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A PEDOLOGIC STUDY OF SOIL PROFILES
IN THE TRANSITIONAL BELT BETWEEN
THE PODZOL AND GRAY-BROWN
PODZOLIC REGIONS IN MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

David R. Gardner

1951



This is to certify that the

thesis entitled

A Pedologic Study of Soil Profiles in the Transi-
tional Belt Between the Podzol and Gray-brown
Podzolic Regions in Michigan

presented by

David Rice Gardner

**has been accepted towards fulfillment
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Master of Science degree in Soil Science

L. M. Turk

Major professor

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A PEDOLOGIC STUDY OF SOIL PROFILES IN THE TRANSITIONAL
BELT BETWEEN THE PODZOL AND GRAY-BROWN PODZOLIC
REGIONS IN MICHIGAN

By

DAVID R. GARDNER

A THESIS

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Department of Soil Science

1951

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A special vote of thanks is due to the man who introduced the author to his first double profile - Professor J.O. Veatch.

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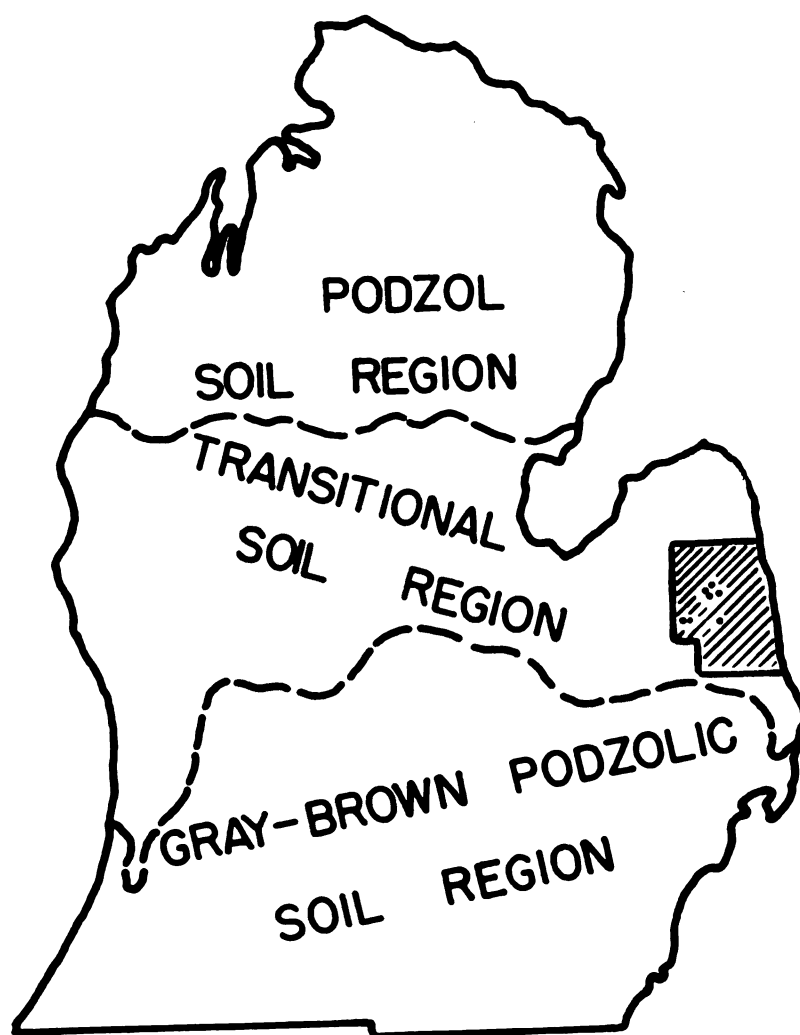
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GENERAL STATEMENT

In many of the problems of soil classification, particularly in those dealing with soil survey, use is constantly made of lines drawn on maps to represent boundaries between dissimilar bodies of soil. These boundary lines, neat, and without width, may be drawn on the scale of a forty acre field to separate simply dissimilar phases, types, or series, or they may be plotted on maps of national or international scope to delineate higher categories such as Great Soil Groups. Whatever the scale of mapping, and no matter how neatly the lines are drawn, it is all too true that the soils themselves are rarely distributed so as to be readily separated by such sharp boundaries. Instead of the neat black lines on the soil map, soils in the field are more commonly separated by zones or belts of a transitional nature. In the case of zonal Great Soil Groups, such transitional belts may be many miles in width and may cover extensive areas.

Lying in such a transitional soil zone is Sanilac county, Michigan, located along the Lake Huron shore in the Thumb region of the lower peninsula of the State. (See Fig.1). This area has been characterized in the past as lying astride the boundary between the Podzol soil region to the North and the Gray-Brown Podzolic soil region to the South. (9), (14),



Location of Sanilac county, (cross-hatched), and sample profiles, (dots), with respect to the zonal soil regions of Michigan. After Vech, (19).

Figure 1.

(19). Zonal soil profiles in such a transitional zone might be expected to exhibit a morphology gradational between those of the above zonal Great Soil Groups. The present study is based on observations over the past two years of these transitional profiles and their relation to different types of parent material and to different drainage positions.

METHODS

1. Descriptions: Soil profiles are described according to the techniques and using the terminology developed by the Division of Soil Survey of the U.S. Department of Agriculture. Color designations are referred to the standardized Munsell system.

2. Mechanical Analyses: The methods used are those of Kilmer and Alexander, (10), except for one step: The samples are not taken to oven dryness prior to dispersion to avoid the danger of an irreversible dehydration of some of the clay minerals.

3. Organic Matter and Lime Determinations: These values were obtained by the dry combustion method of Hopper, (7), using an electric oven at 950°C.

4. pH Determinations: Soil reaction was tested colorimetrically in the field by means of the Truog method.

5. Core Sample Studies: Use was made of the methods of Uhland and O'Neal, (18). Values relating to permeability,

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volume weight, and non-capillary porosity all refer to averages of quintuplicate samples taken in 3" cores.

6. Statistical Methods: Analysis of the cumulative curves of the particle size distributions was based on the techniques of Krumbein and Fettijohn (11).

PHYSICAL DESCRIPTION OF SANILAC COUNTY, MICHIGAN

Before discussing the morphology of the soils of Sanilac county, it is well to establish the area in time and space in terms of the genetic factors of soil formation. As listed by Jenny, (8) and others, the soil forming factors are: Climate, Vegetation, Topography, Parent Material, and Age. These factors are evaluated individually below:

I. Climate: In terms of its average annual values for temperature and precipitation, the climate of Sanilac county, like that of the entire State of Michigan, is defined as cool, humid. Because of the proximity of Lake Huron, however, the distribution of temperature throughout the year suggests a modified marine climate. Precipitation on the average amounts to about 28 inches a year while the average annual temperature of 45 degrees includes average monthly values from 23 degrees for January to 70 degrees for July, (22).

II. Vegetation: Except for a few areas of grassy marsh on muck and peat, all of Sanilac county was originally covered by forest. Extensively cleared, cultivated, drained, and

burned, the surviving forest areas bear little similarity to the original stands. The virgin forest association of the county, although generalized as "Northern Hardwoods", actually included a wide variety of species. On sandy, well drained sites stood nearly pure stands of White pine, (*P. strobus*) while well drained medium to heavy textured soils supported mixed hardwoods such as Birch, (*Betula papyrifera*), Beech, (*Fagus grandifolia*), and Maple, (*Acer saccharum*) with Oak, (*Quercus* sp.) and Hickory, (*Carya ovata*) becoming important in the Southern part of the county. Imperfectly drained sites produced large numbers of Hemlock, (*Tsuga canadensis*) mixed with the hardwoods while the wetter areas supported mixed stands of Elm, (*Ulmus americana*), Ash, (*Fraxinus nigra*), and Red Maple, (*Acer rubrum*) with scattered swamp conifers. (2).

III: Topography: The topography of Sanilac county, in common with that of most of the lower peninsula of Michigan, is generally restricted in extremes of elevation and in steepness of slope. Except for a few morainic ridges, elevations within the county lie between 600 and 800 feet above sea level or about 20 to 220 feet above the present level of Lake Huron. Large areas of the county were, at one time, under the waters of glacial lakes Whittlesey and Warren and occur today as level plains, imperfectly to poorly drained. (6).

IV: Parent Material: Except for extremely limited outcrops of Coldwater shale and Marshall sandstone, the whole of Sanilac county is mantled with glacial drift of Wisconsin age. Originally calcareous to varying degrees, the drift occurs as till on moraines, lake beds, and till plains, as water-worked drift on eskers, beaches, outwash plains and deltas, and as aeolian sand in a few scattered dunes. The texture of the drift varies widely from silty clay loam in the heavy-textured till to pure sand on dunes and light-textured moraines.

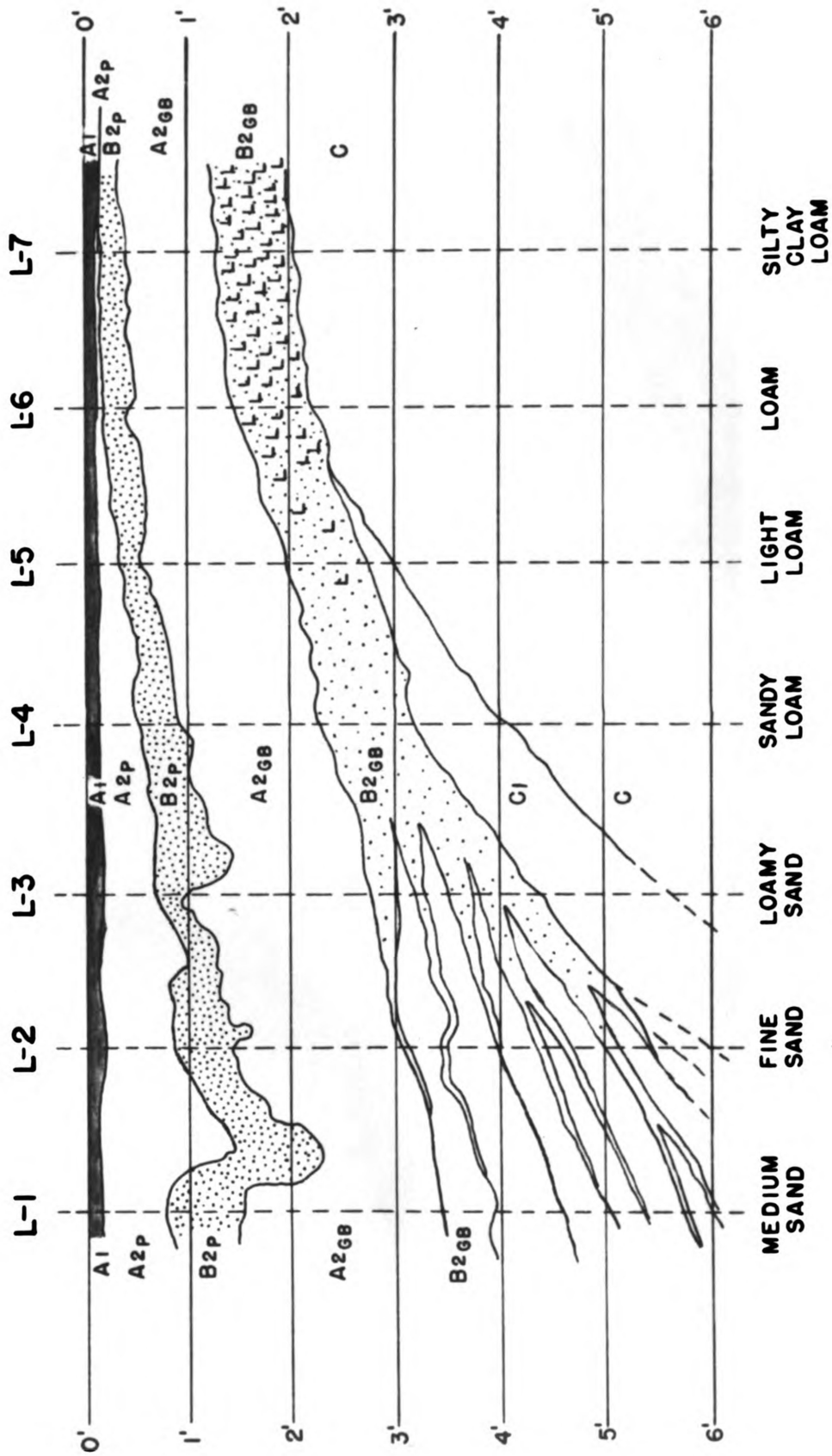
V: Age: The Wisconsin drift of the area is represented by two subtypes, Cary and Mankato. The Mankato material, defined by the outer limit of the Port Huron Moraine, occupies roughly the Eastern quarter of the county and appears briefly in the extreme North-West corner. The remainder of the county, including the bed of glacial lake Whittlesey, is of Cary age. As the Cary drift of Sanilac county is "Late", or "Upper" Cary, it is probably not older than 20,000 years. (4).

Having established the area of Sanilac county geographically as representing a transition between the Podzol soil region to the North and the Gray-Brown Podzolic soil region to the South, the zonal soils of the area may now be considered in relation to various types and textures of parent material.

THE LITHOSEQUENCE

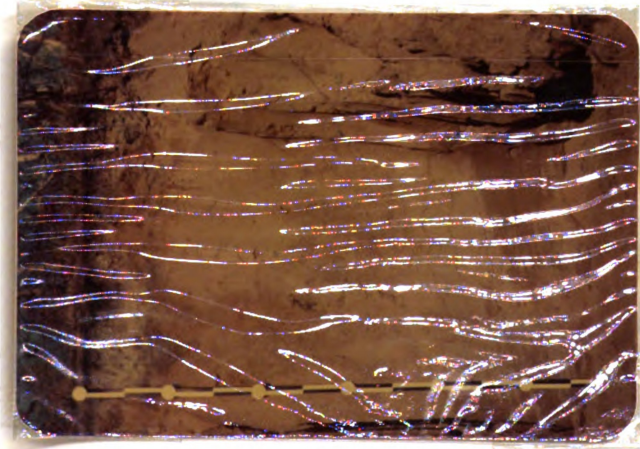
Since the well drained soils of the county are derived from parent materials that vary continuously in texture from sand to silty clay loam, sample profiles over this textural range were selected for analysis and comparison. These profiles are presented photographically in Fig. 3 in decreasing order of sand content and increasing order of lime content of the parent materials. The profiles shown are separated by only a few miles, (Fig. 1), all are on rolling topography, at well drained sites, and in uncultivated areas. The parent material of the seven profiles is Cary drift with the possible exception of profile L-2, an old stabilized dune, which may be somewhat younger. Profiles L-5, L-6 and L-7 have formed on relatively unstratified glacial till and profiles L-1, L-3, and L-4 on water-worked drift. The natural vegetation probably varied from nearly pure stands of White pine on the sands through mixed coniferous-deciduous species on the intermediate textures to predominantly hardwood associations such as Oak-Maple-Beech on the heavier textures.

The seven profiles shown may be thought of as members of a lithosequence of textures, (although there were also vegetative differences as pointed out above), and as such are arranged diagrammatically in Fig. 2 according to the textures of the parent materials on the horizontal axis. The depths in

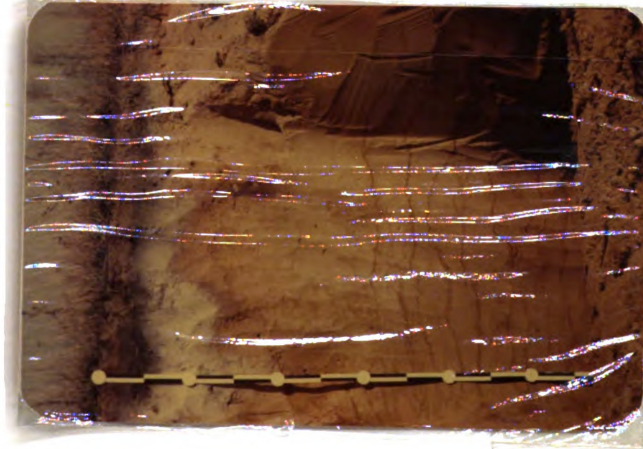


DIAGRAMATIC REPRESENTATION OF SOIL PROFILE DISTRIBUTION AS A FUNCTION OF TEXTURE OF PARENT MATERIAL

FIGURE 2



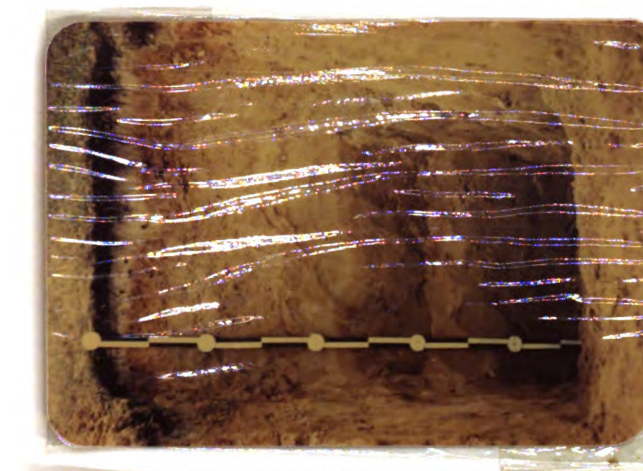
L-1



L-2



L-3



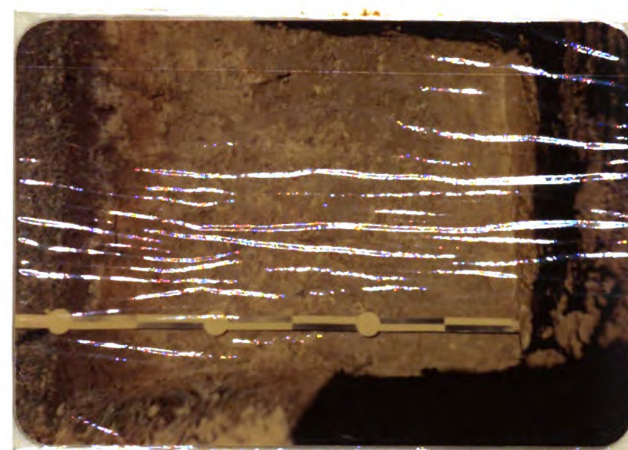
L-4



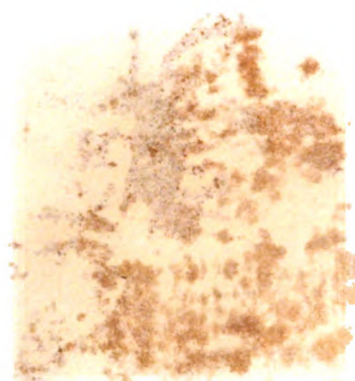
L-5



L-6



L-7



(continued)

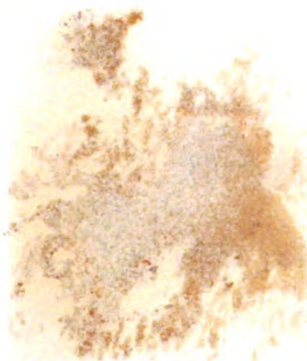


Figure 1. The effect of the concentration of the *Agaricus bisporus* spores on the growth of *Agaricus bisporus* on the substrate.

7. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

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feet from the top of the A₁ horizons are shown on the vertical axis. The permeability of the parent materials and the thickness of the profiles decrease with the sand content of the parent materials. The lime and clay contents of the parent materials generally increase as the sand content of the parent material decreases.

Consideration of the lithosequence indicates clearly that the zonal soil profile of this region is of a double nature with two distinct B₂ or accumulation horizons each underlying an eluvial or A₂ horizon.

The horizon designations in Fig. 2 bear the subscript P in the upper horizons and GB in the lower horizons. These subscripts are used to indicate that the morphology of the upper horizons is typically that of a Podzol soil profile while the properties of the lower horizons strongly suggest those of a Gray-Brown Podzolic soil. (In the scant literature on double profiles, there is no standardized system of horizon designation).

While all members of the lithosequence exhibit the double profile, the important difference seen in Figs. 2 and 3 is ^{that} the sand-derived member is essentially a Podzol with only the faintest of lower horizons while, at the opposite textural extreme, the profile formed on silty clay loam is typically Gray-Brown Podzolic with the entire upper Podzol horizons compressed into the surface few inches. In many places at the

heavy-textured end of the lithosequence, the A_{2p} horizon is discontinuous and the upper profile suggests that of a Brown Podzolic soil.

REVIEW OF LITERATURE

The occurrence of these so-called double profiles in Michigan has been previously reported by Veatch and Miller, (20) who observed a leached horizon lying between the upper orterde and a lower, heavier-textured B horizon. More recently, descriptive and analytical work by Cline and Frei, (1), (5), has revealed the wide-spread occurrence of double profiles in New York. Canadian pedologists, particularly Stobbe, (17) have observed these profiles and Lyford, (13) reports that soils considered to be modal Gray-Brown Podzolic in Ontario actually exhibit the double profile. Pecrot* reports the existence of such profiles in Belgium.

DESCRIPTIONS OF SAMPLE PROFILES

In order to study more closely the characteristics of the members of the lithosequence, three profiles were selected for description, analysis, and comparison. Analyses of these three profiles, L-2, L-4, and L-6 are given in table 1. The profiles are discussed individually below:

*Andre Pecrot, Personal communication

Table 1^a

| Hor-
izon | Depth
in
inches | pH | Org.
Mat. | N, % | C, % | N,
ppm | C, ppm | N, % | C, % | Total
Sand | Silt | Clay |
|-------------------------------|-----------------------|-----|--------------|------|------|-----------|--------|------|------|---------------|------|------|
| Profile L-2 (Fine sand) | | | | | | | | | | | | |
| A _w | 0-2 | 6.0 | 0.1 | 0.0 | 0.4 | 5.0 | 27.0 | 55.0 | 34.7 | 5.0 | 9.0 | |
| A ₁ | 2-6 | 6.0 | 0.0 | 0.0 | 1.8 | 11.5 | 61.0 | 16.0 | 61.0 | 4.1 | 1.0 | |
| A _{2p} | 6-14 | 5.0 | 0.4 | 0.0 | 1.5 | 10.0 | 60.7 | 17.8 | 67.7 | 5.8 | 0.0 | |
| B _{2p} | 14-20 | 6.0 | 1.4 | 0.0 | 0.9 | 8.8 | 66.1 | 11.7 | 67.1 | 1.0 | 1.4 | |
| A _{3GB} | 10-20 | 6.0 | 0.1 | 0.0 | 1.5 | 10.4 | 60.1 | 27.5 | 67.5 | 0.0 | 0.8 | |
| B _{3GB} | 20-22.5 | 7.0 | 0.4 | 0.0 | 1.8 | 10.8 | 60.8 | 15.5 | 67.0 | 1.0 | 1.7 | |
| C ₁ | 22.5-40 | 6.0 | 0.1 | 0.0 | 0.1 | 10.4 | 59.6 | 16.3 | 60.5 | 1.0 | 0.0 | |
| Profile L-4 (Sandy loam) | | | | | | | | | | | | |
| A ₁ | 0-2 | 6.5 | 0.8 | 1.8 | 2.8 | 14.8 | 50.1 | 16.8 | 71.0 | 20.0 | 6.8 | |
| A _{2p} | 2-5 | 5.5 | 0.5 | 1.4 | 0.0 | 15.5 | 50.4 | 12.5 | 60.7 | 27.0 | 5.5 | |
| B _{2p} | 5-9 | 6.0 | 1.8 | 3.1 | 8.7 | 15.9 | 59.4 | 17.0 | 71.0 | 20.0 | 8.0 | |
| A _{3GB} | 9-27 | 6.5 | 0.1 | 1.4 | 5.7 | 3.8 | 40.4 | 37.1 | 69.7 | 2.6 | 1.7 | |
| B _{3GB} | 27-37 | 6.0 | 0.3 | 2.3 | 14.4 | 37.9 | 17.4 | 5.8 | 75.2 | 4.7 | 10.5 | |
| C ₁ L ₁ | 37-68 | 7.0 | 0.1 | 3.7 | 17.7 | 35.7 | 56.0 | 0.7 | 95.8 | 6.0 | 0.0 | |
| D ₂ | 68 + | 8.0 | - | 0.0 | 0.4 | 0.4 | 51.0 | 54.2 | 27.2 | 10.2 | 6.0 | |
| Profile L-6 (Loam) | | | | | | | | | | | | |
| A ₁ | 0-2.5 | 6.5 | 5.7 | 1.1 | 4.1 | 8.4 | 52.0 | 17.9 | 53.6 | 32.4 | 8.0 | |
| A _{2p} | 2.5-5.5 | 6.0 | 0.7 | 1.5 | 4.2 | 8.6 | 52.2 | 17.6 | 54.7 | 40.0 | 5.0 | |
| B _{2p} | 5.5-7 | 5.5 | 1.5 | 1.3 | 4.0 | 7.5 | 19.1 | 14.9 | 40.7 | 37.5 | 16.0 | |
| A _{3GP} | 7-12 | 6.0 | 0.7 | 1.6 | 3.9 | 6.9 | 17.8 | 15.5 | 45.5 | 39.1 | 15.4 | |
| A _{3GB} | 12-18 | 6.0 | 0.5 | 1.9 | 3.6 | 6.0 | 15.8 | 13.1 | 40.3 | 36.7 | 23.0 | |
| B _{3GB} | 18-26 | 7.0 | 0.5 | 1.1 | 2.9 | 5.0 | 15.1 | 11.6 | 38.8 | 32.4 | 23.8 | |
| C | 26 + | 8.0 | - | 3.4 | 3.3 | 4.6 | 10.0 | 10.5 | 31.6 | 40.2 | 28.2 | |

^aPhysic. 1 separated, as determined by the methods of Hilmer and Alexander, (10), are stated as percent of moisture-free, basis-free soil. Org. C, N, water and lime content figures refer to oven-dry soil.

Profile L-2: Sand

Location: On range line, center point of West side of section 16, T 10 N, R 14 E.

Physiography: Steep stabalized horse-shoe dune ridge.

Profile:

| Horizon: | Depth: | Description: |
|------------------|----------|--|
| A _w | 0-2" | Yellowish Brown (10 YR 5/4) fine sand with weakly developed fine crumb structure. Represents a recent aeolian deposit on the true profile. |
| A ₁ | 2-6" | Very dark brown (10 YR 2/2) fine sand with weakly developed fine crumb structure. |
| A _{2P} | 6-14" | Light gray (10 YR 7/2) fine sand with single-grained structure. (Bleicherde). |
| B _{2P} | 14-20" | Dark reddish brown (5 YR 5/4) fine sand. Ortstein discontinuous with orterde. Cemented structure with fragmental cleavage. |
| A _{2GB} | 20-36" | Brownish yellow (10 YR 6/6) fine sand with single-grained structure. |
| B _{2GB} | 36-36.5" | Dark yellowish brown (10 YR 4/4) fine sand, very weakly cohesive. |
| C ₁ | 36.5-42" | Brownish yellow (10 YR 6/6) fine sand with single-grained structure. |

Profile L-2, with a fine sand texture throughout, represents a siliceous, permeable, acid member of the textural sequence. The upper Podzol profile here is at a maximum with a strong though discontinuous ortstein development and a thick, strongly acid bleicherde. The parent material is quartzose sand and the original cover was white pine (*P. strobus*). The lower B_{2GB} horizons are almost too faint to be recognized. They exhibit no significant clay accumulation, but show enrichment in free iron oxide (See Fig. 6), and a very slight enrichment in organic matter (Table I). Microscopic examination of these lower horizons before and after treatment with hydrochloric acid reveals that the iron oxide is present as stable coatings on quartz grains of fine sand and silt size. These horizons are typically multiple in occurrence as seen in the photographs of profiles L-1, L-2, and L-3 (Fig. 3). Figure 4 presents a close-up of these horizons at a depth of 4 to 7 feet showing their characteristic irregular and overlapping configuration.

Although reported by certain Russian pedologists, the brown wavy bands described above have received scant attention in this country except for the work of Smith, et.al.(16).

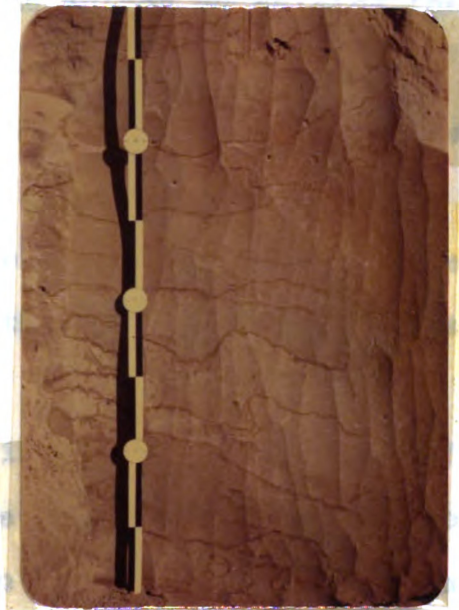


Figure 4

These workers observed similar multiple horizons underlying the very sandy Prairie or Brunigra soils. They have also been observed by the author underlying the very sandy Gray-Brown Podzolic soils.

The suggestion has been made that such horizons are geologic in origin and represent surfaces at various stages of deposition. The author has investigated this possibility and has concluded that such is not the case for the following reasons:

a. The horizons are independent of mode of deposition as indicated by the great similarity of morphology whether formed on windblown sand, (L-2, Fig. 3), or water-worked drift, (L-1, Fig.3). The horizons may be seen to cut across bedding plains.

b. The bands frequently over-lap one-another and may even form over-hanging surfaces (Fig. 4), which are not typical of depositional surfaces.

c. Precise determinations of mechanical analyses above, below, and within the horizons reveal no significant variability in particle size distribution of the sands which would certainly be the case were the bands actually strata rather than horizons.

d. These horizons are found only above the zone of free carbonates. In deep cuts where calcareous sands are reached,

generally at 10 to 12 feet, the lowest brown horizon is found in contact with or directly above the carbonate layer and no additional horizons are seen below.

In view of these characteristics, the most plausible hypothesis for the genesis of these horizons appears to be one of successive precipitation of iron oxide and possibly organic matter at or near the carbonate zone. As the carbonates have moved down, additional horizons have been built so that the youngest are on the bottom and the oldest are on the top. The uppermost few horizons are generally weak and may be in the process of decomposition. The periodicity of this profile formation, however, is still unexplained.

Profile L-4: Sandy Loam.

Location: 200 yards East of a point 1/4 mile south of the intersection of Iles Road and Smeckert Road, Sec. 26, T 21 N, R 13 E.

Physiography: Small, rolling morainic ridge.

Profile:

| Horizon: | Depth: | Description: |
|-----------------|--------|---|
| A ₁ | 0-2" | Black (10 YR 2/1 moist) fine sandy loam with weakly developed medium crumb structure. |
| A _{2p} | 2-5" | Light gray (10 YR 7/2 moist) fine sandy loam with single-grained structure. |
| B _{2p} | 5-9" | Yellowish red (5 YR 4/8 moist) fine sandy loam with medium crumb |

| | | |
|-------------------------------|--------|---|
| | | structure, and some evidence of cementation. |
| A ₂ GB | 9-27" | Brownish yellow (10 YR 6/6 moist) fine sand with single-grained structure. |
| B ₂ GB | 27-37" | Reddish brown (5 YR 4/4 moist) sticky sandy loam with very weak blocky structure. |
| C ₁ D ₁ | 37-68" | Brownish yellow (10 YR 6/8 moist) medium sand with single-grained structure. |
| D ₂ | 68"+ | Yellowish brown (10 YR 5/6 moist) very fine sand, calcareous with single-grained structure. |

Profile L-4 occupies the central position of the lithosequence and exhibits an approximate equality in development of the Podzol in the surface and the Gray-Brown Podzolic horizons below. The stratified nature of the parent material, however, makes interpretation uncertain without additional mineralogical studies. The B_{2p}, a strong orterde, shows a significant accumulation of organic matter, free iron oxide, (Fig. 6), and clay. The typically Gray-Brown Podzolic B₂GB horizon contains a strong accumulation of clay and some iron oxide, but only a slight enrichment in organic matter. The horizons directly below the B₂GB, although occupying the C position, are designated C₁D₁ and D₂ since their mechanical analyses indicate that they differ somewhat from the true parent material of the solum. The upper of these two horizons,

the C_1D_1 is neutral, while the lower, the D_2 contains 6.4% $CaCO_3$.

Profile L-6: Loam.

Location: 670 feet East of fence corner 0.4 miles South of intersection of French Line Road and the Tuscola county line. Sec. 30, T 12 N, R 12 E.

Physiography: Rolling till plain.

Profile:

| Horizon: | Depth: | Description: |
|-----------|----------|--|
| A_1 | 0-2.5" | Very dark brown (10 YR 2/2 moist) sandy loam with weakly developed medium granular structure. |
| A_{2p} | 2.5-3.5" | Pale brown (10 YR 6/3 moist) sandy loam, discontinuous with weakly developed medium granular structure. |
| B_{2p} | 3.5-7" | Strong brown (7.5YR 5/8 moist) loam with weakly developed medium to fine crumb structure and irregular lower boundary. |
| A_{2GB} | 7-12" | Yellowish brown (10 YR 5/4 moist) loam with medium angular blocky structure. |
| A_{3GB} | 12-18" | Dark yellowish brown (10 YR 4/4 moist) loam gradational between the horizons above and below, medium blocky structure. |
| B_{2GB} | 18-26" | Dark brown (10 YR 4/3 moist) clay loam with strongly developed coarse blocky structure and some evidence of colloidal coatings on the structural aggregates. |

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| C | 26" | Yellowish brown (10 YR 5/4 moist)
loam with well developed medium
to thick platy structure,
calcareous. |
|---|-----|--|

Profile L-6, derived from a loam till, shows the tendency toward the weakness of the upper Podzol horizons on the heavier-textured parent materials of the region. In this profile, the C₁ horizon is lacking, the B_{2GB} lying directly upon the parent material, which is in this case a highly calcareous till (17.2% CaCO₃). The upper Podzol B or B_{2p} horizon is of the orterde form with an accumulation of organic matter but with a clay content only slightly higher than that of the horizon below and definitely lower than that of the C horizon. Fig. 6 indicates that the B_{2p} horizon also includes an accumulation of free iron oxide, but to a lesser extent than does the B_{2GB} horizon. Soils with similar profiles a few hundred yards away were correlated as Miami loam, a widely recognized Gray-Brown Podzolic soil in the Tuscola county soil survey (3).

To study the physical properties of the horizons of Profile L-6 in an undisturbed state, use was made of the core sampling techniques described by Uhland and O'Neal (18). Values of permeability, volume weight, and non-capillary porosity for four levels of the profile are given in table 2 below.

| Depth | Horizon(s) | Texture | Permeability
(in./hr.) | Vol.Wt. (gm./cc) | Non-Cap.
porosity (%) |
|--------|--|-----------|---------------------------|------------------|--------------------------|
| 0-4" | A ₁ , A _{2P} , B _{2P} | loam | 1.62 | 1.35 | 11.22 |
| 6-10" | A _{2GB} | loam | 0.14 | 1.48 | 9.50 |
| 18-22" | B _{2GB} | clay loam | 0.01 | 1.67 | 5.46 |
| 28-32" | C | loam | 0.06 | 1.82 | 6.05 |

Table 2: Physical constants for Profile L-6

Since the depth of the core, (3 inches) was greater than the thickness of some of the surface horizons, the three Pedzol horizons are represented by a single sampling zone. In table 2, the B_{2GB} horizon stands out clearly with the lowest permeability and the lowest non-capillary porosity values in the profile. Similarly, the composite surface sample exhibited the greatest permeability and non-capillary porosity values and the lowest volume weight. The greatest volume weight is found in the calcareous till of the C horizon. The greater volume weight of the C horizon in spite of a non-capillary porosity which is higher than that of the B_{2GB} may be accounted for by a loss of CaCO₃ from the B_{2GB}. Calcite, (specific gravity 2.71) is heavier than either silica or the clays which have accumulated after removal of the lime. The extremely low permeability value of the B_{2GB} horizon, (0.01 in./hr.) suggests that a considerable portion of the rain water falling on such a saturated soil on rolling topography

• The first part of the paper discusses the importance of understanding the underlying mechanisms of the observed phenomena.

• The second part of the paper presents a detailed analysis of the data collected during the experiment.

• The third part of the paper discusses the implications of the findings for future research.

• The fourth part of the paper concludes the study and provides a summary of the key findings.

• The fifth part of the paper discusses the limitations of the study and suggests areas for further investigation.

• The sixth part of the paper discusses the potential applications of the findings in the field of research.

• The seventh part of the paper discusses the ethical considerations of the study.

• The eighth part of the paper discusses the funding sources and the role of the research team.

• The ninth part of the paper discusses the acknowledgments and the contributions of the research team.

• The tenth part of the paper discusses the references and the sources of the data used in the study.

• The eleventh part of the paper discusses the appendices and the supplementary materials.

• The twelfth part of the paper discusses the conclusions and the overall findings of the study.

• The thirteenth part of the paper discusses the future directions of the research.

might tend to move diagonally along the top of the B_{2GB} horizon rather than vertically through it.

DISTRIBUTION OF IRON OXIDE AND COLLOID

Further evidence of the distribution of colloidal matter and iron oxide throughout the three profiles is seen in Fig. 5 and 6. Fig. 5 shows the materials in suspension from equal portions of the various horizons when dispersed in equal volumes of water. Profiles L-4 and L-6 were allowed to stand for six days while profile L-2, with very little clay, was photographed after only six hours suspension. In all three cases, all material visible is of colloidal size. Fig. 6 shows the distribution of iron oxide throughout the profiles by comparing air-dry samples with ignited samples, (950° for 12 minutes), of the same horizons.

These pictures indicate clearly that both B horizons, the B_{2p} and the B_{2GP} represent zones of accumulation of both clay and a red mineral fraction, presumably iron oxide. It is further evident that in the heavy profile, L-6, the stronger B horizon, both in terms of the red mineral accumulation and of clay enrichment is the B_{2GB} while, in the profile formed on sand, L-2, a slightly greater development occurs in the B_{2p} horizon. In the intermediate texture, L-4, the lower B horizon is somewhat more strongly developed but there is clearly an accumulation zone in the B_{2p} above. An interesting

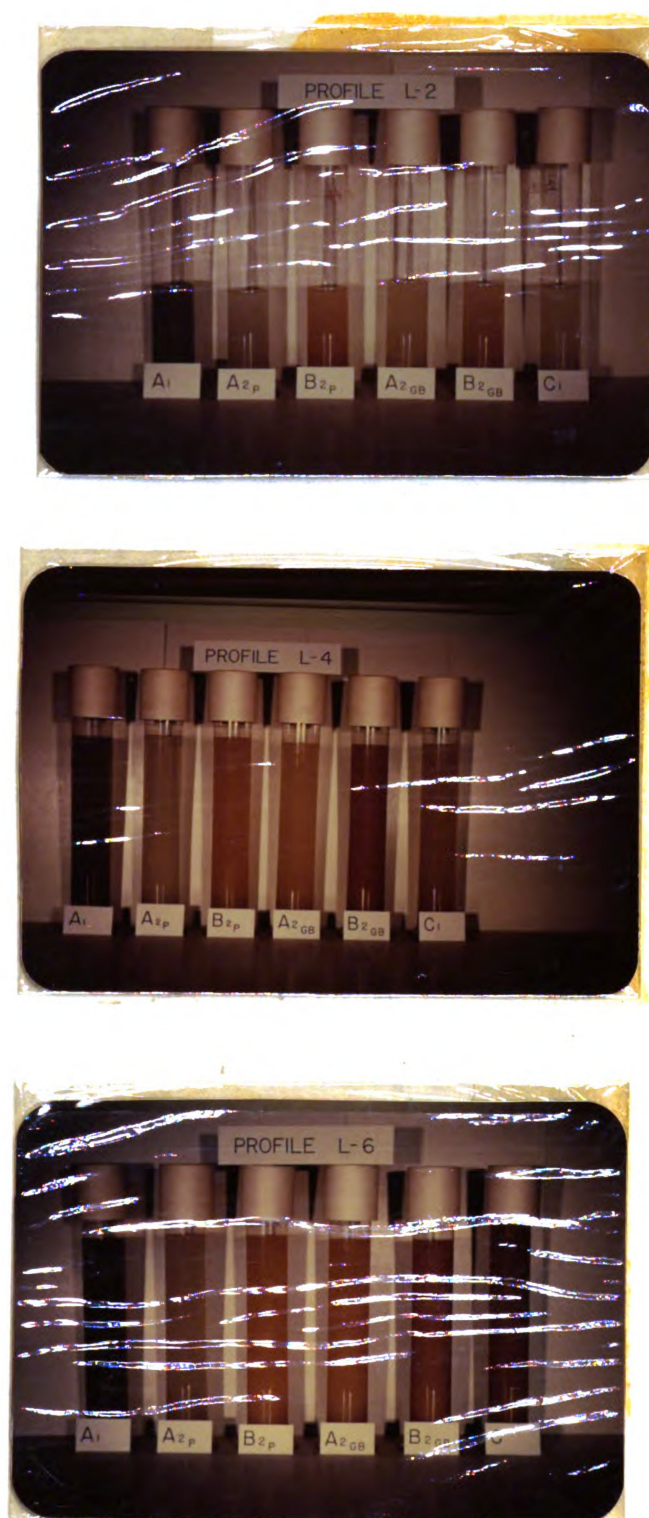


Figure 5.

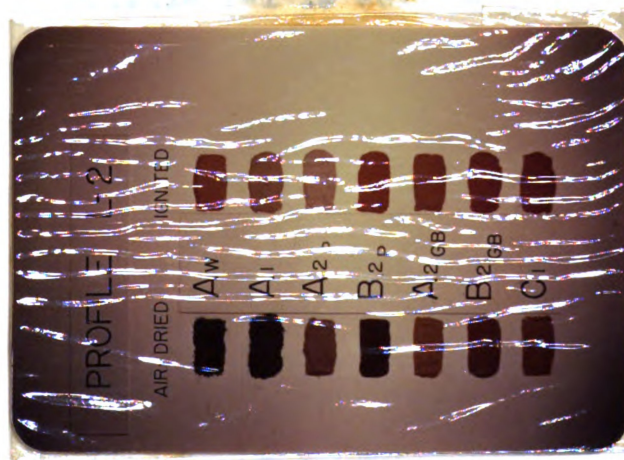


Figure 6.



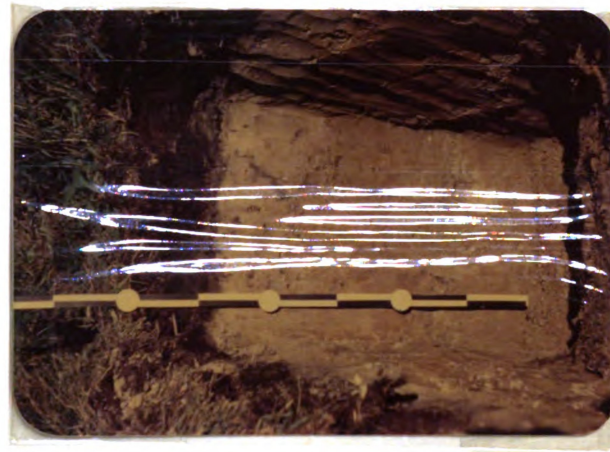
observation on Fig. 6 is that the A_1 horizon in the ignited state is, in all three profiles, darker than the ignited A_{2F} . Thus, the dark colors of the A_1 horizons are due not entirely to organic matter, but also to oxides, presumably of iron and manganese, which are less abundant in the underlying horizon, the A_{2p} or bleicherde.

THE TOPOSEQUENCE

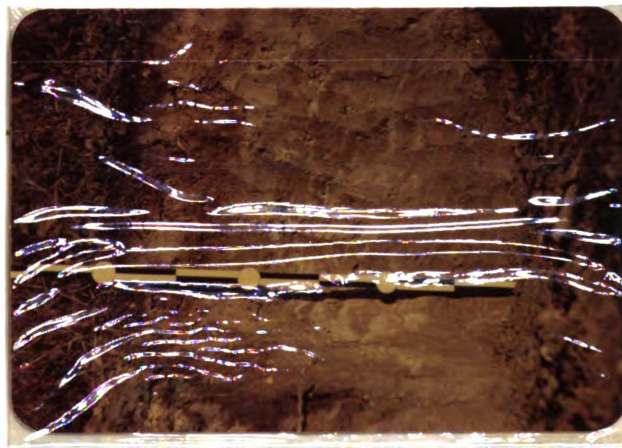
In the consideration of the lithosequence, an attempt was made to compare soil profiles as functions of parent material. It is also possible to observe the morphology of double profiles as a function of topography, particularly drainage position. Thus, profiles of similar texture may form a toposequence from well drained to poorly drained sites. Such a toposequence or catena is seen in Fig. 7. Here the profiles are arranged in the order of decreasing height above the water table; Profile T-1 is well drained, T-2 is moderately well drained, T-3 imperfectly to poorly drained, and T-4 poorly to very poorly drained. The drainage terminology used here is that adopted by Rogers, et.al. (15). The parent material of all the profiles is of a loam texture. It should be noted that profile T-1 of the toposequence is identical with profile L-5 of the lithosequence, (Fig. 3). Thus the lithosequence may be thought of as a "horizontal" sequence while the toposequence is "vertical", the two groupings crossing at the



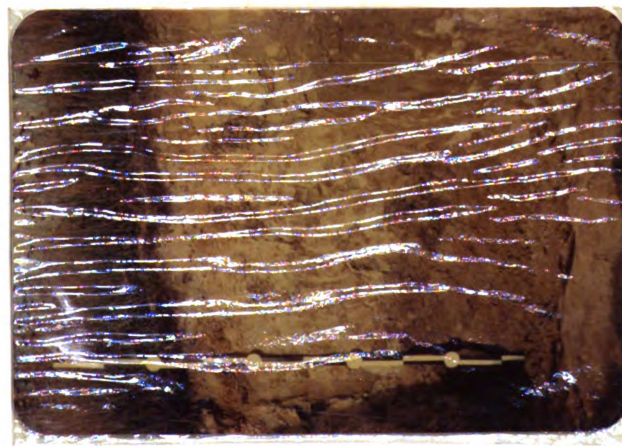
T-4



T-3



T-2



T-1

The first part of the paper discusses the importance of the study of the history of the United States. It is a study of the past which helps us to understand the present and to prepare for the future. The second part of the paper discusses the importance of the study of the history of the world. It is a study of the past which helps us to understand the present and to prepare for the future. The third part of the paper discusses the importance of the study of the history of the United States. It is a study of the past which helps us to understand the present and to prepare for the future.

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well drained loam, profile L-5 or T-1.

Inspection of the four profiles indicates that while the double profile is evident in profiles T-1 and T-2, it does not appear in the wetter sites, T-3 and T-4. It appears therefore, that soils derived from a loam parent material in this area will exhibit the double profile only in sites which are well or moderately well drained. Additional field observation has shown that in the lighter textures, sandy loams, and loamy sands, the double profile might extend down the catena as far as the imperfectly drained position. At no point, however, has the double profile been observed at locations wetter than the imperfectly drained position.

STATISTICAL CONSIDERATION OF SIZE DISTRIBUTION IN "PARENT MATERIAL" HORIZONS

To examine the relationship between mode of deposition of parent material and double profile development, a statistical analysis was made of particle size distribution in one horizon of each of profiles L-2, L-4, and L-6. It should be noted that horizons C_1 of profile L-2 and horizon C_1D_1 of profile L-4 are not truly the parent material of the profiles since they have been leached of lime and, in the case of the C_1D_1 horizon, have been modified somewhat by stratification. For this reason, the words parent material are placed in parantheses above.

The cumulative curves of the particle size distribution of the three horizons are seen in Fig. 8. Statistical values derived from the above curves are listed in table 3.

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Profile L-2 Dune Sand

Profile L-4 Water-Worked Drift

Profile L-6

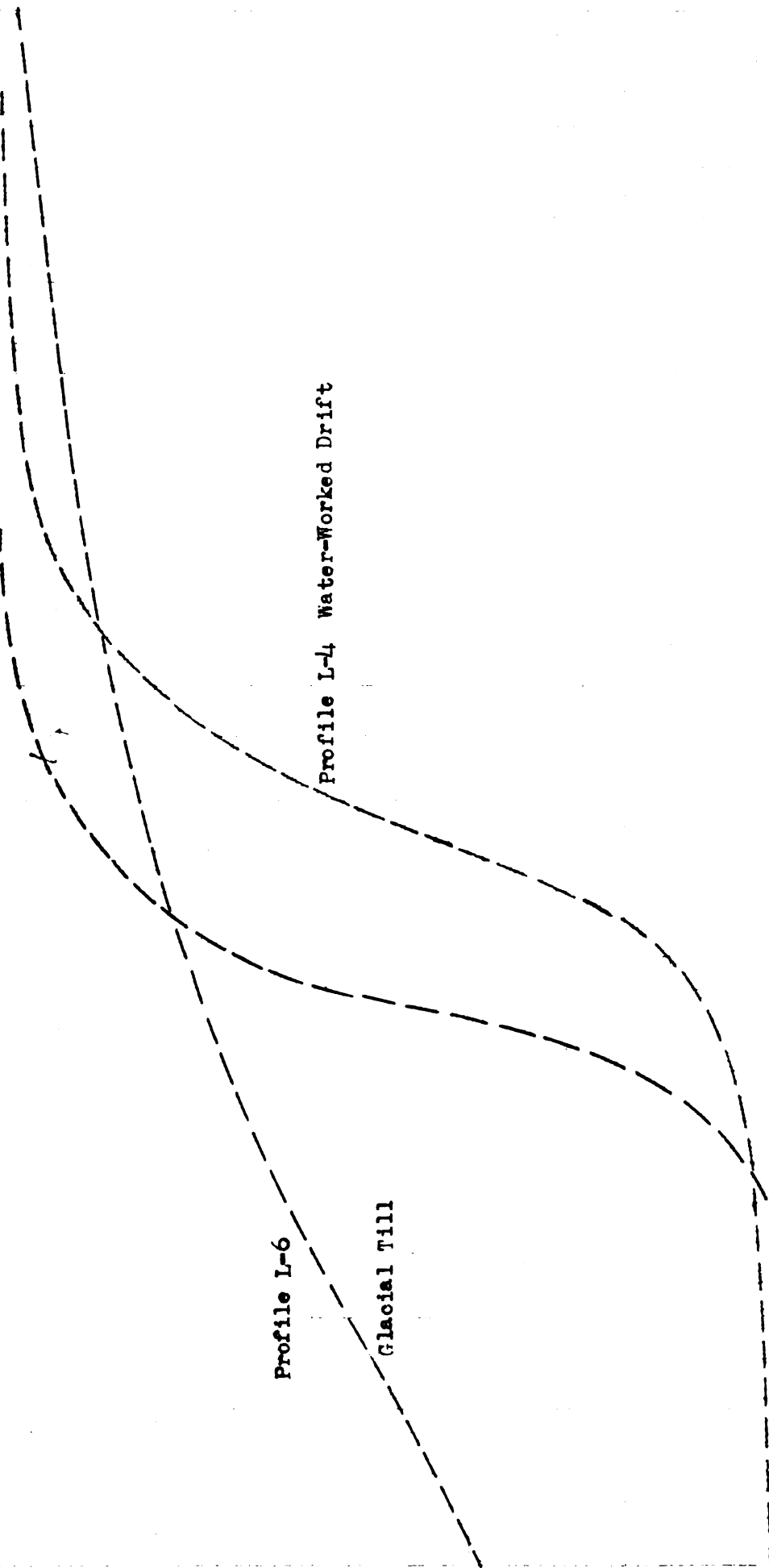
Glacial Till

1.0 mm

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Figure 8. Cumulative Curves of Particle Size Distribution



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Statistical values from "parent material" horizons

| Statistic: | C ₁ horizon of
Profile L-2
(aeolian sand) | C ₁ D ₁ horizon
of Profile L-4
(water-worked
drift) | C horizon of
Profile L-6
(glacial till) |
|-------------------------------------|--|--|---|
| | | | |
| P ₁₀ | 0.07 mm | 0.12 mm | 0.0005 mm |
| P ₂₅ = Q ₁ | 0.96 mm | 0.20 mm | 0.004 mm |
| P ₅₀ = Q ₂ | 0.13 mm | 0.285 mm | 0.025 mm |
| P ₇₅ = Q ₃ | 0.18 mm | 0.48 mm | 0.13 mm |
| P ₉₀ | 0.27 mm | 0.72 mm | 1.20 mm |
| Sorting coefficient: | | | |
| So = $\sqrt{Q_3/Q_1}$ | 1.40 | 1.55 | 5.68 |
| Quartile
Kurtosis: | | | |
| K _q = | | | |
| $\frac{Q_3 - Q_1}{P_{90} - P_{10}}$ | 0.21 | 0.23 | 0.53 |
| Range: | 1.00 mm | 7.00 mm | 14.0 mm |
| | | | |

Field estimation by the author had indicated that profiles L-2, L-4, and L-6 had been derived from parent materials which were dune sand, water-worked drift, and glacial till, respectively. The statistical analyses have borne out these contentions. The sorting value, limited size range, and marked kurtosis (grouping around a central point) of profile L-2 are all typical of aeolian deposits. The poor sorting and extreme

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range of particles in profile L-6 clearly show the ice deposition of glacial till while the values for profile L-4, intermediate between the other two, indicate water deposition. Microscopic observation of sands of the 0.50 - 0.25 mm separate from the three profiles revealed a high degree of roundness with some frosting in the dune sand, markedly less roundness of particles in the water-deposited material, and appreciable angularity in the glacial till.

The conclusion to be drawn from the statistical data is that the development of the double profile is not related to mode of deposition of the parent material and is independent of geological stratification.

DISCUSSION

The occurrence of both orterde and clay-accumulation types of B horizons in these zonal soils poses some perplexing problems concerning the nomenclature of the individual horizons and of the soils as a group. The A₁, A_{2p}, B_{2p}, A_{2GB}, and B_{2GB} horizons, (tentative annotations adopted in this thesis) are all essential parts of the morphology of these soils as was pointed out earlier by Veatch and Millar (20). Only the A₁, A_{2p}, and B_{2p} horizons are usually considered as characteristic of the Podzols and only the A₁, A_{2GB}, and B_{2GB} horizons are usually considered as characteristic of the Gray-Brown Podzolic

soils. Should these soils be in still another Great Soil Group? If not, to which of the preceding groups should they be assigned? Tentatively, in Michigan, they have been assigned to a subdivision of the Podzols (21). Because of the lack of a final correlation for the soils of Sanilac county, the use of series names has been omitted from this paper. A further problem in horizon nomenclature is the designation of the layers between the multiple B_{2GB} horizons of the coarser-textured profiles L-1, L-2, and L-3 in Fig. 3.

Several possibilities have been advanced to account for the genesis of these double profiles:

A: The suggestion that the upper profile is the result of the weathering of a more recent geologic deposit on the lower profile is not borne out by the statistical evidence given above nor by the relatively uniform distribution of stones and gravel in profile L-6 and the uniform fine sand composition of profile L-2. There is no geological evidence to support any claim for two different ages of parent material in these profiles.

B: The hypothesis that the upper profile is a Ground Water Podzol formed due to drainage being restricted by the lower B_{2GB} horizon may be operative in some cases but does not explain the double profile in sites where drainage, both external and internal, is well developed, as in the present examples.

C: The genetic theory proposed by the workers in

New York (1), (5) stating that the upper Podzol profile is the younger, having formed in the acid, relatively siliceous A₂ horizon of an earlier Gray-Brown Podzolic profile seems possible. Thus, there may be a logical chronosequence of development from Gray-Brown Podzolic to Podzolic profiles, more active in siliceous materials, and possibly accelerated by a change in climate toward slightly colder conditions. If this be true, then it is evident that the time required for this sequence of events is shorter than post Mankato time since the profiles described herein on the Cary drift of Sanilac county are also present on the till deposits of Mankato age in the same area.

D: The natures of the Podzol and Gray-Brown Podzolic B horizons, particularly on the more calcareous and argillaceous parent materials, are quite different: The Podzol B horizon is characterized by an accumulation of organic matter and sesquioxides and a granular or cemented structure. The Gray-Brown Podzolic B horizon is differentiated from the overlying and underlying horizons by a greater content of silicate clays and a well developed blocky structure. It may be possible that the processes active in the formation of these two kinds of B horizons are operating simultaneously on the climatic border between the Podzols and the Gray-Brown Podzolic soils.

CONCLUSIONS

While generalizations cannot be applied over too wide an area, it is felt that the considerations of soil genesis and morphology presented herein are representative of zonal soils in Sanilac county and, to some extent, of the soils of the entire central portion of the lower peninsula of Michigan. The zonal soil profile for this region thus emerges as a double profile. While the upper horizons are clearly those of a Podzol, they are underlain by what appear to be the A₂ and B₂ horizons of a Gray-Brown Podzolic soil profile. The Podzol horizons are more strongly expressed on coarse textured siliceous materials while the Gray-Brown Podzolic horizons are best developed on the more calcareous and argillaceous materials.

In terms of land use, little has been done to evaluate the significance of the double profile. Bartelli*, however, reports that workers in the Soil Conservation Service have observed a noticeable difference in crop productivity between Podzol soils which are underlain by a heavier B horizon (double profiles), and those which are not. This difference is apparently due to the root feeding zone supplied by the B₂GB horizon.

Considerations of catena relationships indicate that

*L. J. Bartelli, personal communication.

in loam textures, the double profile does not form in drainage positions wetter than moderately well drained. Profiles developed in materials of lighter texture may exhibit the double profile at the imperfectly drained position.

A statistical study of particle size distribution in "parent material" horizons indicates that the double profile will develop regardless of whether the parent material is wind-deposited, water-deposited, or ice-laid.

While the present study was conducted in a limited geographical area of nearly constant climatic environment, the considerations discussed under the lithosequence suggest the possibility that the changes in horizon distribution from the Podzol soil region across the transitional belt to the Gray-Brown Podzolic soil region may be similar to the changes observed in horizon arrangement in the lithosequence of Fig. 2.

The author concludes that all horizons of the double profile are genetic and are the result of the succession of a younger Podzol profile in the A₂ horizon of an older, deeper Gray-Brown Podzolic soil, or the simultaneous development of all the horizons.

Regardless of the mode of formation of these profiles, they have a morphology which is distinctly different from that of either the Podzols or the Gray-Brown Podzolic Great Soil Groups. This raises some puzzling questions concerning the nomenclature of the soil horizons and the assignment of these

soils to a definite Great Soil Group. The need for a better understanding and definition of the podzolization process is apparent.

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