19.6
Washtenaw Co.	B21t	30-45	-	2.9	7.5	16.4	11.2	38.0	13.3	22.8	25.9
Dump	B22t	45-65	-	2.9	5.9	13.7	8.3	30.8	11.3	24.1	31.8
	B3	65-125	-	1.8	9.5	17.4	8.7	37.4	10.3	20.8	31.8
	C	125-150	-	3.9	6.1	14.1	13.5	37.6	14.1	22.5	25.8
4	Ap	0-20	.1	2.9	12.6	24.4	11.8	51.8	15.4	21.8	11.0
Marlette	whole	20-33	2.4	4.3	14.9	24.6	9.7	55.9	11.4	18.0	14.7
Ingham Co.	B&AsubA	20-33	-	-	-	-	-	52.0	12.1	19.2	16.2
Locke Twp.	subB	20-33	-	4.7	13.9	23.9	10.8	53.3	11.3	18.2	17.2
	B21t	33-48	1.6	3.6	14.4	23.6	9.6	52.8	10.6	9.4	27.2

Table 2 (continued)

Site No., Soil Series & Location	Horizon	Depth cm.	Particle Size in mm 2-1	1-.5	.5-.25	.25-.1	.1-.05	Total Sands	.05-.02	.02-.002	<.002
							%				
4	B22t	48-73	1.5	2.7	15.8	25.1	11.3	56.4	8.9	14.5	20.1
(cont'd.)	B3	73-85	2.8	3.7	15.4	24.7	11.8	47.1	18.3	16.5	18.1
	IIC1	85-105	-	1.9	3.2	19.6	31.2	66.9	8.9	13.0	11.2
	IIC2	105-125	-	2.9	17.6	24.9	13.2	58.6	11.1	16.4	13.9
3	Ap	0-17	-	2.8	14.0	30.3	13.6	60.7	11.7	13.5	14.1
Marlette	A2	17-30	-	3.1	14.7	25.3	11.4	54.5	11.9	20.6	13.0
Ingham Co.	whole	30-52	1.3	1.6	10.3	22.0	12.1	47.3	9.8	20.3	22.6
MSU Campus	B&A subA	30-52	-	3.1	11.7	24.6	11.9	51.3	10.7	17.7	20.3
	subB	30-52	-	2.8	10.5	23.1	10.8	47.2	8.2	18.5	26.1
	B2t	52-80	-	3.4	11.8	23.7	10.4	49.3	8.0	16.5	26.8
	B3	80-97	-	3.2	9.6	20.8	9.6	43.2	11.7	17.1	28.0
	C	97-150	1.6	3.2	13.9	26.4	12.7	43.5	11.5	20.3	24.7
6	A1	0-20	1.6	3.3	15.1	29.0	12.1	61.1	14.0	18.3	6.6
Marlette-	A2(A&B)	20-35	-	3.0	11.4	24.3	12.7	51.4	12.5	22.9	13.3
Miami	B21t	35-55	-	3.3	9.3	20.2	10.4	43.2	13.1	18.1	25.6
Ingham Co.	B22t	55-68	-	3.6	8.2	19.1	9.5	40.4	12.4	20.3	26.9
Meridian Twp.	C1	68-83	-	3.0	6.4	14.3	7.0	30.7	15.7	33.7	16.9
	C2	83-150	-	5.5	9.8	15.4	7.9	38.6	17.6	27.1	16.7

Table 2 (continued)

Site No., Soil Series & Location	Horizon	Depth cm.	Particle Size in mm 2-1	1-.5	.5-.25	.25-.1	.1-.05	Total Sands	.05-.02	.02-.002	<.002
							%				
5	A1	0-8	-	5.6	20.3	30.3	10.2	66.4	11.1	17.8	4.7
Marlette	A2	8-25	2.3	4.1	18.8	29.3	11.0	65.5	10.2	17.0	7.3
(Bisequal)	B2	25-33	1.3	3.4	18.5	29.9	12.3	65.4	10.7	15.6	8.3
Ingham Co.	A2'	33-48	1.2	3.8	17.7	31.3	12.0	66.0	10.9	16.2	6.9
E. Lansing	A&B'	48-65	-	4.2	15.6	30.3	14.1	64.2	11.9	16.2	7.7
Water Treat-	IIB2t'	65-90	0	2.4	10.4	24.4	16.1	53.3	10.8	15.7	20.2
ment Plant	IIB3'	90-115	-	2.3	8.5	21.6	13.3	45.7	13.7	16.2	24.4
	IIC	115-150	-	4.2	9.8	28.9	14.0	56.9	11.6	13.2	18.4

mechanical analyses of till samples from both the Saginaw Lobe and the Huron-Erie Lobe: in spite of an overall overlapping in the distribution of the values, the samples from the Saginaw Lobe average a sandy loam texture, while those from the Huron-Erie Lobe average a loam texture.

a. Total clay fraction

As a whole, the Miami soils have a higher percentage of clay than the Marlette, throughout their profile. For any individual profile (Miami and Marlette), there is an increase in clay content with depth, until a maximum value is reached, after which the percentage of clay drops again with depth. This maximum concentration occurs somewhere in a B subhorizon, either immediately above the calcareous C horizon (B3) or above the horizon overlying the calcareous C horizon (B2).

The concentration of clay particles in a subsurface horizon (argillic horizon) has been recognized as a basic criterion for identification of soil categories, from orders to subgroup levels (Soil Conservation Service, 1975). Although the process of illuviation does not preclude recrystallization and concurrent formation of clay in the illuvial horizon, the bulk of the clay accumulated in the argillic horizon is thought to have occurred by migration and redeposition.

A B/A ratio of clay of 1.2 (20 per cent greater in the B) or higher has been established by the Soil Conservation Service (1975) as the basic requirement for the existence of an argillic horizon. For this index, it is assumed first that the original profile was uniform and second that the increase in clay content of the illuvial horizon has resulted in part from addition of clay minerals from an overlying eluvial horizon.

Some authors (Smith and Wilding, 1972) have recognized that a lithological break in the upper part of the solum can often create conditions under which the B/A ratio of clay minerals does not have the genetic meaning generally associated with these values. These authors have consequently suggested that the B/C ratio could be a better criterion for identifying the argillic horizon in these soils.

B/A and B/C clay ratios of the profiles in Table 2 have been computed and are shown in Table 3. As a whole, the B/A clay ratio is higher for the Marlette than for the Miami soils and, in one case (Site 5), the value is so high (4.3) that a lithologic discontinuity is strongly suggested. There is no clear trend for the B/C ratio, but in any case, it is much lower than the B/A ratio for all profiles, except for Site 7.

Unless there is evidence to the contrary, the increase in clay observed in the B horizon is usually interpreted in these soils as evidence of translocated clays. Indeed, translocated clays have their own specific features that unequivocally distinguish them from residual or freshly released clays. The main characteristic is their occurrence as separate bodies having distinct boundaries and preferentially located on present or former walls or ped faces as oriented masses (Cady, 1965). Associated with these features are the exhibition of birefringence patterns consisting of extinction and illumination of the oriented bodies when the thin sections are

Table 3. Clay and fine clay analyses of 3 selected profiles, followed by B/A and B/C clay ratios of the remaining profiles

Site No., Soil Series & Location	Horizon	Depth cm.	Particle Size (mm) <.002: 2 mm	<.002: B/A Clay	<.002: B/C Clay	<.0002: <2 mm	<.0002: B/A Fine Clay	<.0002: B/C Fine Clay	<.002
			%			%			%
3	Ap	0-17	14.1			3.0			29
Marlette	A2	17-30	13.0			1.9			14
Ingham Co.	whole	30-52	22.6			4.1			20
MSU Campus	B&A subA	30-52	20.3			2.6			20
	subB	30-52	26.1			6.1			24
	B2t	52-80	26.8	1.9	1.08	10.1	3.0	1.9	38
	B3	80-97	28.0			5.2			20
	C	97-150	24.7			5.2			21
7	Ap	0-20	15.8			7.9			44
Miami	B1	20-30	28.6			17.2			58
Ionia Co.	B21t	30-45	25.6	1.6	1.8	14.8	1.7	4.5	57
Wheat Plots	B22t	45-58	25.3			13.5			55
	B3	58-75	26.7			9.9			36
	C	75-125	13.7			3.0			21

Table 3 (continued)

Site No., Soil Series & Location	Horizon	Depth cm.	Particle Size (mm)						
				<.002			<.0002		
			2 mm	B/A Clay	B/C Clay	<2 mm	B/A Fine Clay	B/C Fine Clay	<.002
			%			%			%
8	Ap	0-18	16.8			7.0			38
Miami	B1	18-30	19.6			8.0			39
Washtenaw Co.	B21t	30-45	25.9	2.0	1.3	9.0	1.88	3.4	33
Dump	B22t	45-65	33.8			13.2			37
	B3	65-125	31.0			14.6			42
	C	125-150	25.8			3.8			17
Site 1 = Miami				1.3	1.03				
Site 4 = Marlette				2.4	1.9				
Site 6 = Marlette-Miami				4.0	1.6				
Site 5 = Marlette (Bisequal)				4.3	1.09				

examined on rotation between crossed nichols of a petrographic microscope (Brewer, 1964).

Such oriented clay bodies have been identified in this study and their morphology extensively described in the "Micromorphology" section. Poorly oriented clay bodies were also readily identified and described. They consist of clay materials that could have been present in the original glacial sediment, or they could be masses synthesized in place from products in solution and/or previous minerals, e.g., mica. Such clays were recognized as having a somewhat amorphous, non-birefringent character and were often associated with silt materials and/or organic matter as ground mass.

Another characteristic of translocated clays is the larger proportion of fine clays they contain compared with the total clay fraction (<2 μ).

b. Fine clays (<2 μ)

Data for fine clay percentages and distribution are presented in Table 3. As for the total clays, absolute values are higher for the Miami profiles than for the Marlette profiles. These values usually represent also a much higher percentage of the total clay: 33 to 58 per cent for the Miami profiles, compared with 14 to 38 per cent for the Marlette.

For any given profile (Miami or Marlette), relatively low percentages of fine clays are recorded for the C horizon. They are usually 50 per cent lower than that of the B2t horizon above. Lowest absolute values are recorded for the A2 horizon and the A part of any A and B or B and A horizon of the Marlette profile.

Assuming homogeneity of the original glacial sediments, one must conclude that the higher percentage of fine clay observed in the upper part of the Miami profiles may have originated from neo-formation or synthesis inside the profile, by weathering. Otherwise, the C horizons would have shown higher percentages of fine clay.

Many researchers have suggested that the percentage of fine clays and the ratio of A/B of this component represent a very useful index for tracing the development of an argillic horizon, e.g., Dumanski and St. Arnaud (1966), McKeague and St. Arnaud (1969), Smith and Wilding (1972). It appears that, due to their size and mineralogical makeup, fine clays are likely to move more readily than coarse clays and the pattern of their distribution throughout a soil profile could be used effectively as a more sensitive index for tracing clay illuviation.

c. Genesis of argillic horizons

Since migration is considered a main process associated with the accumulation of the silicates clays in the lower part of the solum, there must be some factors associated with the release of these fine minerals from the upper part of the solum, and some other factors responsible for their deposition in the lower part of the profile.

Clay minerals possess an inherent tendency to disperse in the absence of flocculating agents. Consequently, in natural media, they would tend to be peptized and to go readily into suspension (Smith, 1934). This state of suspension seems to be greatly enhanced by the presence of soluble organic compounds that act as chelating agents that allow Fe and Al to go into solution and to be carried away easily (Barshad, in Bear, 1964). Organic matter may also enhance suspension by shifting the concentration values of the electrolytes necessary for flocculation to a higher concentration.

Once the clay particles go into suspension, they will remain peptized until some new factor induces their deposition. As a whole, deposition can happen in two ways: 1) in some cases, it may consist of mere settlement of the particles as water, their carrying agent, is withdrawn because of differential moisture content of the soil; 2) in other cases, deposition occurs while the particles, still in suspension, come to a state of flocculence after most of their electric potentials have been neutralized by cation adsorption at the edges or the surface of the clay lattices.

The deposition of the clay particles by mere settlement or following water withdrawal has been found to be the major process involved in their accumulation in the textural B horizon. Experimental laboratory work by Smith (1934), Brewer and Haldane (1957), Buol and Hole (1959), and Hallsworth (1963) has established that the mode of deposition of the clay particles greatly affects their morphology.

Materials deposited while still in dispersed suspensions tend to do so in an orderly fashion that later confers to them strong, optically birefringent properties easily observable under a petrographic microscope. On the other hand, materials deposited through flocculation fail to show any orientation pattern. The same authors have also found that development of oriented clay skins is conditioned by a specific water regime consisting of alternate cycles of wetting and drying.

The existence of a network of pores as well as the size of individual pores have also been considered very important factors for clay skin development in an argillic horizon (Soil Conservation Service, 1975). Above a certain pore size, the particles do not deposit, but follow the water downward. On the other hand, there must be a system of voids to allow the water to circulate in massive, dense soils. No sign of clay flow has been observed, and clay skin development does not seem to start until cracks and other voids are well organized in the soil profile.

As mentioned above (Particle sizes, Total clay fraction), most of the profiles examined in this study have shown a maximum accumulation of clay size particles either immediately above the C horizon or above the horizon overlying the C. The simplest explanation is that colloids in suspension have a very strong tendency to flocculate in the vicinity of the calcareous till where the activity of such cations as calcium and magnesium (strong flocculating agents) are considered to be at a maximum. Observation of thin section samples from these horizons have shown that the clay bodies of these horizons are not as well oriented as those of the upper horizons of the profile. This could suggest that the clay that deposits at the upper part of the Bt horizon do so by water withdrawal as they are still in a state of dispersion while the clay deposited at the lower part of the solum has flocculated before their deposition.

The possibility that the silicates may migrate in solution as products of decomposition and later may be resynthesized into clay crystals has been suggested by Oertel (1968) and several others. The validity of this theory may be checked by observation of x-ray diffraction patterns. If the mineralogical analyses show little or no difference between the clay of various horizons, there is a strong possibility that those clay minerals have moved as discrete particles without neoformation.

2. Bulk density

The bulk density values are shown in Table 4. These values represent average figures from 3 to 5 samples. Complete values for all the profiles could not be obtained because a large number of clods could not be maintained intact and consequently were disturbed. On many other occasions, the samples were discarded because bubbles were escaping from the clods while they were being coated. The methods and procedures (Soil Conservation Service, 1972) call for rejection of the sample whenever such bubbling is observed.

As a whole, the values obtained for the lower part of the solum (B2 and B3 horizons) are somewhat comparable between the two soils. There is no definite trend for the variation of the values within these horizons. However, values obtained for the A2 and part of the A and B of the Marlette soils are noticeably higher. Similar values were obtained for quite a few isolated samples collected for comparison purposes during the site investigations.

Table 4. Bulk density and chemical properties of the soils sampled

Site No., Soil Series & Location	Horizon	Depth cm.	Bulk Density	pH	Total C	Inorganic Carbon	$CaCo_3$ Equivalent
					%	%	%
1	Ap	0-18	1.58	6.5	.80	tr.	tr.
Miami	A2	18-25	1.72	6.4	.29	.09	.75
Ingham Co.	B2t	25-38	1.64	7.25	.51	.04	.33
MSU Campus	B3	38-65	1.75	7.72	.82	.8	6.6
	C	65-100	1.84	8.13	2.80	2.76	23.0
3	Ap	0-17	1.64	5.92	.91	.05	.42
Marlette	A2	17-30	1.76-1.82	5.63	.41	tr.	.03
Ingham Co.	whole	30-52	1.70	5.5	.24	0.37	.22
MSU Campus	B&A subA	30-52	-	5.64	.12	.02	.17
	subB	30-52	-	5.42	.12	.01	.83
	B2t	52-80	1.68	5.63	.20	.05	.42
	B3	80-97	1.65	7.8	.90	.89	7.42
	C	97-150	1.79	7.95	1.34	1.35	11.25
4	Ap	0-20	-	5.62	.85	0	0
Marlette	whole	20-33	-	5.87	.24	tr.	tr.
Ingham Co.	B&A subA	20-33	-	6.08	.27	.03	.25
Locke Twp.	subB	20-33	-	5.85	.38	.01	.08
	B21t	33-48	-	6.08	.29	.02	.16
	B22t	48-73	-	6.98	.21	.02	.16
	B3	73-85	-	8.02	2.12	1.91	15.9
	IIC1	85-105	-	8.29	2.32	2.30	19.6
	IIC2	105-120	-	8.24	2.75	2.75	22.90

Table 4 (continued)

Site No., Soil Series & Location	Horizon	Depth cm.	Bulk Density	pH	Total C	Inorganic Carbon	$CaCo_3$ Equivalent
					%	%	%
7	Ap	0-20	1.60	7.32	2.2	.02	.16
Miami	B1	20-30	1.62	7.53	.81	tr.	tr.
Ionia Co.	B21t	30-45	-	7.72	.42	tr.	tr.
Wheat Plots	B22t	45-58	-	7.62	.40	tr.	tr.
	B3	58-75	1.70	7.85	.28	.02	.16
	C	75-125	1.80	8.18	2.9	1.72	14.33
5	A1	0-8	-	7.2	2.07	.02	.17
Marlette	A2	8-25	-	5.38	.62	.01	.08
(Bisequal)	B2	25-33	-	5.42	.22	.02	.16
Ingham Co.	A2'	33-48	-	5.78	.33	0.0	0.0
E. Lansing	A&B	48-65	1.76	5.48	.36	.04	.33
Water Treat-	IIB2t'	65-90	-	5.55	.18	.03	.24
ment Plant	IIB3'	90-115	-	6.39	.33	.02	.19
	IIC	115-150	-	8.21	1.55	1.35	11.2
6	Ap	0-20	-	7.79	1.28	.09	.74
Marlette-Miami	A2(B&A)	20-35	-	7.88	.35	.01	.08
Ingham Co.	B21t	35-55	-	7.89	.24	tr.	tr.
Meridian Twp.	B22t	55-68	-	8.02	.30	.1	.83
	C1	68-83	-	8.34	4.15	4.04	33.6
	C2	83-150	-	8.37	3.94	4.35	36.24

Table 4 (continued)

Site No., Soil Series & Location	Horizon	Depth cm.	Bulk Density	pH	Total C	Inorganic Carbon	$CaCo_3$ Equivalent
					%	%	%
8	Ap	0-18	1.65	6.07	1.35	tr.	tr.
Miami	B1	18-30	1.67	5.56	.45	tr.	tr.
Washtenaw Co.	B21t	30-45	1.70	5.56	.35	tr.	tr.
Dump	B22t	45-65	1.75	5.37	.49	tr.	tr.
	B3	65-125	1.70	5.74	.39	.02	.16
	C	125-150	1.78	7.96	1.85	1.65	13.75

Values as high as 1.85 have been recorded for some samples collected at the bottom of the A2.

Grossman and Carlisle (1969) have reported on results of investigations conducted by many authors on a very compact layer commonly found below the upper sequum of some Spodosols and Alfisols. Such layers, generally known as a "fragipan", have much higher bulk density than both the overlying and the underlying horizons. Buol et al. (1973) have described the basic makeup of these compacted horizons and the Soil Conservation Service (1975) has outlined the process of their genesis and set up criteria for their recognition both in the field and the laboratory.

Features observed both in the field and on thin sections in the laboratory suggest that a fragipan-like layer may be present, or is being formed within some of the Marlette profiles. Such horizons have been recognized and identified in Ingham County, Locke Township, during the summer of 1974 both by the author and other soil scientists (Engel, 1974, 1976). In places, this compacted horizon is easily identified by its whitish color, its brittleness under the pressure of a field auger and its unusual compaction.

Thin section observations have also revealed the presence of similar features in the fabric of the samples of the A2 and A and B horizons of the Marlette. These features have been recognized as compacted bodies of skeletal grains closely packed, and with little or no bracing. The current literature on genesis of the fragipans and the factors responsible for the bonding of these skeltan grains has been substantially reviewed by Grossman and Carlisle (1969).

The high bulk densities observed on these soils can be attributed to several factors, depending on the horizon. The C horizon of many Michigan soils is often characterized by a high bulk density (as high as 1.95). These high figures are due to the presence of more dense minerals (calcite and dolomite) in the C horizon and/or to the fact that the glacial till has been compacted by the load of the glacier. This high bulk density will persist until some development processes reach this horizon (Laurin, 1973). Then dissolution, cracking, cultivation by plant roots and other pedogenic processes will lower the bulk density.

The B2t horizon often shows an increase in bulk density through enrichment of this horizon by illuviation (Marshall and Haseman, 1942). Such a relation has also been recognized by McCaleb and Cline (1949) on some Gray Brown Podzolic soils of New York.

3. Chemical determinations

Values for pH and carbon analyses are given in Table 4 and the results for cation exchange capacity and exchangeable cation determinations for 3 selected profiles are shown in Table 5.

As a whole, the Marlette soils have a lower pH than the Miami soils throughout their sola, except for Site 8 of Miami. This is also the general trend for individual exchangeable cations. For a given horizon, the pH is on the acid side anytime the sum of the exchangeable cations accounts for less than half of the cation exchange capacity.

Among individual cations, Ca is by far the dominant one, followed by Mg. The sum of Na and K ions is very low for all the

Table 5. Cation exchange capacity and exchangeable cations of 3 selected profiles

Site No., Soil Series & Location	Horizon	Depth cm.	C.E.C.	Exchangeable Cations Ca	Mg	Na	K	Total	Base Sat.
			meq/100grs						%
3	Ap	0-17	10.38	.2	.6	.09	.2	1.09	10.5
Marlette	A2	17-30	6.19	.8	.27	.09	.1	1.25	20.3
Ingham Co.	A&B whole	30-52	10.85	3.8	.92	.14	.11	4.97	45.8
MSU Campus	A&B subA	30-52	6.35	1.7	.47	.13	.1	2.4	37.7
	A&B subB	30-52	13.69	3.7	1.32	.15	.13	1.7	12.4
	B2t	52-80	15.56	4.2	1.8	.19	.13	6.32	40.6
	B3	80-97	12.70	7.8	2.5	.23	.13	10.66	83.4
	C	97-150	12.65	12.5	2.36	.22	.13	15.18	100
7	Ap	0-20	21.7	13.0	1.67	.12	.17	15.0	68.9
Miami	B1	20-30	24.05	15.5	2.92	.23	.26	18.9	78.6
Ionia Co.	B21t	30-45	22.73	13.6	3.0	.27	.26	17.1	75.4
Wheat Plots	B22t	45-58	21.18	12.6	2.85	.23	.23	15.9	75.1
	B3	58-75	19.72	12.4	2.7	.38	.23	15.7	79.7
	IIC	75-125	7.41	6.6	1.39	.22	.11	8.18	100
8	Ap	0-18	13.65	5.7	1.1	.25	.2	7.25	53.1
Miami	B1	18-30	12.19	5.4	1.1	.3	.11	6.91	56.9
Washtenaw Co.	B21t	30-45	15.93	6.6	1.4	.3	.15	8.45	53.0
Dump	B22t	45-65	19.70	7.5	2.0	.33	.18	10.0	50.8
	B3	65-125	18.61	7.5	2.2	.33	.18	10.2	53.9
	C	125-150	18.38	18.7	1.7	.34	.11	20.9	100

samples. The large proportions of Ca and Mg are easily explained by the fact that these soils have been developed from a glacial till that had originally a very high content of these cations in the forms of calcitic and dolomitic limestones. These limestones have been leached to the point that the value for $CaCo_3$ equivalent is less than 1 per cent throughout the solum (except for two B3 horizons). The percentage of $CaCo_3$ equivalent of the different C horizons is quite variable (from 11 to 35 per cent) and is believed to reflect mostly the nature of the original glacial till, or partial leaching.

Cation exchange capacity values are similarly lower for the Marlette than for the Miami soils. For a given soil profile, the cation exchange capacities are functions of organic matter, clay content (Cline, 1949), and the types of clay present. It has already been mentioned above (in the particle size section) that the percentage of clay was higher for the Miami soils; furthermore, the fine clay fraction was found to account for a larger proportion of the total clay in the Miami and for a much lower proportion in the Marlette studied.

It has been established (Grim, 1968; Calliere and Henin, 1964) that the size of individual clay particles greatly influences the amount of electrical charge they carry; small-sized particles carry relatively larger quantities of electrically neutralizable bounds than the larger particles. Obviously, this could be singled out as the main factor responsible for the noticeable difference in the cation exchange capacity of the two soils.

Within a given profile (Marlette or Miami), the highest values recorded for the cation exchange capacity always coincide with the highest percentage of fine clays and, similarly, the horizon with the lowest fine clay has the smallest cation exchange capacity.

When all the data (pH, C.E.C., exchangeable cations, $CaCO_3$ equivalent) are considered, they bring out the strong suggestion that the Marlette soils have been subjected to stronger leaching than the Miami. Leaching of a soil on a given parent material may be due to greater age or higher quantities of percolating water (Walker, 1965). Field observations dealing with spatial distribution of the two soils have ruled out the age as a factor of their differentiation. Helen Martin's map on surface formation of Michigan (1955) outlines the morainic pattern created by the advances and retreats of the glaciers over the land. Landform correlation has been successfully used to date fairly accurately the surface of the land. In general, the pattern is that the land surface is older in the southern part of the state and becomes younger as we progress toward the northern portion, where the ice was still active several thousand years after the southern portion of the state had been completely deglaciated. Consequently, if age were the single factor of this differential leaching, the Marlette soil, which is more strongly leached, should be dominant in the south and should phase out stepwise as we go to younger moraines to the north. But this is not the trend observed.

The hypothesis of stronger leaching because of higher quantity of percolating water is very likely to have occurred. Leaching has been recognized as the major factor of transformation of original parent material to soil (Jenny, 1941; Jackson, 1959; Barshad, in Bear, 1964; Embleton and King, 1968). The process of leaching is itself dependent upon other factors among which the texture of the parent material is the most important one. Normally, coarser materials will allow a greater amount of water to enter the profile and furthermore will permit a faster movement of the water through the soil mass. Chelating actions of some soluble organic compounds also influence the removal of some cations.

The coarser texture commonly observed at the surface of the Marlette is believed to have accounted (at least partly) for the more advanced leaching that characterizes this soil. Periglacial processes have been described which could have depleted the initial surface materials of some of their finer components.

Concentration of coarser materials may also result from the modification of superglacial drift by runoff water as deglaciation takes place. This particular phenomenon may occur in a very mixed pattern depending on the local relief; this could explain some of the wide variation in surface texture commonly observed within a very short distance.

4. Leaching as related to vegetation

Leaching of soil parent materials is also a function of soil-plant interaction. This interaction is either an ion-exchange process in which cations are taken up by the roots in exchange for H ions, or solubilization reactions (including chelation) in which organic matter, Fe, Al, etc., after becoming mobile, are transported downward and accumulate in an illuvial horizon. The subsequent enrichment of the micelle in H^+ ions is a major cause of leaching, a normal sequence in the development of soil acidity.

Plant species and plant communities are known for the intensity of leaching they create in a soil, as well as the type of litter they return to the soil surface. Two broad classes of humus have been recognized on the basis of their acidity and the intensity of leaching they develop in the soil.

Wilde (1946) has summarized the basic characteristics of these types of humus as follows.

"Mull humus" is characterized by a high degree of biological activity and a rapid rate of oxidation. Consequently, it has a tendency to retard the leaching of soil or the formation of eluvial and illuvial horizons. The reaction of mull humus ranges from slightly acid to mildly alkaline (pH 5 to 8). Such humus is commonly formed under hardwoods.

"Mor humus" has undergone less decomposition and consequently tends to accumulate on the surface. Its low biological activity generates strong reducing agents which encourage podzolization of the soil.

In Michigan, broad soil regions have been shown to coincide closely with specific forest association boundaries. Messenger et al. (1972), outlining the southern boundary of the podzols of Michigan, have shown that this boundary coincides closely with those of podzol forming tree species such as hemlock and white pine. Wilde (1946) has presented a similar soil-forest province map for the entire continental United States. He has recognized three broad provinces in the Midwest regions as follows.

The Podzol-Northern coniferous forest province dominated by spruce, fir, hemlock and yellow birch; the podzolic soil-mixed hardwood-coniferous forest province dominated by white pine, hemlock, hard maple and beech; and the grood soil[1]--prairies-forest dominated by an oak-hickory population.

According to Wilde, the Southern portion of Michigan may be considered as a podzolic soil-mixed hardwood-coniferous-forest province. Since the plant communities of this province include both podzol-former and non-podzol-former species, it is possible that differences in leaching intensity and stage of profile development observed between the Miami and the Marlette soils are caused to some extent by the local variations in stand composition.

Unfortunately, such a factor is practically impossible to test nowadays: most of the original presettlement vegetation has been disturbed and the vegetation map prepared by Veatch (1959) is rather general. It does not provide enough detail to test the soil-plant distribution relationship on a local level. Finally, as pointed out by Veatch, the basis for reconstruction of many of the vegetation map units has been the accepted correlations between forest types and soil types.

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[1]Grood soils may be considered as synonymous with prairie soils.

VIII. RESULTS AND DISCUSSION - X-RAY ANALYSES

1. Interpretation of diffractograms

Each mineral is characterized by a basal spacing which yields specific diffraction peaks when scanned with the goniometer while being exposed to a given radiation source.

Smectite group: When saturated with magnesium and glycerol solvated, these minerals can be identified by a distinctive interplanar spacing of 17 Å. In the natural conditions, these minerals adsorb various amounts of water, depending upon the ambient humidity, and this reflection is diffuse and varies from 12 to 18 Å. Following K/550°C treatment, the smectite minerals collapse and the 17 Å peak shifts to 10 Å which, if present due to illite, then becomes reinforced.

Chlorite and vermiculite: They are identified by a 14.2 Å spacing. Following the K/550°C treatment, the 14.2 Å shifts to 10 Å in the case of vermiculite but persists (with some weakening) in the case of chlorite.

The *mica* group (illite) shows a spacing of 10 Å which persists on all treatments.

The presence of *kaolinite* is indicated by a 7.1 Å (001) basal spacing for the magnesium saturated samples. Following the 550°C/ heat treatment, kaolinite becomes amorphous and consequently does not yield any reflection peak.

Randomly *interstratified* minerals yield spacings intermediate between the normal (001) spacing of the individual members, depending on the proportions of the species in the mixture (Whittig, 1965).

2. Peak intensity and peak ratios

Although the absolute intensity of the different peaks is a function of factors not always related to the mineralogical composition of the samples (thickness of the sample deposited on the tile, scale factor, etc.), the relative intensity of the different peaks is closely associated with the structure and type of mixture of different minerals present in the sample. The ratio of specific peak heights has been used to trace the origin of glacial materials. In a recent study conducted by Rieck (1976) in an interlobate area in Southeast Michigan, clay mineralogy was found to be the most consistent and reliable property by which the provenance of a drift sample could be determined. Calculated 7 Å/10 Å peak ratios of 0.91 or more were correlated with the Saginaw Lobe while a ratio of 0.90 or less corresponded to glacial sediments from the Huron-Erie Lobe.

3. Interpretation of the diffractograms from the different profiles

The x-ray analyses of the total clays were conducted for 4 profiles. In addition, fine clays were separated and x-ray diffraction data were obtained for *3 profiles*. Due to the striking similarity observed for 3 of these profiles, their mineralogy will be discussed together. On the other hand, the Miami profile of Site 7 exhibits a different pattern and, consequently, will be discussed separately.

Marlette soils, Sites 3 and 5; and Miami, Site 8. The mixed clay mineralogy of these sites is shown by the diversity of the diffraction peaks. Spacings at 14.2 Å on the Mg-glycol treated sample suggest the presence of vermiculite and/or chlorite; but the disappearance of the 14 Å peak on K/550°C treatment shows that chlorite is not a significant component of the mixture.

The well defined peak at 10 Å spacing is an indication of the presence of illite minerals. The persistence of this peak on heating and its corresponding (002 and 003) reflexion at 5 Å and 3.3 Å reinforce this assumption.

The 7.1 Å basal spacing identifies the kaolinite mineral. This peak usually disappears on heating unless chlorite is present in the sample.

The general basic pattern just outlined above does not change significantly within a given profile, except for some slight variation in the peak intensity; but this could be created by conditions outside the mineralogical makeup of the sample.

The 7 Å/10 Å peak ratio theory for tracing the provenance of a given till appears valid for the profiles studied. It is larger than 1.0 for the 2 profiles very likely to have developed from the Saginaw Lobe till while it has a value of .83 for the Site 8 profile sampled in eastern Washtenaw County.

Fine clays. The diffraction patterns of the fine clays show similarity with those of the whole clays. One main difference is that the 14 Å spacing is much weaker or even absent (mostly in the B2 horizon). The peaks are generally broader and flatter than the

Figure 5. X-Ray tracings of total clay and fine clay fractions of Marlette - Site 3 profile. p. 91

Figure 6. X-Ray tracings of total clay fractions of Marlette - Site 5 profile. p. 92

Figure 7. X-Ray tracings of total clay and fine clay fractions of Miami - Site 7 profile. p. 93

Figure 8. X-Ray tracings of total clay and fine clay fractions of Miami - Site 8 profile. p. 94

Treatment (1) Mg-saturated, glycerol solvated.
(2) K-saturated, air dry.
(3) K-saturated and heated 300°C.
(4) K-saturated and heated 550°C.

Scale factor is 8 for all tracings.

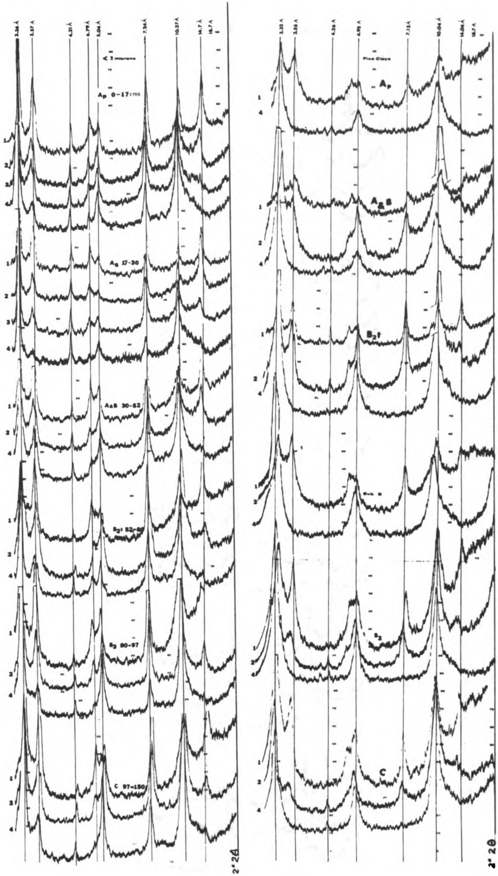

Figure 5, See p. 90

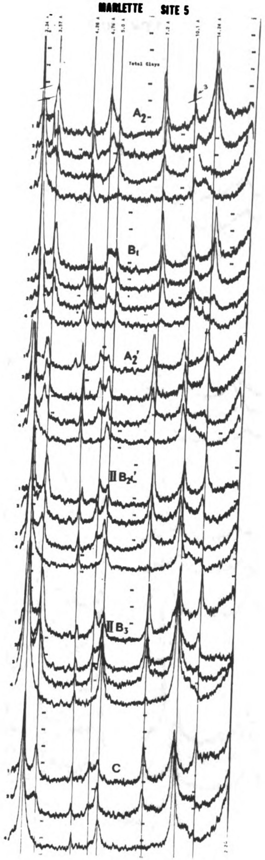

Figure 6, See p. 90

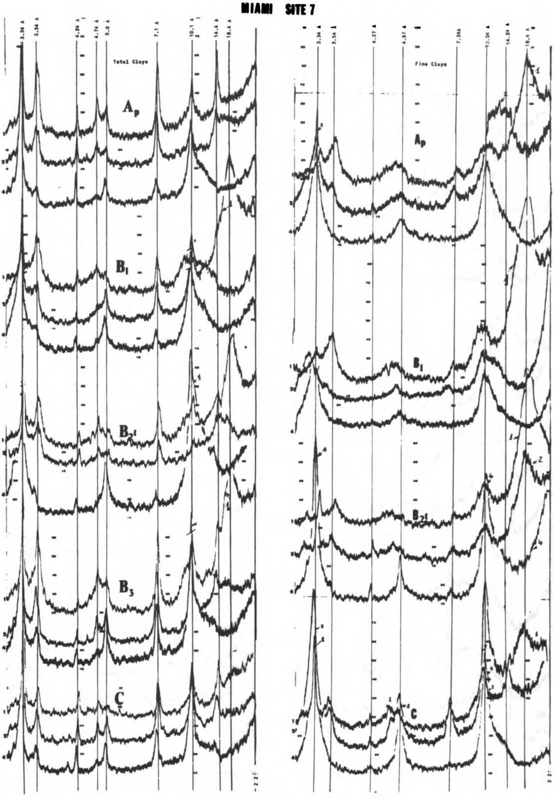

Figure 7, See p.90

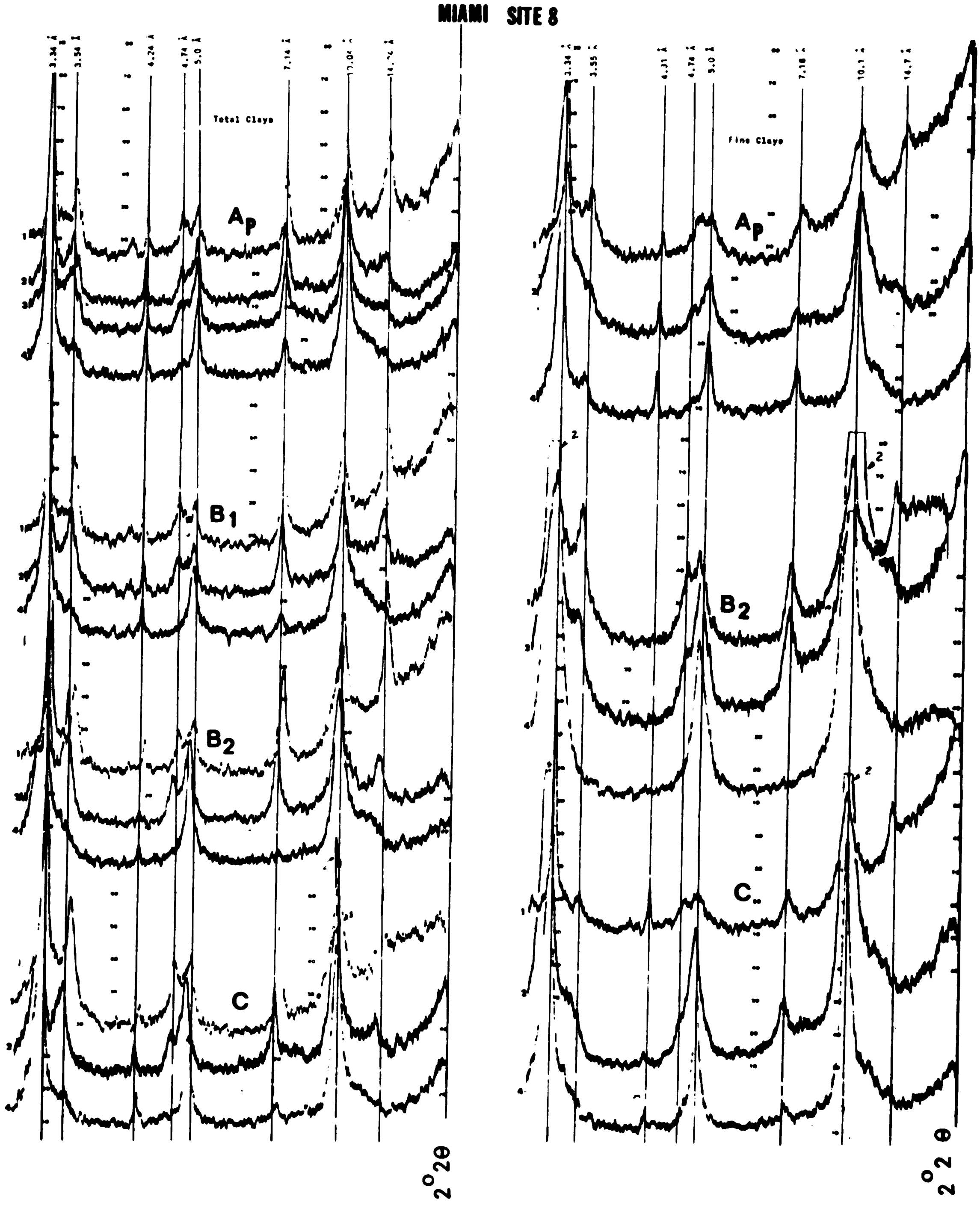

Figure 8, See p. 90

corresponding samples from the whole clay fraction. Following the K/550°C treatment, the 10 Å and its associated (002 and 003) orders are strongly reinforced. As mentioned above, this 10 Å spacing observed on K/550°C treated samples is assigned to illite, vermiculite and illite, but since no 18 Å spacing was observed on Mg-glycol treatment and since the 14 Å itself was quite weak, it becomes therefore quite safe to consider illite as the major component of these fine clays.

Miami Site 7, Ionia Co. plots. Diffractograms from the *whole clay* samples basically differ from those of the 3 profiles discussed above because of the presence of a broad, very intense peak at the 18 Å spacing on all samples from the B horizon. This is the classical basal spacing for the identification of the smectite groups. Following the K/550°C treatment, this spacing shifts to 10.1 Å, thus reinforcing that peak. No such spacing is observed for the samples from either the Ap or the C horizons.

The 14 Å spacing is weak or absent for these B horizon samples but it is well expressed both in the Ap and C horizons.

The diffractograms of the *fine clays* are rather unique: most of the spacing values observed correspond to the smectite groups. The Mg-glycol treatment yields a very broad and intense peak at 18 Å which tends to shift to a weak 12 Å spacing under the K/air dry treatment. Following the K/550°C treatment, the 10 Å peak and its associated second and third orders are greatly reinforced. This is the typical diagnostic feature of smectites.

4. General discussion

The large diversity of x-ray diffraction peaks observed is a good indication of the mixed mineralogy of the soil clay fractions. The relatively great similarity observed among the samples from a given profile (except for Miami Site 7) suggests that clay movement accounts for most of the clay distribution differences observed in these soils.

The bulk of the fine clays is made up of illite, except for the Miami soil of Site 7, for which montmorillonite is by far the major component in portions of the profile.

The fact that little montmorillonite is observed in both the A and the C horizon of Site 7, while it is largely dominant in the whole B horizon, suggests that some fine clay is being formed in place; the broadness and lack of sharpness of the spacing indicate poor crystallization of this mineral.

This "in place" neoformation explains some apparent anomalies observed in this profile. The first anomaly would be the clay distribution throughout the profile: the large amount of clay observed in the B1 could be due to some enrichment caused by recent neoformation. As pointed out by Barshad (1959), maximum clay formation occurs in the horizon just below the surface horizon, and this is probably the case here. The montmorillonite is a normal weathering product of illite and this change can take place by mere oxidation of the Fe with subsequent weakening of the basal plane structure (Harrison et al., 1959), accompanied by K removal.

The presence of a large amount of montmorillonite in the Miami of Site 7 could also explain the greater cation exchange capacity observed throughout the profile; those values (19 to 24 meq/100 grs) are greater than those of the Miami of Site 8 (12 to 19 meq/100 grs). However, the latter has a higher content of clay in the B (as much as 34%), but most of this clay is made up of illite, which has a lower cation exchange capacity than the montmorillonite.

The illite observed in all the samples is probably the mineral that was dominantly present in the original glacial sediment and was inherited from the shale, which is believed to be the major source of the clay minerals of the till-derived soils of the Central United States (Jackson, 1959).

IX. POSSIBLE PRACTICAL SIGNIFICANCE ASSOCIATED WITH THE CHARACTERISTICS OF THE MIAMI AND MARLETTE

Pedological research dealing with characterization of soils becomes more meaningful when it helps land owners and planners recognize soil features that account for specific differences in soil behavior or warrant differences in soil management. Such features may deal with basic physical properties (erosion hazard, compaction, dynamics of water movement, etc.) or chemical makeup of the soil.

1. Erosion hazard

Field observations and basic laboratory data have revealed the presence of a coarser layer, of various thicknesses, at the surface of the Marlette soils. The lower percentage of clay in these horizons induces a lack of cohesion among the sand or silt particles and makes the epipedon more susceptible to surface erosion by running water. When such erosion occurs, the subsurface horizon (A2 or B and A) becomes exposed at the surface.

Many sites observed during the field investigation have actually shown extensive signs of accelerated erosion at these sites. The problem was easily recognizable by the color of the soil surface, showing large patches of bleached materials from the A2 or B and A exposed at the surface, and contrasting with the reddish brown color of the B horizon. In many cases when these observations were made following rainstorms, substantial amounts of sand were found to have been deposited in the lower part of the landscape.

The sandy surface will also confer to the upper part of the profile a relatively lower water holding capacity. This may create more severe droughty conditions during dry seasons. But an offsetting influence may be enhanced infiltration that has already been cited as increasing leaching.

2. Compacted layers

The determination of bulk density has yielded very high values for most of the samples collected from the bottom of the A2 horizon (1.76-1.82). This may be considered as a very unusual figure compared to the value 1.4 to 1.6 commonly recorded for these horizons in virgin areas. As mentioned above (under Bulk Density), the layers for which these values have been obtained are being subjected to some compaction similar to those observed in fragipans.

The practical significance of the presence of a compacted layer above the argillic horizon has been analyzed by Grossman and Carlisle (1969). They have also reviewed the different types of limitations connected with these layers.

Compacted layers unfavorably influence plant growth by restricting root penetration. The depth to such dense layers is a very important factor. Thus, deep fragipans may not be as critical to plant growth while the shallow ones will bring the limitations to a maximum. Erosion can reduce the thickness of the surface horizon, to the point that these compacted layers may finally be exposed to the surface. In these situations, they may seriously interfere with land cultivation.

Veihmeyer and Hendrickson (1948) have conducted laboratory experiments on artificially compacted soils with textures ranging from sand to clay. They were able to develop bulk density of 1.9 or above on sandy soils, particularly those which seem gritty and contain considerable amounts of angular materials. Soil density above which roots did not penetrate differed from soil to soil, but on all soils, no roots were found at densities of 1.9 or above. The significance of the presence of a dense layer under the A horizon of the Marlette soils has been observed in the field both by the author and other members of the Soil Survey party of Ingham County (Engel, 1975). Corn growing on these sites has shown extensive signs of drought related stress (rolling of leaves). These features were absent in similar crops grown on Miami soils.

The presence of compact layers in a soil can also be of great significance when drainage lines and septic tanks have to be installed. The C horizon of both Miami and Marlette may be important in this connection.

3. Water retention

The amount of water a given soil can hold is a function of its texture, type of clay, organic matter content and porosity. Coarse textured soils with low organic matter have normally a lower water holding capacity than finer soils. The percentage of fine clays should also be a determining factor in water retention since these fine colloids, because of their much larger surface area, are expected to hold a greater amount of water than the coarser particles.

The results of mechanical analyses reported in Tables 2 and 3 show values of clays and fine clays higher for the Miami than the Marlette soils. This should give the Miami soil a higher capacity for water retention. In fact, data compiled in characterization handbooks[1] of Michigan soils show that at 1/3 atm. the Miami soils hold twice as much water as the Marlette soil in the Ap horizon and an average of 30 to 40 per cent more water in the B horizon. However, all of this moisture may not be available for plant growth.

4. Argillans

The presence of clay particles around the structural units of the soils and along pores and root channels may be expected to play an important role in the dynamics of water movement and the availability of nutrients. Argillans, being essentially zones of the most active portions of the soil (fine clays), are likely to play an important role in soil fertility. These cutans may influence plant growth in several ways: they may act as a physical barrier to root expansion; they may interfere with ion diffusion; or they may adsorb large amounts of cations by ion exchange phenomena. They may also influence the dynamics of water movement by preferential absorption because of their larger surface area.

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[1]These data are compiled from results of laboratory analyses performed at the Soil Survey Laboratory at Beltsville, Maryland.

The possibility that clay skins can prevent expansion of the root system is apparently quite valid. While describing the soil profiles and collecting samples, there were many evidences of a tendency for the small and medium roots to be preferentially distributed along the faces of the peds, rather than penetrating the peds through the clay skins, wherever these skins were thick. The lack of penetration was verified by the ease with which these roots could be pulled off the peds without substantial breaking. Following experimental works on effects of clay skins, Buol (1974) has concluded that clay skins restrict the roots from fully exploring the interior of the peds.

The effect of clay minerals on soil water properties has long been recognized. Grim (1968) has reviewed the current theories on the nature of the first molecules of water and the subsequent molecular layers (8 to 28 Å). The particularly high density-water is believed to be best developed and appears to reach its greatest thickness on the basal plane surfaces of the expanding-lattice minerals of the montmorillonite group. The presence of a layer of clay at the surface of the peds is also believed to greatly reduce the mobility of water.

The effect of clay skins on nutrient uptake has also been investigated. Khalifa and Buol (1969) have found that total dry weight and uptake of N, P, and K were decreased in wheat plants grown in clay skin-coated peds from a B22t horizon of a Cecil soil compared with similar partially coated peds. They concluded that clay skins reduce plant growth and nutrient uptake by serving as a barrier for root growth and/or by slowing ion diffusion. Soileau

(1964) has similarly investigated the effects of iron kaolinite cutans enveloping the soil aggregates. He concluded that cutans tend to stabilize the aggregates and restrict the plant growth by making nutrients less available. Potassium uptake was particularly restricted.

In more recent works, Tyler (1972), working under Buol, has investigated the diffusion characteristics of artificial clay skins developed on millipore paper using clays of various iron contents and applying them in single or multiple applications to effect the orientation. He found that the diffusion coefficient of the film decreases with increasing solution concentration. He theorized that this decrease of the diffusion was probably due to the increased tortuosity of the system. But, in a more recent letter (1974), Buol has mentioned that he does not believe that clay skins drastically reduce ion diffusion.

X. CONCLUSIONS

On the basis of the field observations and/or laboratory determinations, the following conclusions seem warranted.

The Miami and Marlette soils are two series that are intimately associated, intermingled, in all of southern Michigan. Their respective distributions seem to depend mostly on local factors rather than broad geographical factors. Consequently, the initial hypothesis that the Miami is basically a "Southern" soil that phases out gradually as we progress north could not be verified. At least, when such a trend is observed, it may be due to spatial distribution of other factors rather than a merely geographical-latitudinal pattern.

The textural profile of the parent material has been found to be a strong determining factor in the distribution of these two soils. The surface of the original glacial sediment was probably coarser at the sites where the Marlette soil has developed. Even when the soil surface is found to be a loam, the possibility of a formerly coarser surface should not be disregarded, as observed by Threlkeld and Alfred (1967) and Earle (1972).

The most obvious morphological differences between the two soils is the presence in the Marlette profiles of eluvial bodies in the Bt horizon in the form of tongues and interfingerings. These features qualify the Marlette soil as a Glossoboric Hapludalf as opposed to the Miami soil, which is a Typic Hapludalf because of the absence of these eluvial features (Soil Conservation Service, 1975).

The Marlette soil seems to have been subjected to more intense leaching. As suggested by Walker (1965), leaching is a process that may be related to age or permeability of the parent material. In the case of the Marlette, age difference does not seem to be the dominant factor, leaving the permeability of the parent material and leaching effectiveness of the percolating fluids as the next most probable factors. This more intense leaching is reflected by a lower percentage of exchangeable bases.

Effective leaching by chelating compounds from acid-humus forming tree species formerly widely distributed in southern Michigan may also be considered a possible factor for the distribution of the two soils, but such a possibility could not be determined.

Thin section observations have shown that argillic horizons are formed dominantly by discrete movement of the clay particles from the upper part of the solum and their deposition around natural surfaces (single grains, pores, cracks) in the subsoil as cutans. The absence of cutans in the C horizon suggests that these argillans do not form in soil until a certain stage of development has been reached. Such a stage will imply the arrangement of a system of voids through leaching, shrinking and swelling or freezing and thawing. The absence of pores and lack of leaching are probably the reasons why argillans do not develop extensively in the calcareous C horizon.

The basic similarity of the clay mineral throughout most of the profiles shows that clay neoformation normally accounts for little of the accumulation of silicate minerals observed in the Bt horizon. However, this does not exclude the possibility for enrichment by neoformation as observed in one profile.

The tonguing and interfingering observed in the Marlette are pedogenic features created by a dual process. They may be seen as the product of a destructional process in which a former B horizon (now a B and A) is being gradually destroyed by being stripped of fine materials; hence, the residual bleached color and coarser texture that gradually develops. On the other hand, tongues may be seen as created by slumping of these bleached materials into natural openings such as cracks, pores or inter-pedal interstices. These bleached materials start falling into the openings as the soil becomes cohesionless because of lack of fine particles. Such tongues have a definite regular shape with sharp fabric contrast against the adjacent peds. They usually have a V shape and show as sharply differentiated from the mass of the "B" materials. By contrast, albic materials left behind by removal of clay minerals have a less sharp boundary with the underlying ped.

Possibly, given enough time, the Miami soil will eventually show many of the features observed in the Marlette through lessivage, removal of the fine materials and slumping of the silt and fine sands into the cracks and other openings of the soils.

The presence of a sandier surface on the Marlette soil may make this soil more susceptible to surface erosion and confer to it a lower water holding capacity than the Miami. The beginning of the formation of a compacted layer in some of the Marlette soils will eventually create in these soils some of the limitations connected with the presence of fragipans in some of the Northern Michigan soils.

XI. ADDITIONAL WORKS NEEDED

The degree of development of any science can be evaluated by the level of organization established in the differentiation of the objects that this branch of science classifies. Indeed, the concept of soil classification has progressed from the broad categories recognized by Marbut in 1935 to the more precise seven level system presently used in the new Soil Taxonomy (1975).

The Miami soil name has itself been widely used throughout the Midwest and Northeast United States to designate earlier, all mineral soils developed from glacial till and later the well-drained members of these soils (Baldwin, 1937). It was not until quite recently that soil scientists have started recognizing the tonguing and interfingering features in pedons within the "Miami" mapping units and have suggested establishing different soil series for these pedons. Research work recently conducted by Mahjoory (1975) has verified this scheme for placement of the mineral soils of Michigan in the new Soil Taxonomy without recognizing differentiating criteria between the Miami and the Marlette soils. The above omissions lead us to wonder how much of the tonguing is present into other soil series but has gone unrecorded.

It should therefore be of some interest to investigate how much of these features is present in other soil series. Field investigations, conducted through transects and profile descriptions, should provide answers about the extent of these features and the range of basic soil properties under which they occur. Undoubtedly, this could help test some of the basic hypotheses suggested in this study and possibly help point out more of the practical significance associated with the development of these features.

APPENDICES

APPENDIX A

OFFICIAL PROFILE DESCRIPTION OF THE MIAMI AND MARLETTE SOILS

Established Series
Rev. JEF-RWS
9/27/74

MARLETTE SERIES

The Marlette series is a member of the fine-loamy, mixed, mesic family of Glossoboric Hapludalfs. Typically, these soils have dark grayish brown loam Ap horizons, B&A horizons occurring as brown ped coatings interfingering into dark brown loam Bt horizons, dark brown clay loam B2 horizons and brown mildly alkline horizons.

Typifying Pedon: Marlette loam - cultivated
(Colors are for moist soil unless otherwise stated.)

Ap -- 0-9"--Dark grayish brown (10YR 4/2) loam; weak medium granular structure; friable; many fine and medium roots; 5 percent coarse fragments; neutral; abrupt smooth boundary. (6 to 12 inches thick)

B&A -- 9-17"--Dark brown (7.5YR 4/4) clay loam (B part) and brown (10YR 5/3) loam, light gray (10YR 7/1) dry (A part) as coatings more than 2mm in thickness on surfaces of peds and along root and worm channels (more than 15 percent by volume), vertical extention is through the horizon; weak medium prismatic structure parting to weak medium angular blocky; firm (B part); very friable (A part); common fine roots; thin clay films on surfaces of some peds; 5 percent coarse fragments; slightly acid; clear wavy boundary. (5 to 12 inches thick)

B21t -- 17-26"--Dark brown (7.5YR 4/4) clay loam; weak medium prismatic parting to moderate coarse angular blocky; firm; common fine roots; many discontinuous moderately thick reddish brown (5YR 4/3) clay films on surfaces of peds; 5 percent coarse fragments; medium acid; gradual wavy boundary. (6 to 12 inches thick)

B22t -- 26-34"--Dark brown (7.5YR 4/4) clay loam; weak coarse angular blocky structure; firm; few fine roots; continuous moderately thick reddish brown (5YR 4/3) clay films on surfaces of peds; 5 percent coarse fragments; medium acid; gradual wavy boundary. (6 to 10 inches thick.

B23t -- 34-38"--Dark brown (7.5YR 4/4) clay loam; weak coarse angular blocky structure; firm; few very fine roots; few discontinuous moderately thick and thin reddish brown (5YR 4/3) clay films on surfaces of peds and root channels; 5 percent coarse fragments; slightly acid; clear wavy boundary. (3 to 6 inches thick)

C -- 38-60"--Brown (10YR 4/3) loam; massive; friable; 6 percent coarse fragments; mildly alkaline; slight effervescence.

Type Location: Eaton County, Michigan; about 7 miles northwest of Charlotte; 382 feet north and 250 feet east of the southwest corner of the NE1/4, Sec. 15, T. 3 N., R. 5 W.

Range in Characteristics: The thickness of the solum ranges from 25 to 40 inches and coincides with the depth to free carbonates. The reaction in the solum ranges from medium acid to neutral with some lower B2 horizons ranging from medium acid to mildly alkaline. Coarse fragments range from 2 to 10 percent throughout the solum and C horizons. The mean annual soil temperature ranges from 47 to 54°F. The Ap horizon is dark grayish brown (10YR 4/2), brown (10YR 4/3 or 10YR 5/3) or very dark grayish brown (10YR 3/2), light brownish gray (10YR 6/3) dry. In wooded areas there is an A1 horizon, 1 to 4 inches thick of very dark brown (10YR 2/2), very dark grayish brown (10YR 3/2) or very dark gray (10YR 3/1). An A2, if present, is grayish brown (10YR 5/2), brown (10YR 5/3), pale brown (10YR 6/3) or light grayish brown (10YR 6/2). The A horizon is loam of sandy loam. The B&A horizon has color and textural characteristics both of the overlying A2 and the underlying B2t horizon. The A2 horizon penetrates the B2t horizon in thin fingers which range from 2 to 10mm in width several inches in length and is more than 15 percent by volume. The C horizon has hue of 10YR, value of 4 to 6 and chroma of 2 or 3, and is loam or light clay loam.

The B2t horizon has 7.5YR or 10YR hue, value of 4 or 5 and chroma of 3 through 6 and is heavy loam, clay loam or silty clay loam. The 10 to 40 inch control section averages between 25 and 35 percent clay. The C horizon has hue of 10YR, value of 4 to 6 and chroma of 2 or 3, and is loam or light clay loam.

Competing Series and Their Differentiae: These are the Cazenovia, Conesus, Guelph, Hilton, Honeoye, Hortonville, Lansing, Lima, Ontario, Wampsville, Wassaic, series in the same family and Capac, Hillsdale, Lapeer, McBride, Miami ad Nester series. Cazenovia, Hilton and Hortonville soils have redder hue in the B horizons. In addition, Hilton soils contain more silt in the C horzon, Hilton soils contain more coarse fragments throughout and Hortonville soils have mottles in the lower part of the Bt horizon. Conesus and Lima contains more coarse fragments in the solum and have mottles in the B horizon. Guelph soils contain free carbonates above a depth of 25 inches and are more alkaline. Honeoye, Lansing and Ontario soils contain more coarse fragments and in addition the Lansing soils are more acid in the upper part of the solum. Wampsville soils formed in stratified deposits. Wassaic soils have limestone bedrock within 40 inches. Capac soils have low chroma mottles in the argillic horizon. Hillsdale and Lapeer soils are coarse-loamy, lack interfingering and have sandy loam C horizons. McBride soils have coarser textured sola, a fragipan and sandy loam C horizons. Miami soils lack interfingering of an albic horizon into the argillic horizon. Nester soils have finer textured sola, a colder climate.

Setting: Marlette soils occur typically on moraines and till plains of Wisconsinan age, with nearly level to steep topography. The typical slope gradients range from 3 to 10 percent with an extreme range of 2 to 35 percent. Climate is continental. Mean annual precipitation ranges from 28 to 38 inches. Mean annual temperature is about 44°F. and mean annual summer temperature is about 66°F.

Principal Associated Soils: These are the competing Capac and Guelph soils and the Parkhill soils. The somewhat poorly drained Capac and the poorly drained Parkhill soils are in a drainage sequence with Marlette soils.

Drainage and Permeability: Well and moderately well drained. Surface runoff is medium to very rapid, depending upon slope. Permeablity is moderate.

Use and Vegetation: Most areas are cropped to corn, beans, wheat and grass legume hay. A small part, usually the steeper areas, is in pasture or hardwood forest.

Distribution and Extent: Central Michigan and possibly adjoining areas in Canada. The series is of large extent.

Series Established: Sanilac County, Michigan, 1955.

Remarks: Marlette soils were formerly classified as having a Podzols upper sequum and a Gray Wooded lower sequum. Recent field study of the series indicates that any evidence of spodic horizon is very thin and discontinuous and occurs primarily in undisturbed areas.

National Cooperative Soil Survey
U. S. A.

USDA-SCS-LINCOLN, NEBR 1974
ECONOMY OFFSET

Established Series
Rev. ALZ-HPU-FWS
1/4/74

MIAMI SERIES

The Miami series is a member of the fine-loamy, mixed, mesic family of Typic Hapludalfs. Miami soils typically have very dark grayish brown silt loam A horizons about 3 inches thick and brown and yellowish brown silt loam A2 horizons, dark brown silty clay loam and clay loam upper B horizon, dark brown loam lower B horizons and light yellowish brown C horizons at depths of about 30 inches. The C horizons are glacial till containing free carbonates.

Typifying Pedon: Miami silt loam - on a SE facing convex slope of 3 percent under mixed hardwood
(Colors are for moist soil.)

A1 -- 0-3"--Very dark grayish brown (10YR 3/2) silt loam; moderate medium and coarse granular structure; friable; slightly acid; clear wavy boundary. (1 to 3 inches thick)

A21 -- 3-8"--Brown (10YR 5/3) silt loam; moderate fine medium granular structure; friable; medium acid; clear smooth boundary. (0 to 7 inches thick)

A22 -- 8-12"--Yellowish brown (10YR 5/4) silt loam; weak medium platy structure; friable; medium acid; clear wavy boundary. (0 to 5 inches thick)

IIB21t -- 12-17"--Dark brown (7.5YR 4/4) silty clay loam; moderate medium subangular blocky structure; friable; thin discontinuous pale brown (10YR 6/3) clay films on faces of peds; few pebbles; medium acid; clear smooth boundary. (4 to 7 inches thick)

IIB22t -- 17-25"--Dark brown (10YR 4/3) clay loam; moderate medium and coarse angular blocky structure; firm; thin pale brown (10YR 6/3) and dark brown (7.5YR 4/4) continuous clay films on faces of peds and lining some voids; few pebbles: medium acid; clear wavy boundary. (4 to 10 inches thick)

IIB23t -- 25-29"--Dark brown (10YR 4/3) loam; weak coarse subangular blocky structure; friable; few thin discontinuous dark brown (7.5YR 4/4) clay films on faces of peds and lining some voids; few pebbles; neutral; clear wavy boundary. (3 to 6 inches thick)

IIB3 -- 29-36"--Brown (10YR 5/3) loam; massive; friable; thin discontinuous dark brown (10YR 4/3) clay films; few pebbles; mildly alkaline; slight effervescence; clear irregular boundary.

IIC -- 36-60"--Light yellowish brown (10YR 6/4) loam till; massive; firm; few pebbles: moderately alkaline; strong effervescence.

Type Location: Rush County, Indiana; 1½ miles SW of Rushville; 500 feet west and 25 feet south of the NE corner of Sec. 12. T. 13 N., R 9 E.

Range in Characteristics: Solum thickness typically is 28 to 36 inches and ranges from 24 to 42 inches. Carbonates are at depths of less than 42 inches. Coarse fragments in the solum averages less than 10 percent by volume. The A1 horizon is very dark grayish brown (10YR 3/2) or very dark gray (10YR 3/1). It commonly is loam or silt loam and less commonly sandy loam or fine sandy loam. Cultivated areas have an Ap horizon that typically is dark grayish brown (10YR 4/2), brown (10YR 5/3) or very dark brown (10YR 3/2) moist and light brownish gray (10YR 6/3) dry. It is loam, silt loam, fine sandy loam or sandy loam and on eroded areas it is commonly clay loam. The A2 horizon is typically dark grayish brown (10YR 4/2), yellowish brown (10YR 5/4), brown (10YR 5/3), or light yellowish brown (10YR 6/4). It is loam, silt loam, sandy loam or fine sandy loam. Some pedons have B1, A&B or B&A horizons between the A and B2t horizons. The IIB2 horizon ranges in thickness from 14 to 23 inches. It has hue of 10YR or 7.5YR, and less commonly 5YR, value of 4 through 6 and chroma of 3 through 6. The IIB2t horizon commonly is clay loam but individual horizons are loam, sandy clay loam, silty clay loam or sandy loam. The upper 20 inches of the argillic horizon averages between 25 and 35 percent clay. Clay films on faces of peds and lining of voids range from thin to thick and patchy or discontinuous. The IIB2 horizon commonly has moderate medium subangular or angularblocky structure. It is firm or friable. The most acid part of the B2 horizon is commonly medium or strong acid and individual horizons are neutral or slightly acid. The B3 horizon is commonly loam or clay loam. It ranges from slightly acid to moderately alkaline and commonly contains free carbonates in the lower part. The C horizon is typically brown (10YR 5/3) or light yellowish brown (10YR 6/4) loam or heavy sandy loam calcareous till.

Competing Series and Their Differentiae: These are the Belmore, Chili, Coggon, Conestoga, Douds, Hanna, Hayden, Hebron, Hickory, High Gap, Hollinger, Kendallville, Kennan, Kidder, Letort, Lindley, Mandeville, Martinsville, McHenry, Mifflin, Norden, Ockley, Owosso, Pecatonica, Princeton, Rawson, Relay, Renova, Riddles, Roseville, Sisson, Strawn, Summitville, Tuscola, Waymore, Westville, Whalan, Woodbine and Wynn soils in the same family. Belmore soils contain more gravel and sand in the lower part of the sola. Chili and Douds soils have more acid lower sola. Coggon soils contain less clay in the sola. Conestoga, Hollinger and Letort soils have a significant mica content. Hanna, Hickory, Martinsville, Ockley, Renova and Riddles soils have sola more than 40 inches thick. Hayden and Lindley soils are dominately montmorillonitic in mineralogy. Hebron soils contain more silt and clay in the lower part of the sola. High Gap, Mifflin, Norden, Roseville, Whalen and Wynn soils have part of sola formed in material weathered from bedrock and sola terminated by a lithic or paralithic contact. Kendallville soils contain more gravel in the sola. Kennan soils contain granitic cobbles and boulders. Kidder soils formed in sandy loam till and are sandy loam in the lower part of the sola and in the C horizon. Mandeville soils have shale fragments in the lower part of the B horizon and soft shale within depths of 40 inches. McHenry soils have sandy loam till within depths of 40 inches. Owosso soils contain more sand in the upper part of the sola. Pecatonica, Waymor and Westville soils have 5YR or redder hue in the matrix or on faces of peds in one or more subhorizons. Princeton soils contain less clay in the sola. Rawson soils contain more clay in the lower part of the sola. Relay soils have hue of 2.5Y or yellower. Sisson and Tuscola soils have more fine sand and silt in the sola. Strawn soils have sola less than 24 inches thick. Summitville soils have reddish brown shaly silt clay in the lower part of the sola. Woodbine soils are silty clay loam or clay in the lower part of the sola.

Setting: Miami soils are on moraines, drumlins and till plains. Slopes range from nearly level to steep. Miami soils formed in as much as 18 inches of loess and calcareous loam to light clay loam glacial till. Illite is the dominant clay mineral in the glacial till. The climate is midcontinental type; summers are hot, and winters are cold. The average daily maximum temperature in July is as high as 88°F., and the average daily minimum temperature is about 22°F. in January. Mean annual precipitation ranges from 30 to 40 inches, and mean annual temperature from 46 to 54°F.

Principal Associated Soils: The Miami soils are in a drainage sequence with the moderately well drained Celina soils, somewhat poorly drained Conover, Crosier, and Crosby soils and very poorly drained Kokomo and Brookston soils. The Octagon and Parr soils form a biosequence with the Miami soils.

Drainage and Permeability: Well drained. Runoff is medium on the gentle slopes and rapid on the steeper slopes. Permeability is moderate in the sola and moderate to moderately slow in the underlying material.

Use and Vegetation: A large part is under cultivation. The principal crops are corn, soybeans, small grain and hay. Much of the more sloping part is in permanent pasture or forest.

Distribution and Extent: Indiana, southern Michigan, northeastern Illinois, southwestern Wisconsin, and western Ohio. The soil is extensive, more than 100,000 acres.

Series Established: Montgomery County, Ohio, 1910.

Remarks: The Miami soils were formerly classified as Gray Brown Podzolic.

National Cooperative Soil Survey
U. S. A.

USDA SCS-LINCOLN, NEBR 1974

APPENDIX B

FIELD LOG OF THE STOPS OBSERVED

Note: Other stops where the soil series were not closely related to Miami or Marlette soils have not been recorded.

Summary of Field Logs - Stops Observed

Lenawee County

Stop 1: Location. N.E. 1/4 N.E. 1/4 Sect. 17. T.5S. - R.1E. Woodstock TWP. in an Alfalfa field.

Soil Type: Celina loam.

Classification: Aquic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 48 inches (120 cms) thick. Ap in a loam. No A2 is present. B2t is a clayloam, does not show any signs of structure development, although the amount of clay is higher in this horizon. Some gray mottlings in the argillic horizon. C is a loam.

1a. A second observation 200 feet away shows presence of a weak A2, better expressed structure development and a few interfingerings: Classification is still Typic Hapludalf, fine loamy.

Stop 2: Location. N.E. 1/4 of N.E. 1/4 Sect. 29 T.63. - R.1E. Rollins TWP. In a cornfield, on a moraine.

Soil Type: Miami loam. Slope: 10%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 40 inches (100 cms) thick. B2t is a clay loam. There is no development of good structure and clay. Skins are absent. No sign of interfingering or tongues. C is a loam.

Stop 3: Location. N.W. 1/4 of N.W. 1/4 of Sect. 17; T.GS. - R.1E. Rollins TWP.

Soil Type: Miami sandy loam; border line to Owosso and Marlette.

Classification: Typic Hapludalf, fine-loamy mixed, mesic.

General description: Solum is 41" (102 cms) thick; A2 is present, so is B + A. B2t is a clay loam with angular blocky structure. Argillans are well developed. Evidence of tonguing of A2 in the B. But volume wise not extensive enough for classification as Glossoboric Hapludalf.

Stop 4: Location. N.W. 1/4 of S.W. 1/4 of Sect. 9; T.63. - R.1E. Rollins TWP.

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 38 inches (95 cms) thick. A very thin Broken A2 lies below the A1. B & A is 6 inches (15 cms) thick and is a gritty loam to sandy loam. B2t is a clay loam with strong, angular blocky structure. Argillans are well expressed but are broken. Many peds surfaces are covered with siltan coatings. The C is a loam. Note: Proximity of Sugar maple and Hemlock.

Stop 6: Location. S.W. 1/4 N.W. 1/4 Section 33; T.5S - 4.1E. Woodstock TWP.

Soil Type: Owosso sandy loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 32 in. (80 cms). Texture of the solum is rather on the coarser side. (Almost a sandy loam) No tonguing or interfingering observed.

Stop 7: Location. N.W. 1/4 S.E. 1/4 Section 29; T.5S - R.1E. Woodstock TWP.

Soil Type: Marlette loam. Slope: 16%.

Vegetation: White Oak.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The A1 is a loam, on the coarse side. A2 is present and is relatively thick. 5-1/2 in. (14 cms). There is an AB with siltant coatings, the A + B is 3 inches thick. B21t and B22t are loam and clay loam respectively with argillans well formed in the B2t. Till is a loam.

Stop 8: Location. S.W. 1/4 N.E. 1/4 Section 17; T.5S. - R.1E. Woodstock TWP.

Soil Type: Miami loam. Slope: 6%.

Vegetation: White Oak.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 30 inches thick (75 cms). A2 is a sandy loam. B2t is a clay loam with angular blocky structure and broken argillans coatings on ped surface. The till is a loam.

Stop 9: Location. N.W. 1/2 N.W. 1/4 Section 4; T.5S. - R.1E. Woodstock TWP. Woodstock at Jackson Co. line; in a pasture.

Soil Type: Metea loamy sand. Slope: 4%.

Classification: Arenic Hapludalf, coarse-loamy, mixed, mesic.

General description: Upper 30 inches (75 cms) of the Solum is loamy sand. Lower part is a loam. No sign of interfingering or tonguing or coarser materials in the loam layer.

Washtenaw County

Stop 1: Location. S.E. 1/4 N.E. 1/4 Section 20; T.1S - R.4E. Dexter TWP.

Soil Type: Sisson silt loam. Slope: 5%.

Classification: Typic Hapludalf, fine-loamy mixed, mesic.

General description: Solum is 40 inches (100 cms) thick. A1 is a silt loam. A2 is 5 inches (12 cms) thick. The B2t is a clay loam with coarse angular blocky structure and evidence of clay skins. Trace of interfingering of A2 material into the B2t as siltan coatings. Notes: Whole unit contains large inclusions of spinks and Sisson.

Stop 2: Location. S.E. 1/4 N.E. 1/4 Section 9; T.2S. - R.4E. Lima TWP. In a cornfield.

Soil Type: Miami loam (Deep solum variant). Slope: 5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 58 inches (145 cms) thick. A2 is 6 inches (15 cms) thick. B2t is 15 inches (38 cms) thick and is a clay loam with angular blocky structure and extensive argillan development in the form of clay coatings. Some eluvial materials on ped faces are obvious but color 10 YR 5/4 does not meet requirement for albic, and neither are they extensive enough.

Stop 3: Location. S.W. 1/4 N.W. 1/4 Section 25; T.2S. - R.3E. Sylvan TWP. In a harvested cornfield.

Soil Type: Miami loam. Slope: 2 to 5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 19 inches (48 cms) thick. No A2 is present; B2t is 7 inches (17 cms) thick and has a clay loam texture. Structure is strong subangular to angular blocky and discontinuous clay skins cover 35% to 50% at the ped faces. B3 is 4 inches (10 cms) thick and shows no signs of clay skin. Till is a loam. Note: 4 auger samples were taken.

Stop 4: Location. S.W. 1/4 S.W. 1/4 Section 27; T.2S. - R.4E. Lima TWP. At a road cut, forested area.

Soil Type: Marlette sandy loam. Slope: 36%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Surface grades toward a sandy loam. A2 is thin and discontinuous. A & B is present. B2t has a clay loam texture. Structure of this B2t is angular blocky with generalized, but somehow broken, clay skin. Small tongues: 1 inch (2.5 cms) wide penetrate deep into B2 and B3. Solum is 36 inches (90 cms) thick. Till is a loam.

Stop 5: Location. N.W. 1/4 S.W. 1/4 Section 12; T.2S. - R.4E. Lima TWP. In a plowed field.

Soil Type: Miami loam. Slope: 4%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 36 inches (90 cms) thick. No A2 is obvious; B2t is a clay loam. Clay skins are obvious but discontinuous and broken at the top of this horizon. In general the amount of clay skin decreases with depth. Lower part of the B2t shows many bleached 10 yr 8/3 ped faces 50%. But these bleached surfaces are thought to be more eluvial than depositional. The till is a coarse loam.

Stop 6: Location. N.W. 1/4 N.E. 1/4 Section 8; T.3S. - R.4E. Freedom TWP. In a pasture.

Soil Type: Marlette loam. Slope: 10%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 42 inches (105 cms) thick. An "A & Bt" horizon is present and is a gritty loam to sandy loam. This A + B shows many bleached ped faces and some remnants of clay coatings. The B2 is a clay loam and has an angular and subangular blocky structure with 65% of the ped faces covered with argillan coatings.

Stop 7: Location. S.W. 1/4 S.E. 1/4 Section 10; T.3S. - R.4E. Freedom TWP. In a cultivated cornfield.

Soil Type: Marlette sandy loam. Slope: 14%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 35 inches (87.5 cms) thick. "B & A" is present and consists of a loam. Many bleached ped faces (siltan coatings: 10 YR 7/4). The B2t is a clay loam; the structure is angular blocky, with discontinuous clay coatings, and many bleached ped faces. 10 YR 7/4. The broken pattern of the clay skins is observed all the way to the bottom of the B3.

Stop 8: Location. N.W. 1/4 N.E. 1/4 Section 1; T.3S. - R.4E. Freedom TWP. In a pasture.

Soil Series: Marlette-Miami borderline. Slope: 8%.

Classification: Borderline Glossoboric-Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 30 inches (75 cms) thick. A2 is a loam. B2t is a clay loam. The ped surfaces of the B2t are covered with many broken clay skins. Areas not coated with argillans are bleached (10 YR 8/3).

Stop 9: Location. S.W. 1/4 S.E. 1/4 Section 19; T.3S. - R.4E. Freedom TWP. At a road cut.

Soil Type: Marlette loam. Slope: 4%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The solum is 26 inches (65 cms) thick. Structure is strong throughout the solum. B + A is well expressed. The bleached ped surfaces have a dominant color of 10 YR 4/4; and the structure of the B2t is angular blocky. Tongues are well developed even into the upper part of the C1 which has a loam texture. Note: The pedon observed is located 20' away from a large white oak tree.

Stop 11: Location. N.W. 1/4 N.W. 1/4 Section 26; T.3S. - R.4E. Freedom TWP. In a plowed field.

Soil Type: Miami loam. Slope: 8%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Pedon is very similar to Stop 5. The solum is 29 inches (73 cms) thick.

Stop 12: Location. S.W. 1/4 S.W. 1/4 Section 11; T.1S. - R.7E. Salem TWP. In a cornfield.

Soil Type: Miami loam. Slope: 5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The texture of the whole solum is finer than what is usually observed for the Miami but this pedon still fits into the Miami series. Ap is a loam. The B22t is a fine clay loam. Structure is not well developed and there are remnants of clay skins. The C is a fine loam. There is no evidence of tonguing or interfingering. The C is at 21 inches (52 cms).

Stop 13: Location. S.W. 1/4 S.E. 1/4 Section 13; T.1S. - R.7E. Salem TWP. In an abandoned cornfield (now a dump).

Soil Type: Miami loam. Slope: 25%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: This solum is quite similar to the one observed on Site 12, except that the solum is thicker (34 inches [85 cms]). Note: This stop was selected for sampling. See Site 8, Appendix C.

13a: In a nearby cornfield.
The pedon is a typical Miami. No tongues were observed.

Soil Type: Miami loam. Slope: 10%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

Stop 14: Location. S.E. 1/4 S.E. 1/4 Section 6; T.2S. - R.7E. Superior TWP. In a pumpkin field, strongly rolling.

Soil Series: Fox and Riddle.

Classification: Typic Hapludalf, fine-loamy, over sandy and Typic Hapludalf, fine-loamy.

Stop 15: Location. S.W. 1/4 N.E. 1/4 Section 32; T.1S. - R.7E. Salem TWP. In an alfalfa field.

Soil Type: Celina loam. Slope: 2%.

Classification: Aquic Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap is a loam. There is no evidence of A2. There is no sign of tonguing. The texture is finer within the B, but there is no good sign of good structural development (clay skins, etc.).

Stop 16: Location. S.E. 1/4 S.E. 1/4 Section 10; T.2S. - R.6E. Ann Arbor TWP. On a moraine.

Soil Type: Morley loam. Slope: 7%.

Classification: Typic Hapludalf, fine, illitic, mesic.

General description: Texture is fine through the whole profile. There is no A2 present. The B horizon is finer than the A (which is a fine loam). Structure is not well developed, clay skins are developed to a minimum. The C is a loam and occurs at 25 inches (63 cms).

Stop 17: Location. N.E. 1/4 N.E. 1/4 Section 22; T.3S. - R.6E. Pittsfield. In a harvested cornfield, on a till plain.

Soil Type: Celina loam. Slope: 2.5%.

Classification: Aquic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 30 inches (75 cms). There is no sign of A2. There is no evidence of tonguing or interfingering. Although the argillic horizon is well developed (texture wise), structure is not well defined and clay skins are absent. Mottlings start at 25 inches (63 cms).

Stop 18: Location. S.W. 1/4 S.W. 1/4 Section 1; T.3S. - R.5E. Lodi TWP. At a road cut.

Soil Type: Marlette loam (close to sandy loam). Slope: 2%.

Soil Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Texture of surface is a coarse loam grading toward a sandy loam. The sequence of horizons is as follows: A1, A2, A & B, B & A, B2t, B3 and C. The tongues are relatively large and penetrate deeply into the lower part of the solum.

Stop 19: Location. N.W. 1/4 N.E. 1/4 Section 14; T.4S. - R.5E. Saline TWP. In a harvested cornfield.

Soil Series: Morley. Slope: 3%.

Classification: Typic Hapludalf, fine, mixed, mesic.

General description: The texture of the whole profile is quite fine, reaching a silty clay at the bottom of the B. There is no evidence of tonguing or interfingering.

Stop 20: Location. S.E. 1/4 N.W. 1/4 Section 2; T.4S. - R.5E. Saline TWP. In a garden next to a cornfield.

Soil Type: Miami loam. Slope: 5%.

Classification: Typic Hapludalf, fine-loamy to fine, mixed, mesic.

General description: The Ap is a loam, B21t is a clay loam, B22t is a silty clay and the C is a clay loam. There is no sign of A2. The clay skins are not very extensively developed.

Stop 21: Location. S.W. 1/4 S.W. 1/4 Section 21; T.4S. - R.5E. Saline TWP. On a road cut.

Soil Type: Miami laom (borderline to Marlette). Slope: 3%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: This pedon is somewhat borderline between a Typic and a Glossoboric Hapludalf. The surface is a coarse loam. A2 is weakly developed. There is not a well developed A & B. But many siltan coatings are present. Volume wise there is not enough to qualify this pedon as glossoboric. B2t was a well developed structure with many argillans.

Stop 22: Location. S.E. 1/4 N.E. 1/4 Section 31; T.4S. - R.5E. Saline TWP. In a cornfield, on edge of a moraine.

Soil Type: Miami loam. Slope: 10%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The unit has been mapped as Morley, but the pedon is well within the range of Miami. It is a typical Miami except that some silty materials have been incorporated within the C horizon.

Eaton County

Stop 1: Location. N.E. 1/4 S.E. 1/4 Section 22; T.1N. - R.6W. Bellevue TWP. On a road cut.

Soil Type: Miami loam. Slope: 5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a loam; an A2 is present. It is 4 inches (10 cms) thick and is a coarse loam. The B2t is 20 inches (50 cms) thick and is a clay loam with angular blocky structure with many continuous clay skins. The loam till is at 32 inches (80 cms).

Stop 2: Location. S.W. 1/4 N.E. 1/4 Section 22; T.1N. - R.6W. Bellevue TWP. In a cornfield.

Soil Type: Marlette (Eroded). Slope: 3%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The whole area seems to have been subjected to severe erosion with substantial amounts of sandy material at the surface. The B & A is well developed, is 6 inches (15 cms) thick and is a loam. The dominant color is reddish brown with many bleached (10 YR 6.5/3) peds coated with siltans and very fine sand. The till is a loam and occurs at 31 inches (78 cms).

Stop 10: Location. N.E. 1/4 N.E. 1/4 Section 1; T.4N. - R.3W. Delta TWP. In a grassy orchard.

Soil Type: Marlette loam (coarse loam surface). Slope: 7%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 31 inches (77.5 cms) thick. The A & B horizon is 2-1/2 inches (6.5 cms) thick and is sandy loam (10 YR 6/3) mixed with a loam (10 YR 5/4). Many roots are present. Both the B21t and B22t have a clay loam texture and many peds faces have a bleached color (10 YR 5/4) that are believed to be siltan coatings. Clay skins are particularly well developed in the B22t. Note: A second boring made 10 feet S. of the first is a Riddle loam (non-calcareous).

Stop 11: Location. S.E. 1/4 S.W. 1/4 Section 3; T.4N. - R.3W. Delta TWP. In a steep road cut. Next to the Delta TWP waste water.

Soil Type: Marlette sandy loam. Slope: 20%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 26 inches (65 cms) thick. The A2 grades toward a sandy loam and is a loam (10 YR 6/4) with many roots. Boundary is very wavy and broken. The B22t is a clay loam and surface of the peds are covered with well developed continuous argillans. Some bleached ped faces are also observable. Till is a loam.

Stop 12: Location. S.W. 1/4 S.E. 1/4 Section 16; T.4N. - R.3W. Delta TWP. In a plowed field, recently planted in corn.

Soil Type: Marlette loam. Slope: 4%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The original surface has been removed (by erosion or else); the color of the surface is reddish brown with many white streaks. The field has been deeply plowed and the A & B (or B & A) has been exposed; Albic materials are common deep into the solum. Till is a loam.

Stop 13: Location. S.W. 1/4 S.W. 1/4 Section 18; T.4N. - R.3W. Delta TWP. In a garden.

Soil Type: Marlette loam (wet variant). Slope: 3%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: The profile shows evidence of insufficient drainage with gray mottlings (10 YR 6/2) in the upper part of the B horizon. A2 is very light in color (10 YR 7/1 dry). Structure is not well defined but there is evidence of presence of albic materials in the B2 horizon. The till is a loam on the gritty side and is 40 inches (1 meter) deep.

Stop 14: Location. N.E. 1/4 S.W. 1/4 Section 16; T.3N. - R.3W. Windsor TWP. In a recently planted cornfield.

Soil Type: Marlette loam. Slope: 6%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The site shows signs of severe erosion with the Ap horizon almost entirely removed. The B2 is 7.5 YR 5/4 clay loam with many 10 YR 6/4 sandy loam tongues. Some of the tongues, due to their size, are thought to be, at least partly, lithology related.

Stop 15: Location. N.E. 1/4 N.E. 1/4 Section 23; T.4N. - R.3W. Delta TWP. In a plowed field.

Soil Type: Marlette loam. Slope: 14%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: A and a portion of the B have been plowed. There is, however, substantial evidence that A2 was once present and has been destroyed. Many 10 YR 6.5/3 bleached albic materials. The B2 is a fine clay loam. There is a lack of evidence of development of good clay skins (possibly because of artificial disturbance). Many bleached remnants of albic features are present. Structure of B3 is massive, but grades toward subangular blocky. Calcareous loam underlies the solum at a depth of 36 inches (90 cms).

15b: Location. S.W. 1/4 N.E. 1/4 Section 25; Benton TWP. Along a road cut on Kings Road.

Soil Series: Marlette (topsoil has been removed).

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: A long stretch of the road shows a continuous pattern of tonguing with even some fragipan development. B2t shows good clay skin development in an angular blocky structure.

Stop 16: Location. S.E. 1/4 N.W. 1/4 Section 20; T.3N. - R.3W. Windsor TWP. In an alfalfa field.

Soil Type: Marlette sandy loam. Slope: 5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Surface and part of the B is a sandy loam. There is no good development of clay skin into the B. Albic features are rather well expressed in the B2t. The till is a calcareous loam.

16b: Location. S.E. 1/4 S.W. 1/4 Section 20; T.3N. - R.3W. Windsor TWP. In a borrow pit of the Eaton Co. Rd. Commission.

Soil Type: Marlette loam (on the coarse side).

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: This exposure illustrates very well the process of tongue formation and destructional processes involved in the development of A2 horizon. The pedon shows existence of a former B that retains some remnants of original texture and color of the former B. B2t is well developed with a subangular structure strongly expressed. Clay skins are generalized but there is evidence that they are migrating deeper into the solum. Many peds are partly covered with bleached materials, siltans, which have a whitish color (10 YR 8/2 dry).

Stop 17: Location. S.E. 1/4 S.E. 1/4 Section 32; T.2N. - R.4W. Eaton TWP. On 2 road cuts.

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Profile observation shows well developed extensive tongues.

Stop 18: Location. N.W. 1/4 S.E. 1/4 Section 25; T.3N. - R.3W. Windsor TWP. In a plowed field.

Soil Type: Marlette loam. Slope: 12%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is gone and most of the A2 is exposed to the surface. A2 is strongly expressed and contains remnants of B. B2 is a clay loam and shows evidence that tongues were formed by crevasse filing; sand and silt sized materials coat the ped faces. The till is a calcareous loam that occurs at 30 inches (75 cms).

Stop 19: Location. S.W. 1/4 S.W. 1/4 Section 36; T.3N. - R.3W. Windsor TWP. In a plowed field.

Soil Type: Marlette loam (eroded phase). Slope: 28%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Pedon is very similar to the one observed at Site 18. The calcareous loam till occurs at 32 inches (80 cms).

Stop 20: Location. S.W. 1/4 S.W. 1/4 Section 14; T.2N. - R.4W. Eaton TWP.

Soil Type: Marlette loam. Slope: 5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 35 inches (87.5 cms) thick. A2 is present. B2t shows many filling related, bleached coatings. Clay skins are visible and are best developed on contact of stones. The till is a calcareous loam.

Stop 21: Location. N.E. 1/4 N.E. 1/4 Section 36; T.2N. - R.3W. Eaton TWP. In a plowed field.

Soil Type: Marlette loam. Slope: 3%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: Observation was made in a moderately well drained unit. A2 has been plowed. A & B has been destroyed but there is much evidence of its previous existence. B2t shows some remnants of clay skins. The calcareous loam is at 36 inches (90 cms).

Stop 22: Location. N.W. 1/4 S.W. 1/4 Section 13; T.1N. - R.3W. Hamlin TWP. In a road cut.

Soil Type: Marlette loam (coarse loam).

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Al is a coarse loam, A2 is a light loam to sandy loam (10 YR 6/3). B2t is a clay loam. The structure is angular blocky and most of the peds are coated with well developed argillans. Many ped surfaces are coated also with bleached materials. Many pores and cracks are filled with sand or coarse silt materials. The calcareous loam is at 150 cms. Ultimate Marlette.

Stop 23: Location. S.W. 1/4 S.E. 1/4 Section 35; T.1N. - R.3W. Hamlin TWP. In a cornfield.

Soil Series: Marlette-Miami borderline. Slope: 4%.

Classification: Glosso-Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 34 inches (35 cms) thick. Surface is covered with sand, possibly because of erosion. An A2 is present and is very light in color (10 YR 7/2), B2 is a clay loa, color is dominantly 10 YR 4/4 with some ped faces coated with siltans (10 YR 7/2). Interfingering argillans are obvious. Both interfingering and clay skins decrease sharply with depth.

Stop 24: Location. N.W. 1/4 N.E. 1/4 Section 12; T.3N. - R.4W. Benton TWP. On a road cut.

Soil Type: Marlette silt loam. Slope: 5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Tongues are well developed and are thought to be "crack-filling" related. Solum has a silty texture.

Stop 25: Location. N.E. 1/4 N.W. 1/4 Section 25; T.3N. - R.4W. Benton TWP. In a plowed field.

Soil Type: Owosso sandy loam. Slope: 3%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Surface is a sandy loam. A weakly expressed "A2" is present. The solum is bisequal with a weak fragipan. No sign of interfingering.

Stop 26: Location. S.E. 1/4 S.E. 1/4 Section 28; T.3N. - R.4W. Benton TWP. On a road cut.

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The Al is a light loam; A2 is well developed and is 10 YR 6.5/3, sandy loam. A & B is also well developed and shows extensive tongues penetrating deeply into the B2t. The tongues are thought to be crack related. Wedge shaped, 6 inches (15 cms) deep by 3 inches (7.5 cms) wide. Clay skins are particularly well developed also.

Stop 27: Location. N.W. 1/4 N.W. 1/4 Section 3; T.2N. - R.4W. Eaton TWP. In a cornfield.

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap is a loam; A2 has been destroyed but some relics are present. Structure is not well developed in the B2t and there are few signs of deposition of coarser materials on the surface of the peds.

Stop 28: Location. S.E. 1/4 S.E. 1/4 Section 6; T.4N. - R.6W. Sunfield TWP. In a pasture.

Soil Type: Marlette loam. Slope: 6%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: Solum is 42 inches (105 cms) thick. Ap is a coarse loam, A2 is not well developed. B2t is a clay loam. The structure is not well developed; clay skins are rather rare. But tongue features are well developed and penetrate deep into the B2 and upper part of B3. There is sign of insufficient drainage in the B horizon with development of few faint mottles (10 YR 5/2) contrasting with the dominant 7.5 YR 4/3 color of this horizon. Also several Fe and Mg segregations as black spots are present. Note: The mapping unit contains 3 observations of Fox soils.

Ionia County

Stop 1: Location. S.W. 1/4 S.W. 1/4 Section 25; T.8N. - R.8W. Otisco TWP. In a pasture.

Soil Type: Marlette sandy loam (wet variant). Slope: 2%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: Ap approaches a sandy loam. An A + B horizon is present under the A2 and is a sandy loam. B2t is a clay loam and shows signs of extensive tonguing and interfingering of the A2 (thick loamy sand lenses, 10 YR 7/2). Tongues are often continuous. Water stays high in the profiles around 35 inches (87.5 cms). The calcareous loam till is reached at 40 inches (100 cms).

Stop 2: Location. S.W. 1/4 S.W. 1/4 Section 3; T.7N. - R.8W. Keene TWP. In a fallow field.

Soil Type: Marlette sandy loam. Slope: 3%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap is quite thin; no A2 is present, but a B & A horizon is well developed. It is a sandy loam, 10 YR 5/4 in color, with about 30% of more sandy materials (10 YR 6/3) in color. The B21t and B22t are finer in texture, loam and clay loam, respectively, with many gray (10 YR 6/2 and 10 YR 5/3) sandy loam and loamy sand tongues. The solum is 38 inches (95 cms) thick and the till is a calcareous loam.

Stop 3: Location. S.E. 1/4 N.W. 1/4 Section 20; T.7N. - R.8W. Keene TWP. In a recently planted wheat field.

Soil Type: Marlette loam. Slope: 3%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap is a gritty loam. The A2 is 4 inches (10 cms) thick and is weakly expressed. The tongues (10 YR 5/3) are developed in the B22t which is dominantly a coarse clay loam (7.5 YR 4/4). Very few signs of tonguing or interfingering in the B21. Structure development is lost in the B3; so are the albic features. The calcareous loam comes at 53 inches (132.5 cms).

Stop 4: Location. N.W. 1/4 S.E. 1/4 Section 24; T.7N. - R.8W. Keene TWP. In a harvested cornfield.

Soil Series: Marlette.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Tongues are present and seem to follow general structural pattern: well developed in the upper part of the B (just like the structure) but not in the lower part of the solum where structure is massive and texture much finer. Till is a calcareous loam.

Stop 5: Location. S.W. 1/4 S.W. 1/4 Section 26; T.6N. - R.8W. Boston TWP. In a cornfield.

Soil Type: Marlette sandy loam. Slope: 3%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Surface is a sandy loam. No A2 is obvious, "B" and "A" approaches a sandy loam. B2t is a clay loam with significant signs of tonguing and interfingering. Those albic features have a texture of loamy sand and have a color of 10 YR 5/3 that contrasts with the 7.5 YR 4/4 of the surrounding soil mass. The pedon is calcareous at 37 inches (92.5 cms). And the C horizon is a loam.

Stop 6: Location. N.W. 1/4 S.E. 1/4 Section 16; T.7N. - R.7W. Eaton TWP. On a road cut.

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The solum is finer than has been so far observed. No A2 is observed, no "A and B" is present either. The B2t is finer than average (as generally observed so far in the area). Structure of the B in angular blocky and most of the ped faces is covered with continuous coatings of argillans. The C horizon is a loam.

Stop 8: Location. S.E. 1/4 N.W. 1/4 Section 18; T.8N. - R.7W. Orleans TWP. In an orchard (apple).

Soil Type: Marlette loam. Slope: 5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap horizon is a loam. An A + B is present, well expressed and the albic features are dominantly loamy sand. No intensive development of clay skins in the B2t horizon but texture of this horizon is definitely finer than the ones above. The profile is leached more deeply than usual: 46 inches (115 cms) and the till is a loam that is very strongly calcareous and pink in color.

Stop 9: Location. N.E. 1/4 N.W. 1/4 Section 36; T.8N. - R.7W. Orleans TWP. In a plowed field.

Soil Type: Marlette sandy loam (deeply leached variant, non-calcareous).

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Ap approaches a sandy loam; A2 is thin. The B goes from a loam to a clay loam. Interfingerings are well expressed in the B2 but phase out in the B3 which has a more massive structure and a finer texture.

No good pattern of structure development is obvious throughout the solum which is also particularly deeply leached. Calcareous materials not encountered.

Stop 11: Location. S.W. 1/4 S.E. 1/4 Section 9; T.8N. - R.5W. North Plains TWP. In a grassy area.

Soil Type: Marlette loam (eroded phase). Slope: 15%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is very thin, A2 is well expressed and is 10 YR 7/4 fine sandy loam. Boundary is weavy and broken. B and A is present and well developed. B2t is a clay loam. The structure of this horizon is predominantly angular blocky with well developed clay skins and many siltan coatings. The siltan coatings penetrate throughout the B3 and up to the top of the C, which comes at 32 inches (80 cms).

Stop 12: Location. N.W. 1/4 S.E. 1/4 Section 27; T.8N. - R.6W. Ronald TWP. In a hay field.

Soil Type: Miami sandy loam. Slope: 3%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a sandy loa. Just a trace of A2 is present. B21t is a loam on the fine side, without structure development. A few interfingering features are present, but they are quantitatively insufficient to qualify the pedon as "Glossoboric." B22t is clay loam, on the finer side. In this B22t horizon, there is no good structure development, no interfingering, no well expressed clay skin development. The color is reddish. The B3 is coarser in texture (light clay loam). The C is a loam. Solum is 36 inches (90 cms) thick.

Stop 13: Location. S.E. 1/4 S.E. 1/4 Section 2; T.7N. - R.6W. Ionia TWP. In a plowed field.

Soil Type: Miami loam. Slope: 3 to 5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The field has been plowed deeply and the upper part of the solum is severely altered. B is finer than average (fine side of a clay loam). Structure is dominantly angular blocky. Structure expression is lost in the B3 and the till itself is a fine clay loam. No interfingering features are observed throughout the solum.

Stop 14: Location. S.W. 1/4 S.W. 1/4 Section 1; T.7N. - R.6W. Ionia TWP. In a cornfield.

Soil Type: Miami loam. Slope: 4%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: This pedon is very similar to pedon observed on Site 13. Texture is quite fine throughout the solum and the till itself is richer in clay.

Stop 17: Location. N.E. 1/4 N.W. 1/4 Section 35; T.8N. - R.5W. North Plains TWP. On a steep slide slope, on the edge of a pasture field.

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: An A2 is present but weakly expressed. B2 is a clay loam with maximum development of clay skins. No interfingering is observable. The C is a fine loam.

Stop 19: Location. S.W. 1/4 S.E. 1/4 Section 32; T.7N. - R.6W. Ionia TWP. In a recently planted winter wheat field.

Soil Type: Marlette sandy loam. Slope: 2.5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

Description: Surface is sandy loam. B & A averages a sandy loam with intensive tongue development. B2 is a coarse loam with some tongues; structure is not well developed. The C is a coarse loam.

Stop 22: Location. N.W. 1/4 N.E. 1/4 Section 29; T.5N. - R.5W. Danby TWP. In a road cut.

Soil Types: Marlette sandy loam; Miami loam.

Classification: Glossoboric and Typic Hapludalf, fine-loamy, mixed, mesic.

General description: This is a twin observation. Very good example of relationship between tongues and texture of solum. On north side of the road the soil type is a *Marlette loam* (coarse side) (Glossoboric Hapludalf). Solum is coarser in texture, clay skins are well developed in the B2t. Starting with the B3 the texture of the solum is coarser to the point of lithologic discontinuity in the C. By contrast, the soil on the south side of the road cut is a *Miami loam*. Texture is finer, clay skins are better developed and no tongues are present. The till itself is finer than across the road.

Stop 23: Location. S.W. 1/4 S.E. 1/4 Section 15; T.6N. - R.5W. Portland TWP. In an open field, not far from fence.

Soil Type: Miami loam. Slope: 7%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a loam and has been partly cut. The A2 is weakly developed. The B2t is heavy clay loam and relatively thin. The structure of the B is subangular and angular blocky with a few bleached ped faces (mostly by loss of skins rather than by deposition of siltans). Structure is not well developed in B3. The C comes at 36 inches (90 cms). Its texture suggests some lithologic discontinuity, with bands of silt loam and very fine sandy loam.

Stop 26: Location. S.W. 1/4 S.W. 1/4 Section 25; T.5N. - R.5W. Danby TWP. In a bean field.

Soil Type: Marlette loam (moderately well drained variant). Slope: 2.5%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a loam, somewhat gritty. B & A is closer to a clay loam with well developed tongues. B2t is a fine clay loam with no traces of tongues or interfingering. The B2 is also a clay loam but without structural development; it has many gray mottles. The C is a loam and comes at 36 inches (90 cms).

<u>Lapeer County</u>

Stop 1: Location. N.E. 1/4 S.E. 1/4 Section 6; T.9N. - R.9E. Marathon TWP. In an open field.

Soil Type: Marlette sandy loam. Slope: 3%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Texture of solum is somewhat sandier than the "modal" Miami or Marlette. An A2 horizon is present and is a sandy loam. A and B is well developed and is a loam with sandy loam tongues. The tongues are still well expressed into the B2, which is a clay loam. No pattern of well developed structure is observable into the B2t and clay skins are weakly developed. B3 is thick and solum itself is leached very deeply: more than 60 inches (150 cms). Some coarser materials are observable at the bottom of the pedon.

Stop 3: Location. S.W. 1/4 N.E. 1/4 Section 3; T.9N. - R.11E. North Branch TWP. In an alfalfa field.

Soil Type: Marlette loam. Slope: 3.5%.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a coarse loam. The B and A is a loam with many siltan coatings on the ped faces. The peds themselves are angular to subangular blocky. B3 is coarser in texture without good structure development and with very few clay skins. The calcareous loam till comes at 29 inches (72 cms).

Stop 6: Location. S.W. 1/4 N.E. 1/4 Section 22; T.9N. - R.12E. Burnside TWP. In a cornfield.

Soil Type: Marlette sandy loam (moderately well drained variant).

Classification: Glossaquic Hapludalf, fine-loamy, mixed, mesic.

General description: Texture is coarse (on the silty side). Tongues are extensively developed; clay skins are rather rare. A few gray mottles (drainage related) are observed in the B3. Rare traces of clay skins. Over all texture is on silty side.

Stop 7: Location. N.W. 1/4 S.W. 1/4 Section 23; T.9N. - R.12E. Burnside TWP. On a road cut.

Soil Type: Miami loam. Slope: 3.5%.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

General description: The Ap horizon is a loam. The A2 is thin, weakly developed. B2t is a clay loam with subangular blocky to blocky structure. Clay skins are well developed in the B2t but broken in the B3. Very few bleached ped faces are present. The calcareous till is a loam and occurs at 28 inches (70 cms).

<u>Barry County</u>

Stop 1: Location. N.W. 1/4 S.W. 1/4 Section 5; T.2N. - R.7W. Castelton TWP. In a cornfield.

Soil Type: Marlette loam (moderately well drained, variant), cobbly phase. Slope: 3.5%.

Classification: Glossaquic Hapludalf, fine-loamy, mixed.

General description: Ap is thicker than usual (11 inches, 28 cms) and has a coarse loam texture. The A2 is well developed and is a sandy loam. B & A is present but there is evidence of moisture related mottling (10 YR 4/4, 10 YR 4/8 + 10 YR 6/1 gray mottlings). B2 is a clay loam, and has many grayish tongues. Clay skins are present but are not very extensive; they are broken. The calcareous till is a loam and occurs at 36 inches (90 cms).

1a: In the same field but further up; slope 6.5%. Ap is thinner; horizon differentiation is less obvious. There is no A2, no A + B and the B horizon does not show any extensive development of clay skins. The C is a loam and occurs at 30 inches (75 cms). This pedon is classified as Miami loam.

1b: Further upon the landscape; slope 3%. The texture of the surface is finer (loam); AB is well developed; tongues are well expressed. Structure is well developed in the B with many continuous skins; this pedon is classified as Marlette (Glossoboric Hapludalf, fine-loamy).

Stop 2: Location. N.E. 1/4 S.W. 1/4 Section 11; T.3N. - R.7W. Castelton TWP. In an alfalfa field.

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

General description: Ap is a loam (on the coarse side). A2 is present and is a sandy loam. The B & A is dominantly a clay loam (10 YR 5/4) with intensive 10 YR 7/1 tongues. The tongues are continuous, sandy loam to loamy sandy texture, and penetrate deeply into the solum to the B3 horizon. The B2 has a well developed structure (subangular) with many bleached ped faces (the coatings on these peds are dominantly of ine sand size). B3 is a clay loam; structure is not generally well developed; there are many remnants of clay skins and tongues.

APPENDIX C

FIELD DESCRIPTION OF THE PROFILES STUDIED

Site 1

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

Location: N.W. 1/4 S.E. 1/4 S.W. 1/4 Section 6; T.3N. - R.1N. Alaiedon TWP, Ingham Co.

Vegetation: Grass.

Parent material: Glacial (loam) till.

Physiography: Till plain.

Slope: 5%.

Drainage: well drained.

Horizon	Depth (cms)	Description[1]
Ap	0-18	Dark yellowish brown (10 YR 3/3, moist) to grayish yellowish brown (10 YR 5/2, dry); loam; moderate, medium subangular blocky structure; friable; few neutral; abrupt, wavy boundary.
A2	18-25	Moderate yellowish brown (10 YR 5/3); coarse loam; moderate, medium, subangular blocky structure; friable, neutral; clear, wavy boundary.
B2t	25-38	Moderate brown (7.5 YR 4/4); clay loam; strong, medium, subangular blocky structure; thick discontinuous light brown (10 YR 5/4) clay skins on ped faces and earthworm channels; few gravel; firm; neutral; gradual, smooth boundary.
B3	38-65	Moderate brown (7.5 YR 4/4); loam; few discontinuous clay skins; weak, coarse, subangular blocky structure; friable to firm; mildly alkaline; clear, wavy boundary.
C	65-100	Light brown (10 YR 5/4); loam to silt loam; massive; friable to firm; moderately alkaline; calcareous.

[1] Color names are from Intersociety Color Committee, National Bureau of Standards system.

Site 3

Soil Type: Marlette sandy loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

Location: N.W. 1/4 S.E. 1/4 S.W. 1/4 Section 6; T.3N. - R.1W.
Alaiedon TWP, Ingham Co.

Vegetation: Grass.

Parent material: Glacial loam till.

Physiography: Till plain.

Slope: 3%.

Drainage: well drained.

Horizon	Depth (cms)	Description
Ap	0-17	Dark yellowish brown (10 YR 3/3) moist; light yellowish brown (10 YR 6/3) dry; sandy loam; moderate, medium, subangular blocky structure; friable; many roots; medium acid; clear smooth boundary.
A2	17-30	Grayish yellowish brown (10 YR 5/2); loamy sand; weak, fine, platy structure; friable; common roots; medium acid; clear, irregular to broken boundary.
B & A	30-52	Moderate brown (7.5 YR 4/4); loam; with pockets or tongues of light yellowish brown (10 YR 7/3) sandy loam; the sandy loam part of the horizon shows many small, vesicular pores; strong, medium, subangular blocky structure; firm; medium acid; clear, smooth boundary.
B2t	52-80	Moderate brown (7.5 YR 4/4); clay loam; strong, coarse, angular blocky structure; many continuous argillans on the ped faces; very firm; slightly acid; clear, smooth boundary.
B3	80-97	Moderate yellowish brown (10 YR 4/3); loam; many moderate brown (7.5 YR 4/4) discontinuous clay coatings; strong, coarse, subangular blocky structure; very firm; neutral; clear, smooth boundary.
C	97-150	Moderate yellowish brown (10 YR 5/3); loam; moderate, medium, subangular blocky structure; very firm; moderately alkaline; calcareous.

Site 4

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

Location: S.E. 1/4 N.W. 1/4 S.E. 1/4 Section 2; T.4N. - R.2E. Locke TWP, 300 feet E. of Bent of road, Ingham Co.

Vegetation: Cornfield.

Parent material: Glacial loam till.

Physiography: Till plain.

Slope: 6%.

Drainage: well drained.

Horizon	Depth (cms)	Description
Ap	0-20	Moderate yellowish brown (10 YR 4/3, moist), light grayish yellowish brown (10 YR 6/2, dry); gritty loam; weak, medium, subangular blocky structure; friable; medium acid; abrupt, wavy boundary.
B & A	20-33	Grayish yellowish brown (10 YR 5/2); sandy loam, and moderate yellowish brown (10 YR 4/4) loam; many thin sandy loam and silt loam, light grayish yellowish brown coatings (10 YR 6/2, dry), interfingering on more than 50% of the ped surface; strong, medium, subangular blocky structure; portion of the horizon related to the A horizon is friable and masses related to B2 are firm; slightly acid; clear, broken boundary.
B21t	33-48	Moderate yellowish brown (9 YR 4/4); loam to clay loam; few moderate brown (10 YR 4/4) clay coatings with many light grayish brown coating remnants; strong, medium, subangular blocky structure; firm; slightly acid; gradual, smooth boundary.
B22t	48-73	Moderate brown (10 YR 4/4); clay loam; many continuous clay skins on ped surfaces and on large root channels; a few discontinuous yellowish gray (10 YR 7/2) siltan coatings; strong, medium subangular blocky structure; firm; neutral; gradual, irregular boundary.

Horizon	Depth (cms)	Description
B3	73-85	Moderate yellowish brown (10 YR 5/4); loam; strong, medium, subangular blocky structure; few broken argillans on ped surfaces; firm; moderately alkaline; clear, wavy boundary.
IIC	85-125	Moderate yellowish brown (10 YR 5/4); loam; isolated pockets of sandy loam masses; moderate, medium platy, breaking to fine, subangular blocky structure; friable; moderately alkaline; calcareous.

Note: The C horizon was sampled as 2 separated subsamples: IIC1 from 85 to 105 cm, and IIC2 from 105 to 125 cms.

Site 5

Soil Type: Marlette sandy loam (Owosso sandy loam?).

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

Location: S.E. 1/4 S.E. 1/4 S.E. 1/4 Section 9; T.4N. - R.1W.
Meridian TWP, Ingham Co.

Vegetation: White oak.

Parent material: Glacial loam till.

Physiography: Till plain.

Slope: 3%.

Drainage: well drained.

Horizon	Depth (cms)	Description
A1	0-8	Very dark grayish brown (10 YR 3/2, moist), to brownish gray (10 YR 4/1, dry); sandy loam; strong, medium, granular structure; friable; abundant roots; few pebbles; neutral; abrupt, wavy boundary.
A2	8-25	Strong yellowish brown (10 YR 5/5); sandy loam; loam weak, medium, subangular blocky structure; friable; abundant roots; strongly acid; clear, wavy boundary.
B2	25-33	Moderate yellowish brown (10 YR 5/4); sandy loam; moderate, coarse, subangular blocky structure; friable; abundant roots; strongly acid; wavy to broken boundary.

Horizon	Depth (cms)	Description
A2'	33-48	Light grayish yellowish brown (10 YR 7/2) and moderate yellowish brown (10 YR 4/4); sandy loam; weak, medium, angular blocky structure; firm; common roots; medium acid; clear, wavy to broken boundary.
A & B'	48-65	Light grayish yellowish brown (10 YR 7/2); sandy loam and moderate yellowish brown (10 YR 4/4) loam; moderate, coarse, subangular blocky structure; firm; the sandy loam portion of the horizon occupies approximately 60% of the volume of the whole horizon; the root system decreases sharply at 58 cms; medium acid; clear, broken boundary.
IIB2t'	65-90	Moderate yellowish brown (10 YR 4/3); clay loam, with many yellowish gray (10 YR 7/2) sandy loam tongues; approximately 40% of the ped faces are coated with moderate brown (7.5 YR 4/4) argillans; strong, coarse, subangular blocky structure; a few brownish black (10 YR 2/1) manganese and iron coatings; firm to very firm; medium acid; diffuse boundary.
IIB3	90-115	Moderate yellowish brown (10 YR 4/4); fine loam; moderate, coarse, subangular blocky structure; many broken, moderate brown (7.5 YR 4/3) argillan coatings on about 25% of ped faces; very firm; neutral; clear, wavy boundary.
IIC	115-150	Moderate yellowish brown (10 YR 4/3); loam; few, broken, moderate brown (7.5 YR 4/3) argillan coatings; strong, medium, subangular blocky structure; firm; moderately alkaline; calcareous.

Note: Digging was very difficult from 30 to 55 cms; roots were found to be completely restricted at this same depth.

Site 6

Soil Type: Marlette loam.

Classification: Glossoboric Hapludalf, fine-loamy, mixed, mesic.

Location: S.E. 1/4 S.W. 1/4 N.E. 1/4 Section 5; T.4N. - R.1W. Meridian TWP, 144 feet E. of Park Lake Road, Ingham Co.

Vegetation: Grasses.

Parent material: Glacial till.

Physiography: Till plain.

Slope: 11%.

Drainage: well drained.

Horizon	Depth (cms)	Description
A1	0-20	Dark yellowish brown (10 YR 3/3, moist), grayish yellowish brown (10 YR 5/ , dry); loam; moderate, fine, subangular blocky structure; friable to firm; abundant roots; many worm channels; moderately alkaline; abrupt, smooth boundary.
A & B	20-35	Grayish yellowish brown (10 YR 5/3); sandy loam and moderate brown (7.5 YR 4/4) loam; the sandy loam material occupies approximately 80% of the mass of the horizon; strong, medium, subangular blocky structure; friable; many earthworm channels; mildly alkaline; diffuse, wavy boundary.
B21t	35-55	Moderate brown (7.5 YR 4/4); clay loam; many brownish gray (10 YR 3/1) iron and manganese coatings on the ped surfaces; many broken argillans coatings. Many very pale orange (10 YR 8/2, dry) streaks interfingering; strong, coarse, subangular blocky structure; friable; moderately alkaline; diffuse, broken boundary.
B22t	55-68	Moderate brown (7.5 YR 4/4); clay loam; strong, coarse, subangular blocky structure; fewer clay skins; trace of siltan coatings; firm; moderately alkaline; diffuse, wavy boundary.
C1	68-83	Moderate yellowish brown (10 YR 4/4); loam and yellowish gray (10 YR 7/1); silt loam; moderate, coarse platy structure breaking to medium, subangular blocky; firm; moderately alkaline to calcareous; abrupt, wavy boundary.
C2	83-150	Moderate brown (10 YR 4/4) and light gray (7.5 YR 8/0); loam; strong, coarse platy breaking to medium, subangular blocky structure; very firm; moderately alkaline to calcareous.

Site 7

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

Location: N.W. 1/4 N.E. 1/4 N.W. 1/4 Section 8; T.6N. - R.7W.
Berlin TWP, Ionia Co.

Vegetation: Wheat (experimental plot).

Physiography: Till plain at the edge of a moraine.

Slope: 1.5%.

Drainage: well drained.

Horizon	Depth (cms)	Description
Ap	0-20	Dark grayish yellowish brown (10 YR 3/2, moist), grayish yellowish brown (10 YR 5/2, dry); loam; weak, coarse, subangular blocky structure; friable; many small roots; neutral; abrupt, smooth boundary.
B1	20-30	Moderate yellowish brown (10 YR 5/4), with very few faint strong yellowish brown mottles; coarse loam; moderate, medium, subangular blocky structure; friable; few roots; many continuous earthworm channels; neutral; clear, wavy boundary.
B21t	30-45	Moderate yellowish brown (10 YR 5/4); clay loam; strong to medium to fine subangular blocky structure; friable to firm; few, discontinuous (10 YR 4/4) clay coatings; gradual, wavy boundary.
B22t	45-58	Moderate yellowish brown (10 YR 5/4); clay loam; strong, medium, subangular blocky structure; many continuous strong yellowish brown (10 YR 5/8) clay coatings; firm; gradual, wavy boundary.
B3	58-75	Moderate yellowish brown (10 YR 5/4) and strong yellowish brown (10 YR 5/8); loam; strong, medium, subangular blocky structure; firm; very few, broken argillans; neutral; clear, irregular boundary.
C	75-125	Moderate yellowish brown (10 YR 5/4) and grayish yellowish brown (10 YR 6/3); loam; strong, fine, angular blocky structure; firm; mildly alkaline.

Site 8

Soil Type: Miami loam.

Classification: Typic Hapludalf, fine-loamy, mixed, mesic.

Location: N.E. 1/4 S.E. 1/4 S.E. 1/4 Section 13; T.1S. - R.7E. Salem TWP, 120 feet W of fence, 60 feet N. of driveway across the street, Washtenaw Co.

Vegetation: Corn (harvested).

Parent material: Glacial loam till.

Physiography: Moraine.

Slope: 10%.

Drainage: well drained.

Horizon	Depth (cms)	Description
Ap	0-18	Moderate, yellowish brown (10 YR 4/3, moist), grayish yellowish brown (10 YR 5/4, dry); loam; weak, medium (breaking to small) granular structure; friable; many roots; slightly acid; clear, smooth boundary.
B1	18-30	Moderate, yellowish brown (10 YR 4/4 and 10 YR 5/3); clay loam; slight trace of coarse loam; A2 remnants; strong, medium, subangular blocky structure; friable; many roots (becoming few, below 25 cms); common earthworm channels; slightly acid; clear, wavy boundary.
B21t	30-45	Moderate brown (7.5 YR 4/3); clay loam; strong, medium, angular blocky structure; many continuous thick argillans on 75% of the ped surfaces; firm; slightly acid; gradual, wavy boundary.
B22t	45-65	Moderate brown (7.5 YR 4/3); clay loam, heavier than B21t; strong, medium, subangular blocky structure; many continuous thick coatings of argillans; firm to very firm; slightly acid; gradual, wavy boundary.

Horizon	Depth (cms)	Description
B3	65-125	Strong yellowish brown (10 YR 5/5); loam; moderate, medium, subangular blocky structure; firm to very firm; few broken, moderate brown (7.5 YR 4/3) argillans; gradually decreasing with depth; firm to very firm; clear; slightly acid; clear, wavy boundary.
C	120-150	Moderate yellowish brown (10 YR 4/4); fine loam; moderate, coarse, subangular blocky structure; firm to very firm; mildly alkaline to slightly calcareous.

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