

A STUDY OF  
PEDOLOGICAL PROCESSES IN CERTAIN  
MANITOBA SOILS

A THESIS

Submitted to the Faculty of Post-Graduate  
Studies And Research of The University of Manitoba

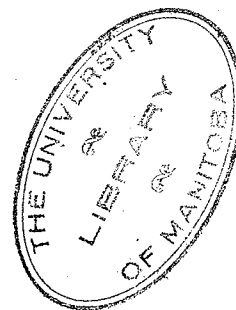
by

J. ARNOLD BARR

In Partial Fulfillment of the Requirements for the  
Degree of

MASTER OF SCIENCE

April, 1950.



### ACKNOWLEDGMENT

The writer wishes to express his indebtedness to Professor J. H. Ellis of the Soils Department, University of Manitoba, who suggested the problem, and under whose direction the project was conducted.

Acknowledgment is also made to Dr. J. A. Hobbs, formerly Assistant Professor of Soils, University of Manitoba, and to Mr. W. A. Ehrlich, Soil Specialist, Dominion Department of Agriculture, for supervision in the course of laboratory experimentation.

## TABLE OF CONTENTS

	<u>page</u>
I. STATEMENT OF PROBLEM .....	1
2. LITERATURE REVIEW .....	1
3. MORPHOLOGICAL DESCRIPTIONS OF THE SOIL TYPES STUDIED	4
4. GENERAL DESCRIPTION OF SOILS STUDIED .....	11
5. CLIMATIC DATA .....	15
6. EXPERIMENTAL DATA .....	20
I. CHEMICAL STUDIES .....	20
A. TOTAL ANALYSIS (FUSION) AND REACTION .....	20
(a) Methods .....	20
(b) Data .....	34
(c) Discussion of Results .....	34
B. ORGANIC MATTER AND NITROGEN .....	36
(a) Methods .....	36
(b) Data .....	36
(c) Discussion of Results .....	36
(d) Carbon-Nitrogen Relationship .....	40
C. BASE EXCHANGE AND SOLUBILITY PRODUCTS .....	40
(a) Methods .....	41
(b) Data .....	43
(c) Discussion of Results .....	43
II. PHYSICAL STUDIES .....	51
A. MECHANICAL ANALYSIS .....	51
(a) Methods .....	52
(b) Data .....	52
(c) Discussion of Results .....	52
B. MOISTURE EQUIVALENTS .....	58
(a) Method .....	58
(b) Data .....	58
(c) Discussion of Results .....	58
C. AGGREGATE OR STRUCTURAL ANALYSIS .....	60
(a) Method .....	60
(b) Data .....	60
(c) Discussion of Results .....	60

## TABLE OF CONTENTS

	<u>page</u>
7. GENERAL SUMMARY .....	63
8. CONCLUSIONS .....	67
9. BIBLIOGRAPHY .....	70

# INDEX OF TABLES

<u>Number</u>		<u>Page</u>
1.	The Mean Monthly Precipitation Data for the Stations from which the Soil Profiles Were Obtained.....	17
2.	The Mean Monthly Temperature Data for the Stations from which the Soil Profiles Were Obtained.....	17
3.	Thorntwaite or P-E Values for the Stations from which the Soil Profiles were obtained...	19
4.	Total Analysis by Fusion, Inorganic Carbon and Calcium Carbonate Content of the Darlingford Phytomorphic Associate; Expressed as Percent of the Ignited Sample.....	27
5.	Total Analysis by Fusion, Inorganic Carbon and Calcium Carbonate Content of the Waskada Phytomorphic Associate; Expressed as Percent of the Ignited Sample.....	28
6.	Total Analysis by Fusion, Inorganic Carbon and Calcium Carbonate Content of the Newdale Phytomorphic Associate; Expressed as Percent of the Ignited Sample.....	29
7.	Total Analysis by Fusion, Inorganic Carbon and Calcium Carbonate Content of the Erickson Phytomorphic Associate; Expressed as Percent of the Moisture Free Sample.....	30
8.	Total Analysis of the Erickson Phytomorphic Associate, Calculated on Ignited Basis.....	31
9.	Hydrogen Ion Concentration of Darlingford, Waskada, Newdale and Erickson Phytomorphic Associates.....	32
10.	Organic Matter and Nitrogen Content, Carbon-Nitrogen Relationship of the Soils Studied...	37
11.	Total Organic Content of the Soil Profiles; Expressed as Pounds per Acre.....	39
12.	Darlingford Phytomorphic Associate. Exchangeable Bases, Hydrogen and Solubility Products, Expressed as Milliequivalents, Extracted by Neutral Normal Ammonium Acetate Solution.....	44
13.	Darlingford Phytomorphic Associate. Exchangeable and Soluble Bases and Hydrogen as Percent of the Total Bases and Hydrogen Extracted.....	44

# TABLES

<u>Number</u>		<u>Page</u>
14.	Waskada Phytomorphic Associate. Exchangeable Bases, Hydrogen and Solubility Products, Expressed as Milliequivalents, Extracted by Neutral Normal Ammonium Acetate Solution .....	45
15.	Waskada Phytomorphic Associate. Exchangeable and Soluble Bases, and Hydrogen, as Percent of the Total Bases and Hydrogen Extracted .....	45
16.	Newdale Phytomorphic Associate. Exchangeable Bases, Hydrogen and Solubility Products, Expressed as Milliequivalents, Extracted by Neutral Normal Ammonium Acetate Solution .....	46
17.	Newdale Phytomorphic Associate. Exchangeable and Soluble Bases and Hydrogen, as Percent of the Total Bases and Hydrogen Extracted .....	46
18.	Mechanical Analysis of Darlingford, Waskada and Newdale Phytomorphic Associates. Percentage of Soil Fractions Based on Oven Dry Weight	53
19.	Mechanical Analysis. Percentages on Ignited Basis .....	54
20.	Mechanical Analysis and Textural Classes .....	55
21.	The Moisture Equivalents of the Darlingford, Waskada and Newdale Phytomorphic associates...	59
22.	The Aggregate or Structural Analysis of the Darlingford, Waskada and Newdale Phytomorphic Associates .....	61

## INDEX OF CHARTS

<u>Number</u>		<u>Page</u>
1.	Sketches of the Soil Profiles Studied .....	12
2.	Average Monthly Precipitation and Temperatures Data from the Profile Areas .....	18
3.	The Calcim Carbonate Content of the Soil Pro- files Studied .....	33
4.	The Organic Matter Content of the Soil Profiles Studied .....	38
5.	Darlingford Phytomorphic Associate. The Extracted Calcium, Magnesium, Sodium, Potassium and Hydrogen in Percent of the Total Bases Absorbed .....	47
6.	Waskada Phytomorphic Associate. The Extracted Calcium, Magnesium, Sodium, Potassium and Hydrogen in Percent of the Total Bases Absorbed .....	47
7.	Newdale Phytomorphic Associate. The Extracted Calcium, Magnesium, Sodium, Potassium and Hydrogen in Percent of the Total Bases Absorbed .....	47
8.	Darlingford Phytomorphic Associate. Mechanical Analysis Expressed as Percent on Ig- nited Basis .....	56
9.	Waskada Phytomorphic Associate. Mechanical Analysis, Expressed as Percent on Ig- nited Basis .....	56
10.	Newdale Phytomorphic Associate. Mechanical Analysis, Expressed as Percent on Ig- nited Basis .....	56

A STUDY OF  
PEDOLOGICAL PROCESSES IN CERTAIN  
MANITOBA SOILS

1. STATEMENT OF PROBLEMS:

The blackearth soils cover a large portion of Southern Manitoba. These soils have been mapped by the Manitoba Soil Survey and classified on the basis of morphological characteristics. It was noted that the dark color of the surface horizons was common to all the soils. However, there was considerable variation in the color of the sub-surface horizons, in the structure, and in other morphological features.

An investigation was undertaken to ascertain if chemical and physical studies would provide criteria for differentiating the blackearth soils of Manitoba.

2. LITERATURE REVIEW:

The first investigation of chernozem soils, of which we have record, was carried out by Russian soil scientists. Glinka (19), in his publication, "The Great Soil Groups of the World and Their Development" showed the gradual change in the concept of chernozem development. Early scientists, such as Tomonosoff, Pallas, Murchison, Petzhold, believed that the chernozem originated as a marine deposit left behind when the Arctic Ocean receded. The high nitrogen content was explained as due to animal origin.

Rupprecht (19) was first to attack the problem from a botanical standpoint. He stated that the chernozem had developed from steppe grass vegetation and was a land plant soil wholly analogous for the grassy soils of northern Russia. Karpinski (19) held that the character of the parent rock had a



predominant influence.

In 1883, Dokutschajeff, in his publication "The Russian Tschernosem" maintained that the chernozem could not be developed under frost conditions, and that the influence of climate in the soil forming process was many sided. The climate influenced the type of vegetation, the annual increase in accumulated vegetable matter, the amount of decomposition of plant materials, and the character of the decomposition processes. He also realized that the humus content would be strongly influenced by the mechanical constitution of the parent rock, since it is the latter that determines the water and air permeability of the soil. This permeability would determine the rate of decomposition of the organic matter present in the profile.

Dokutschajeff recognized one of the characteristic features of all chernozems; the occurrence of passage ways of burrowing animals. These appeared in the soil profile as oval or irregular formed spots which could be seen in the humus horizon only when they were filled with the lighter colored parent rock, or in the latter only when they were filled with material from the humus horizon.

The Russians (19) divided their chernozem into three main zones:

1. Northern or leached chernozems.
2. Deep or thick chernozems.
3. Southern or ordinary chernozems.

These soil zones paralleled the climatic zones. In the center of the region the dark coloring of the soil was most striking, the amount of humus the greatest, and the humus layer the thickest.

Investigation was also carried on into the development of root systems in the different horizons of the chernozems. The largest number of roots was found in the A horizon, with the B<sub>2</sub> horizon having the least. In the thick chernozems an abundance of root systems penetrated to a great depth. Penetration depended on moisture, nutritive matter, temperature and condition of aeration.

Dokutschajeff (18), who was the founder of soil science in Russia, established many fundamental principles. Among his principles were:

1. Geographical distribution - dependence of the character of soil on its geographical position.
2. Topographical distribution - connection between the nature of soil and the relief.

Neustruev (37) dealt with the factors and processes responsible for the formation of a definite profile. The processes were manifested by a succession of horizons characterized by certain morphological properties such as color, texture, structure, chemical composition, constitution, consistency, etc. The factors of soil formation deal with climate, parent material and relief.

Tumin's classification (37) dealt with the following variations:

1. thickness of the humus horizons,
2. quantity of humus,
3. depth of effervescence level,
4. form in which carbonates were manifested,
5. structure of humus and humus-less horizons,
6. activity of burrowing animals,
7. parent rock.

Joffe (24) states that one of the fundamental laws of pedology is the law of the adaptability of soil types of the

globe to definite natural (primarily climatic) conditions.

One of the aims of pedology is to unravel the fundamental laws governing the processes of soil formation in relation to weathering, one of the primary physio-chemical forces of nature responsible for soil genesis. Each type of soil formation, with its inherent characteristics and properties, could be identified with a definite zone of homologous soil forming processes. Weathering processes include oxidation, hydration, carbonation, solution and deposition.

Zakharov (Joffe 24) investigated the relation of climate to the process of weathering. He noted that in arid and semi-arid temperature climates, leaching took place but not sufficiently for thorough percolation, and, as a result the carbonates were retained in the belt of weathering.

Dokutschajeff (Joffe 24) concluded that the now-prevailing climate is an all important factor in formation; therefore chernozem was a recent formation.

### 3. MORPHOLOGICAL DESCRIPTION OF THE SOIL TYPES STUDIED:

The blackearth soils studied by the author were obtained from selected sites typical of the morphological conditions under investigation. The blackearth soil profile (Darlingford) was obtained from the north-west corner of 5-3-6W. The brown-blackearth soil profile (Waskada) was obtained from the southwest of 10-3-20W. The northern blackearth soil profile (Newdale) was obtained from the eastern portion of 18-14-24W. These areas had already been covered by a reconnaissance soil survey. The morphological descriptions of these soils were obtained at the time of sampling.

These descriptions are given below:

Darlingford Phytomorphic Associate

Location - .21 miles S. N.W. 5-3-6W.

<u>Horizon depth</u>	<u>Description</u>
0 - 12"	Color: * Black to very dark grey. (10 Y R 2/1 to 10 Y R 3/1) **  Texture: Heavy clay loam to clay loam.  Structure: Granular; forming weak, irregular columns 2 - 3" in diameter.  Consistence: Very friable.  Intrusions and concretions: Tongued into the horizon below.  Reaction: Slightly alkaline.
12"- 21"	Color: Black to very dark brown (10 Y R 2/1 to 10 Y R 2/2) gradually decreasing in intensity with increasing depth.  Texture: Heavy clay loam.  Structure: Coarsely granular to small nutty angular aggregates, tends to form irregular columnar clods.  Consistence: Friable.  Intrusions and concretions: Flecked with lime carbonate in lower portion.  Reaction: Slightly alkaline.
21"- 33"	Horizon of lime carbonate accumulation.  Concretions: Mottled with lime carbonate. Reaction: Alkaline.
33" +	Color: Light grey to very pale brown (10 Y R 7/2 to 10 Y R 7/3).  Texture: Clay loam.  Structure: Laminated in the lower portions.  Concretions: Lime carbonate.  Reaction: Alkaline.

Darlingford Phytomorphic Associate - (cont.)

Geological Parent Material: Calcareous boulder till  
(limestone and some shale).

Topography: Slightly undulating.

Stones: Few

Drainage: Well drained

Vegetation: Tall prairie grasses and associated herbs.

\* color of soil in air dry condition.

\*\* designation of color by Munsell Soil Color Chart.

Waskada Phytomorphic Associate

Location: .8 miles S.W. 10-3-20W.

<u>Horizon depth</u>	<u>Description</u>
0 - 5"	Color: Very dark grey brown (10 Y R 2/2). Texture: Silty clay loam to clay loam. Structure: Finely granular. Consistence: Very friable. Intrusions: Slightly tongued into horizon below. Reaction: Slightly acid.
5" - 14"	Color: Brown (10 Y R 4/3), color becoming lighter with increasing depth. Texture: Clay loam. Structure: Column-like, grading into prismatic; columns irregular and bluntly pointed; nutty aggregates. Consistence: Compact. Intrusions: Roots elongated. Reaction: Slightly acid.
14" - 28"	Horizon of lime carbonate accumulation. Texture: Clay loam. Concretions: Lime carbonate. Reaction: Alkaline.
28" +	Color: Very pale brown to pale brown (10 Y R 7/3 to 10 Y R 6/3). Structure: Laminated. Concretions: Lime, carbonate. Reaction: Alkaline.

Waskada Phytomorphic Associate - (cont.)

Geological Parent Material: Calcareous boulder till.

Topography: Undulating (gentle slopes  $1\frac{1}{2}$  - 3%).

Stones: Few

Drainage: Well drained

Vegetation: Mixed tall and short prairie grasses with  
associated herbs.

Newdale Phytomorphic Associate

Location: E<sup>1</sup> 18-14-24W.

<u>Horizon depth</u>	<u>Description</u>
0 - 8"	Color: Very dark grey (10 Y R 3/1). Texture: Clay loam. Structure: Finely granular. Consistence: Very friable. Intrusions: Slight tonguing into horizon below. Reaction: Slightly acid.
8" - 18"	Color: Dark brown (25 Y R 3/2), color fading from upper to lower portion of this horizon (due to infiltration of dust particles from horizon above); surface of aggregates darker in color than interior. Texture: Heavy clay loam. Structure: Nutty aggregates, forming weak columns. Consistence: Compact. Concretions: Flecked with lime carbonate in lower portion. Reaction: Slightly alkaline.
18" - 32"	Horizon of lime carbonate accumulation. Texture: Clay loam. Concretions: Lime carbonate. Reaction: Alkaline.
32" +	Color: Light brownish grey to light grey (10 Y R 6/3 to 10 Y R 7/2). Texture: Clay loam. Concretions: Lime carbonate. Reaction: Alkaline.



Newdale Phytomorphic Associate - (cont.)

Geological Parent Material: Calcareous boulder till.

Topography: Undulating.

Stones: Few

Drainage: Well drained

Vegetation: Tall prairie grasses and associated herbs.

A study was also made, for comparison purposes, of a grey-wooded soil associate. The soil used was the Erickson Phytomorphic Associate. The soil samples were obtained during the soil survey of the Rossburn area in Manitoba. The description was obtained from the soil survey data (59).

Description of Soil Profile Showing "Grey-wooded" Soil Characteristics. Mapped as the Grey-wooded Phytomorphic Member of the Erickson Soil Association

---

Location: East Centre of N.E.  $\frac{1}{4}$  of 31-19-22

Collected and described by R. E. Wicklund, Oct. 9, 1940.

<u>Depth</u>	<u>Description</u>
0--1 $\frac{1}{2}$ "	Leaf litter, undecomposed.
$\frac{1}{2}$ --2"	Black fairly well decomposed organic matter, charred in appearance. Abrupt division between this and the lower horizon.
2--5 $\frac{1}{2}$ "	Brownish grey fine sandy clay loam, grey and ash-like when dry, platy macro structure, pulverulent micro structure. Crumbles readily. Acid reaction.
5 $\frac{1}{2}$ --11"	Light brown clay loam, fine nutty aggregates, firm and hard when dry. Acid reaction.
11--17"	Light brown clay loam, coarsely nutty aggregates with brown organic coating. Firm when dry, somewhat tacky when wet. Neutral to alkaline reaction.
17--24"	Grey brown, slightly altered glacial till, breaks into cubes or small aggregates. Alkaline in reaction. Effervesces. (Some shale mixed with limestone till).
24" +	Khaki glacial till with calcareous mottling.

Geology - Glacial till.

Association Member - Phytomorphic.

Stones - Few.

Vegetation - Aspen, willow, birch, cranberry, cherry, hazel.

4. GENERAL DESCRIPTION OF SOILS STUDIED:

Darlingford Phytomorphic Associates:

This soil profile was obtained from the Manitou-Clearwater Prairie area which lies between the 1400 and 1600 foot contours.

# Chart No. I SKETCHES OF THE SOIL PROFILES STUDIED

SOIL  
ZONE

DARK BROWN-BLACK  
EARTH TRANSITION

BLACKEARTH

NORTHERN BLACK EARTH

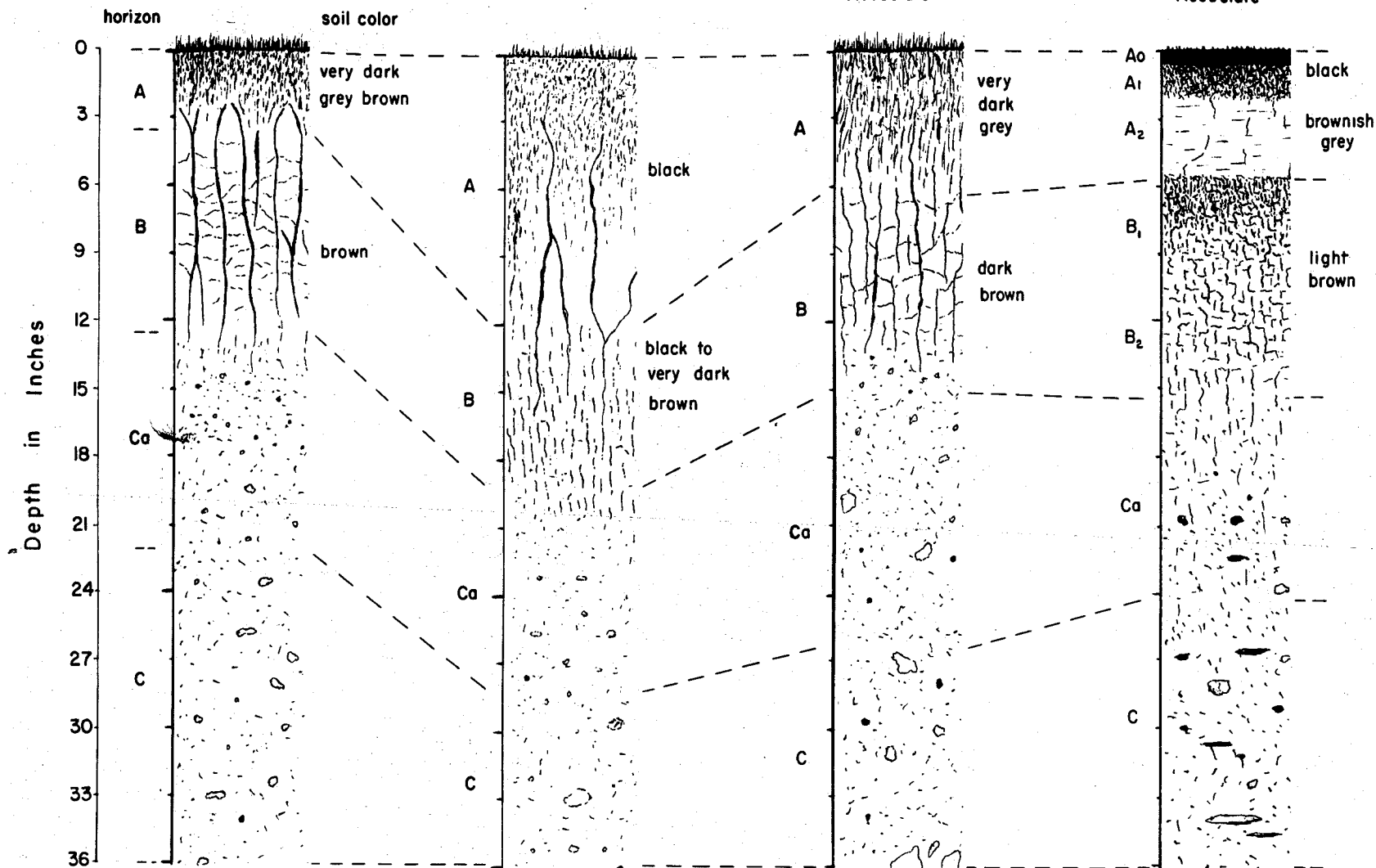
GREY WOODED

Waskada  
Phytomorphic  
Associate

Darlingford  
Phytomorphic  
Associate

Newdale  
Phytomorphic  
Associate

Erickson  
Phytomorphic  
Associate



The topography of the Darlingford soil is generally smoothly undulating and in some cases almost level. The soil is developed on light khaki boulder till under tall prairie grass vegetation, with islands of aspen poplar interspersed as groves in locally humid sites. This type of vegetation, in comparison with that on the Waskada soil, indicates a more favourable soil-moisture climate.

Observations of crops grown indicate that these soils may be used for any type of agriculture, and with good management they can be expected to produce satisfactory crops of wheat, coarse grains, corn, intertilled crops and fair crops of grasses and legumes. However droughts may occur occasionally and moisture conservation practices are required.

Waskada Phytomorphic Associate:

This soil profile was obtained from the Waskada Till Plain Area with an elevation of from 1550 to 1900 feet.

The topography of the Waskada soils varies from roughly to smoothly undulating, and as a result a variable complex of soils are found in association with the well drained associate. Consequently, there is a topographical sequence in which the drainage is variable. Drainage is excessive on the knolls and hillocks, and imperfect to poor in the depressions. Due to the variation in drainage and in the amount of water that enters the soil profile, the soil may vary considerably in different parts of the same field. The soils on the higher positions are shallow and subject to erosion. In the lower positions the soils are darker in color and are generally saline where drainage is impeded.

This soil was developed on light khaki glacial till under mixed tall and short prairie grasses, characteristic of mixed prairie and steppe vegetation, with associated herbs. This native vegetation indicates a transitional climate between that of the drier and semi-arid steppe to the west and that of the sub-humid prairie to the east. The combination of dry land and prairie types of vegetation indicates a fluctuation between dry and moist seasons and points to severe drought periods interspersed with relative moist seasons. Tree vegetation occurs only where the ravines are deep enough to give protection and to form effective snow traps. The open treeless aspect of this area is in marked contrast to the Darlingford area with its scattered aspen groves.

The Waskada soils are largely used for the production of wheat. In favorable years the yield of wheat, crested wheat and legumes is good while the yield of oats and barley is only fair to poor. Where irrigation is provided these soils produce excellent gardens.

Newdale Phytomorphic Associate:

This soil profile was obtained from the Newdale Till Area with an elevation of from 1550 to 1900 feet.

The topography is generally undulating with numerous ravines, depressions and knolls. Drainage varies from excessive on the knolls to poor and impeded in the depressions. In this area grassland and aspen grove vegetation predominates with the well drained soils developed under grassland conditions. In the southern portion of the belt, rings of aspen occur in the depressions.

The Newdale soils are suitable for general agriculture.

For a long time this soil type has been referred to as the "oat country" due to the excellent crops of oats with heavy weight per bushel. It has been suggested that this is due to the cooler conditions which prevailed, resulting in higher precipitation - effectivity, although the actual rainfall was similar to that in the southwestern portion of the province. This point will be dealt with in more detail in a later chapter.

#### Erickson Phytomorphic Associate:

This is a grey-wooded soil that was obtained from the Riding Mountain Area at an elevation slightly above 1900 feet.

The Erickson soils were formed at higher altitudes and under the influence of more moist conditions than the blackearth soils. The soil characteristics indicate that there was sufficient moisture to cause leaching of the upper part of the profile, but not enough to leach the lime out of the soil profile. It was also noted that there was not so marked a difference in the depth of the profile on the higher positions and the slopes as in the case of the grassland soils.

The original vegetation was spruce and allied deciduous boreal forest trees. Due to forest fires the vegetation at the present time is dominantly broad leafed trees, especially poplar, which have come in as second growth.

These soils are favorable for mixed farming, livestock production and forestry.

#### 5. CLIMATIC DATA:

The climatic data was compiled by the Soils Department, University of Manitoba, from meteorological records published by

the Meteorological Division, Department of Transport. The stations nearest to the sites from which the profiles were obtained were selected. The records from Pilot Mound (16 years)<sup>\*</sup> were used as representative of the Darlingford area; the records from Boissevain (21 years) were used as representative of the Waskada area; and the records from Hamiota (20 years) were used as representative of the Newdale area.

The mean monthly precipitation and temperature data are given in Tables No. 1 and 2.

A graph with the average monthly summer precipitation and temperature data is shown as Chart No. 2. All the results showed the same trend with the greatest variation in the precipitation data. During the months of April and May the precipitation was considerably lower for the Newdale profile; while during the months of June and July it was lower for the Waskada member. Temperature relations were similar for the first part of the summer with more variations through July to October.

These climatic relationships can be calculated to a numerical value by the Thornthwaite system (Thornthwaite 1931). The precipitation effectivity (P.E.) was calculated by Thornthwaite's mathematical equation from the precipitation and temperature data. These values are shown in Table No. 3. Comparing the tables and Thornthwaite's chart, it was noted that the soils fall generally within the 32-63 P-E index group, which is the sub-humid region with grassland type vegetation. However, during a few months the value fell below this index into the semi-arid class. This was most noticeable for the Waskada area during the month of October.

<sup>\*</sup> Number of years for which the climatic data had been reported.

TABLE NO. 1.

MEAN MONTHLY PRECIPITATION FOR THE STATIONS  
FROM WHICH THE SOIL PROFILES WERE OBTAINED.

Station:	<u>Pilot Mound</u> (Darlingford)	<u>Boissevain</u> (Waskada)	<u>Hamiota</u> (Newdale)
Month:	inches	inches	inches
April	1.31	1.46	.99
May	2.01	2.12	1.55
June	3.16	2.52	3.20
July	2.56	2.34	2.57
August	2.54	2.31	2.25
September	1.58	1.63	1.55
October	1.27	.67	.89

TABLE NO. 2.

MEAN MONTHLY TEMPERATURES (in Degrees Fahr.)  
FOR THE STATIONS FROM WHICH THE SOIL PROFILES WERE OBTAINED.

Station	<u>Pilot Mound</u> (Darlingford)	<u>Boissevain</u> (Waskada)	<u>Hamiota</u> (Newdale)
Month:	°F	°F	°F
April	38.05	37.00	37.00
May	51.75	50.31	51.30
June	59.42	60.03	59.62
July	67.55	67.35	65.83
August	65.36	64.15	62.78
September	55.36	53.61	52.10
October	46.63	40.90	39.20



Chart No. 2

Average Monthly Precipitation and Temperature Data  
from Profile Areas

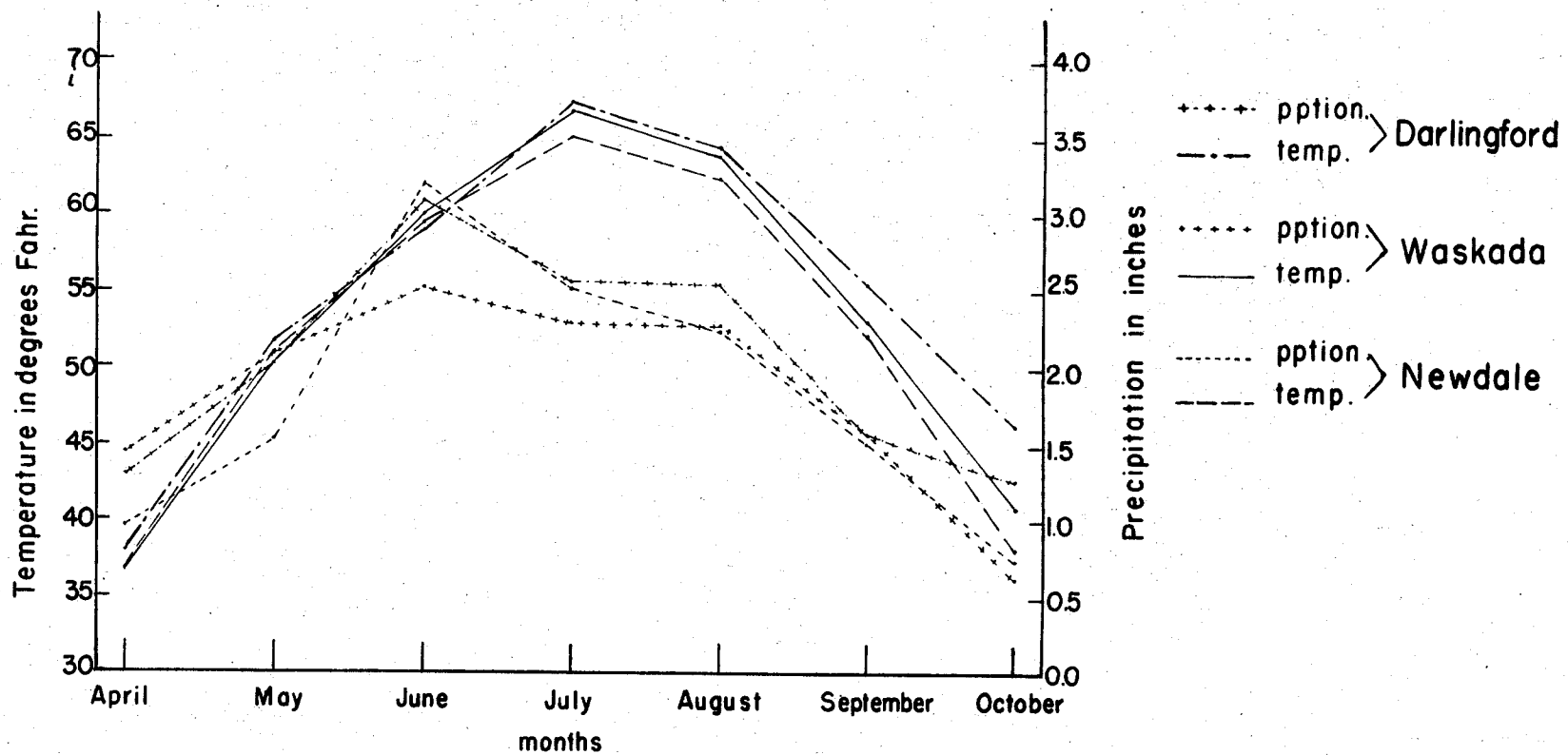


TABLE NO. 3.

THORNTHWAITE OR P-E VALUE.

Station:	<u>Pilot Mound</u>	<u>Boissevain</u>	<u>Hamiota</u>
	(Darlingford)	(Waskada)	(Newdale)
Month:			
April	.38	.45	.28
May	.41	.42	.30
June	.54	.41	.54
July	.37	.33	.37
August	.38	.34	.34
September	.27	.30	.29
October	.27	.16	.24

On examination of the Table No. 3, it was noted that the same trend was common to all profile area with a high P.E. index during the month of June and falling off to a low during the month of October. The index for the Newdale profile was low for the months of April and May in comparison to the other profiles. This was due to the lower amount of precipitation during those two months. The same relation was also found for the Waskada profile during the months of June and July, with a drop <sup>in</sup> the amount of precipitation and an increasing temperature.

Although all the profiles showed a low index for the month of October, the index of the Waskada was considerably below those of the other soil members. This would have considerable effect on the moisture reserve of the Waskada soil.

This data does not show a high P.E. value for the Newdale profile.

## 6. EXPERIMENTAL DATA:

### I. CHEMICAL STUDIES

The chemical studies undertaken included total analysis by the fusion method; the determination of the reaction, organic matter and nitrogen content; and the determination of the base exchange capacity of the soils.

#### A. Total Analysis and Reaction:

##### (a) Methods:

##### Preparation of the Sample:

The sample was received in the laboratory in the air dry condition. It was ground and passed through a 2 m.m. sieve. Stones that did not pass through were rejected. The sample was thoroughly mixed and a portion of it was further ground and

passed through a 100 mesh sieve.

Moisture determination:

Two grams of soil were weighed in a moisture dish. The dish and contents were dried over-night in a drying oven regulated at  $110^{\circ}\text{C}$ .

Loss on ignition:

The sample from the moisture determination was weighed accurately and placed in an electric furnace. The temperature was increased for  $800^{\circ}\text{C}$ . and held there for one-half hour. The crucible and contents were then cooled and weighed.

Fusion with Sodium Carbonate: (46)

The residue from the loss on ignition determination was mixed with five times its weight of sodium carbonate. The covered platinum crucible was heated cautiously until the flux had melted and the fusion was quiet. The full heat of a Bunsen burner was applied for ten minutes more. While the contents of the crucible were still molten, the crucible was whirled with the tongs in such a manner as to congeal the contents on the sides, leaving as little as possible on the bottom. The crucible was then rapidly cooled and the contents detached immediately from the crucible by inverting it over a beaker and rolling it between the fingers with gentle pressure against the sides. The melt was thoroughly disintegrated with hot water. After disintegration of the melt, the material adhering to the crucible and cover was thoroughly washed into the dish, and a few drops of ethanol added to reduce the green manganate.

Determination of Silica: (46)

When the greenish color of the disintegrated mass had

disappeared 15 ml. of pure concentrated hydrochloric acid was added slowly. After the reaction had ceased, the material adhering to the cover and sides of the dish was washed into the dish and the contents evaporated to dryness. The evaporation was continued until the silica gel was sufficiently dehydrated. The residue was taken up with 15 ml. of strong hydrochloric acid and hot water, filtered and washed until practically free from chloride. The silica precipitate was ignited in the same crucible in which the fusion was made. It was ignited slowly at first to avoid mechanical loss, then over the full flame of a Bunsen burner for one-half hour after the carbon had been thoroughly burned from the precipitate. When a nearly constant weight was obtained the silica was moistened with water, from six to eight milliliters of hydrofluoric acid and a few drops of sulphuric acid were added, and the content of the crucible were evaporated to dryness, cautiously ignited and weighed. If the residue was more than two or three milligrams, the hydrofluoric acid treatment was repeated. The loss in weight was taken as the weight of silica. The contents of the crucible were fused with one gram of sodium carbonate, filtered and added to the original filtrate.

Determination of Sesquioxides: (34)

An aliquot of the filtrate from the silica determination was neutralized with ten percent sodium carbonate. Twenty-five milliliters of ten percent sodium acetate solution were added and the solution made slightly acid with acetic acid; then heated to boiling and filtered immediately. The precipitate was washed with a dilute solution of sodium acetate until free from chlorides. The precipitate was then dissolved in hydrochloric acid, reprecipitated with concentrated ammonium hydroxide and filtered. The

precipitate was then washed with hot water and the process repeated until all of the manganese had passed into solution. The filter and contents were dried, ignited at 350°-400°C. and weighed.

Determination of Iron: (53)

To the ignited precipitate from the sesquioxide determination, 15 milliliters of hydrochloric acid (60 + 40)\* were added and digested on low heat over-night. The solution was diluted to 200 milliliters, heated to boiling and a solution of stannous chloride added drop-wise until the whole became colorless; and then four drops in excess. After cooling, the excess stannous chloride was neutralized with mercuric chloride solution. The solution was then titrated with potassium dichromate using diphenylamine as an indicator.

Determination of Calcium: (34)

An excess of recently dissolved ammonium oxalate was added to an aliquot of the original filtrate which had been heated to boiling. As a preventative against magnesium precipitation a small quantity of ammonium chloride had been added before treatment. The precipitate was digested over-night at room temperature and then filtered through a fine filter paper. It was then dissolved in hydrochloric acid, reprecipitated as oxalate, filtered, and after drying, ignited in the muffle furnace at red heat; cooled and weighed. The combined filtrates were reserved for the magnesium determination.

Determination of Magnesium: (34)

An excess of sodium hydrogen phosphate was added to the combined filtrates from the calcium determination. Enough strong

---

\* 60 c.c. HCl + 40 c.c. H<sub>2</sub>O

ammonia was slowly added to make the solution about five percent with respect to ammonia and the stirring was continued. The precipitate was allowed to stand over-night in a cool place. It was then filtered and washed with dilute ammonia (1:9). The precipitate was dissolved in hydrochloric acid and precipitated with a slight excess of sodium hydrogen phosphate in a solution containing approximately five percent ammonia. It was allowed to stand for three hours in a cool place, filtered and washed with dilute ammonia until free from chlorides. The precipitate was dried, ignited in the muffle furnace at  $900^{\circ}\text{C}$ , cooled and weighed as  $\text{Mg}_2\text{P}_2\text{O}_7$ .

Determination of Manganese: (42)

A portion of the filtrate was evaporated to dryness, treated with hydrochloric and nitric acid, again evaporated to dryness and taken up with phosphoric acid. The manganese in this solution was determined colorimetrically, with potassium periodate.

Determination of Sulphur: (34)

A portion of the filtrate was heated to boiling, treated with an excess of barium chloride and allowed to stand for several hours. The precipitate was then filtered, washed with hot water, dried, ignited in the muffle furnace at  $700^{\circ}\text{C}$ . and weighed as barium sulphate.

Determination of Phosphorus: (53) & (42)

A fresh sample of soil was moistened with a solution of magnesium nitrate, evaporated to dryness and ignited. The residue was then treated with a solution made up of water, hydrochloric and nitric acids, and allowed to digest on low heat

over-night. After treatment with hydrochloric acid the mixture was filtered and made up to volume in a volumetric flask; from which aliquots were taken for phosphorus determination. The phosphorus in this solution was determined colorimetrically, the color being developed by molybdate reagent and sulphonic acid.

Determination of Potassium and Sodium by  
J. Lawrence Smith Fusion: (53)

A sample of soil was fused with ammonium chloride and calcium carbonate in a platinum crucible over a Bunsen burner flame. The melt was disintegrated with hot water and filtered. The filtrate was treated with ammonium carbonate and ammonium oxalate to precipitate the lime and calcium. After filtration the filtrate was evaporated to dryness and heated in the furnace to  $400^{\circ}\text{C}$ . to drive off the ammonia. The residue was taken up with water and hydrochloric acid, transferred to a volumetric flask and made up to volume with distilled water.

Determination of Sodium:

A portion of the solution was treated with an excess of magnesium uranyl acetate and allowed to stand at room temperature for twenty-four hours. The mixture was filtered through a Gooch crucible, washed with alcohol that had been saturated with triple sodium salt, dried in an oven at  $110^{\circ}\text{C}$ . and weighed as sodium magnesium uranyl acetate.

Determination of Potassium:

A portion of the solution was also treated with an excess of sodium cobaltinitrate and allowed to stand for two hours. The mixture was filtered through a gooch crucible, dried at  $110^{\circ}\text{C}$ . and weighed as potassium sodium cobaltinitrate.



The fusion analysis methods used by Robinson (46) were adapted from methods of Hillebrand and Lundell (21) for the analysis of minerals and rocks. The fusion analysis of soil is used by the soil scientist to ascertain if material has moved from one horizon to another. However, this method gives little evidence as to the manner in which the various elements are combined or to their availability for plant production.

The National Soil Survey Committee has recommended that the results of all analysis, with the exception of analysis by the fusion method, be expressed as the element. The committee suggested that the results of analysis of soils by the fusion method be reported as the oxide of the element. This would give a check on the accuracy of the determinations as the summation of the percentages should equal 100. Accuracy in the determination of soils may not approach that of minerals or rocks due to the presence of organic matter, clay minerals of indefinite degrees of hydration, the different degrees of oxidation of iron and other elements, and the volatilization of some elements.

Fusion analysis of soils is not used universally. Robinson began using this method in his investigation of the soils of the United States, and the method is considered as standard procedure in studies made of soils by the United States Soil Survey.

According to Barstad (2) the variation in chemical composition among soils is considerable and is a reflection of the difference in mineralogical composition of the parent materials. However, the variation in chemical composition with depth in each profile is a reflection of the variation in the movement of materials from one horizon to another.

TABLE NO. 4.

TOTAL ANALYSIS BY FUSION (Ignited Basis)

DARLINGFORD PHYTOMORPHIC ASSOCIATE.

Location--N.W. 5-3-6W

Depth of Sample:	0-6"	6-12"	12-21"	21-27"	27-33"	33-42"
	%	%	%	%	%	%
SiO <sub>2</sub>	75.78	75.61	72.70	60.20	62.97	64.24
Al <sub>2</sub> O <sub>3</sub> +TiO <sub>2</sub>	10.48	10.34	12.73	12.31	10.45	10.52
Fe <sub>2</sub> O <sub>3</sub>	1.86	1.94	2.07	2.07	1.98	1.94
MnO	.069	.072	.067	.065	.067	.064
CaO	5.08	5.94	5.94	16.17	16.69	14.74
MgO	2.38	1.19	1.51	4.07	3.83	2.97
K <sub>2</sub> O	2.20	2.27	2.80	2.85	2.44	2.96
Na <sub>2</sub> O	.509	.666	.667	.460	.589	.553
P <sub>2</sub> O <sub>5</sub>	.495	.420	.290	.478	.477	.478
SO <sub>3</sub>	.356	.680	.702	.583	.383	.473
Total %	99.209	99.128	99.476	99.256	99.876	98.938
Inorganic Carbon	.17	.13	.27	2.16	2.64	2.54
CaCO <sub>3</sub>	1.42	1.08	2.25	18.00	22.00	21.17

TABLE No. 5.

TOTAL ANALYSIS BY FUSION (Ignited Basis)

WASKADA PHYTOMORPHIC ASSOCIATE.

Location--S.W. 10-3-20W

Depth of Sample	0-5"	5-9"	9-14"	14-20"	20-28"	28"+
	%	%	%	%	%	%
SiO <sub>2</sub>	75.94	79.20	78.82	75.25	67.55	61.01
Al <sub>2</sub> O <sub>3</sub> +TiO <sub>2</sub>	8.22	8.32	8.98	7.35	9.69	8.52
Fe <sub>2</sub> O <sub>3</sub>	1.47	1.72	1.79	1.37	1.46	1.81
MnO	.072	.068	.070	.069	.068	.065
CaO	3.79	2.81	3.32	8.33	12.15	19.10
MgO	2.53	1.05	1.30	3.09	3.54	4.41
K <sub>2</sub> O	2.90	3.11	2.77	1.97	2.47	2.64
Na <sub>2</sub> O	3.63	2.76	2.33	1.44	1.15	1.20
P <sub>2</sub> O <sub>5</sub>	.329	.362	.256	.340	.303	.349
SO <sub>3</sub>	.161	.141	.319	.083	.684	.520
Total %	99.042	99.541	99.955	99.292	99.065	99.624
Inorganic Carbon	.06	.34	.43	1.56	3.34	2.99
CaCO <sub>3</sub>	.50	2.83	3.58	13.00	27.83	24.92

TABLE NO. 6.

TOTAL ANALYSIS BY FUSION (Ignited Basis)

NEWDALE PHYTOMORPHIC ASSOCIATE.

Location--18-14-24W

Depth of Sample:	0-8"	8-14"	14-18"	18-25"	25-32"	32"+
	%	%	%	%	%	%
SiO <sub>2</sub>	79.76	73.19	71.82	65.39	64.46	64.86
Al <sub>2</sub> O <sub>3</sub> +TiO <sub>2</sub>	9.16	10.85	10.11	8.97	10.18	11.19
Fe <sub>2</sub> O <sub>3</sub>	1.88	2.09	2.35	2.18	2.08	2.16
MnO	.072	.067	.067	.066	.068	.069
CaO	2.60	8.94	11.88	16.37	16.39	13.91
MgO	.452	.872	.642	3.21	2.75	3.25
K <sub>2</sub> O	3.03	2.54	2.32	2.16	2.10	2.22
Na <sub>2</sub> O	.949	1.30	1.04	.930	.816	.987
P <sub>2</sub> O <sub>5</sub>	.620	.287	.274	.275	.365	.347
SO <sub>3</sub>	.486	.371	.128	trace	.264	.341
Total %	99.009	100.507	100.631	99.551	99.473	99.334
Inorganic Carbon	.20	.30	.42	2.04	2.23	2.24
CaCO <sub>3</sub>	1.67	2.50	3.50	17.00	18.58	18.67

TABLE NO. 7.

TOTAL ANALYSIS BY FUSION (Moisture Free Basis)

ERICKSON PHYTOMORPHIC ASSOCIATE.

Location: East Centre of N.E. $\frac{1}{4}$  31-19-22

Depth of Sample:	0- $\frac{1}{2}$ "	$\frac{1}{2}$ -5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ -11"	11-17"	17-24"	24-35"	35-45"
	%	%	%	%	%	%	%
SiO <sub>2</sub>	37.59	72.90	66.24	67.06	55.73	51.87	52.46
Al <sub>2</sub> O <sub>3</sub>	2.41	4.54	7.05	3.48	3.75	5.98	6.39
Fe <sub>2</sub> O <sub>3</sub>	1.41	2.11	2.82	3.17	3.87	3.52	3.53
MnO	0.28	0.14	0.15	0.22	0.15	0.17	0.14
CaO	4.50	9.00	9.80	12.20	14.10	16.60	15.70
MgO	1.88	1.77	2.32	1.59	4.49	4.96	4.31
K <sub>2</sub> O	0.98	1.70	1.87	1.65	1.42	1.32	1.32
Na <sub>2</sub> O	0.57	1.19	0.87	1.01	0.78	0.77	0.79
P <sub>2</sub> O <sub>5</sub>	0.32	0.14	0.19	0.21	0.22	0.18	0.17
SO <sub>3</sub>	0.43	0.13	0.23	0.06	0.11	0.16	0.21
Ignition loss	48.79	5.75	8.40	8.54	14.45	13.73	14.58
Total %	99.16	99.37	99.94	99.19	99.07	99.26	99.60
Inorganic Carbon		.03	.03	.22	2.41	3.23	3.14
CaCO <sub>3</sub>		.25	.25	1.83	20.11	26.91	26.15

TABLE NO. 8.

ANALYSES CALCULATED ON MOISTURE FREE  
AND IGNITED BASIS

ERICKSON PHYTOMORPHIC ASSOCIATE

Location: East Centre of N.E.  $\frac{1}{4}$  31-19-22

Depth of Sample	0- $\frac{1}{2}$ "	$\frac{1}{2}$ -5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ -11"	11-17"	17-24"	24-35"	35-45"
	%	%	%	%	%	%	%
SiO <sub>2</sub>	74.63	77.87	72.36	73.98	65.86	60.64	61.70
Al <sub>2</sub> O <sub>3</sub>	4.78	4.85	7.70	3.84	4.43	6.99	7.50
Fe <sub>2</sub> O <sub>3</sub>	2.80	2.25	3.08	3.50	4.57	4.11	4.15
MnO	0.56	0.15	0.16	0.24	0.18	0.20	0.16
CaO	8.93	9.61	10.71	13.46	16.66	19.41	18.47
MgO	3.73	1.89	2.53	1.75	5.31	5.80	5.07
K <sub>2</sub> O	1.95	1.82	2.04	1.82	1.68	1.54	1.55
Na <sub>2</sub> O	1.13	1.27	0.95	1.11	0.92	0.90	0.93
P <sub>2</sub> O <sub>5</sub>	0.63	0.15	0.21	0.23	0.26	0.21	0.20
SO <sub>3</sub>	0.85	0.14	0.25	0.07	0.13	0.19	0.25

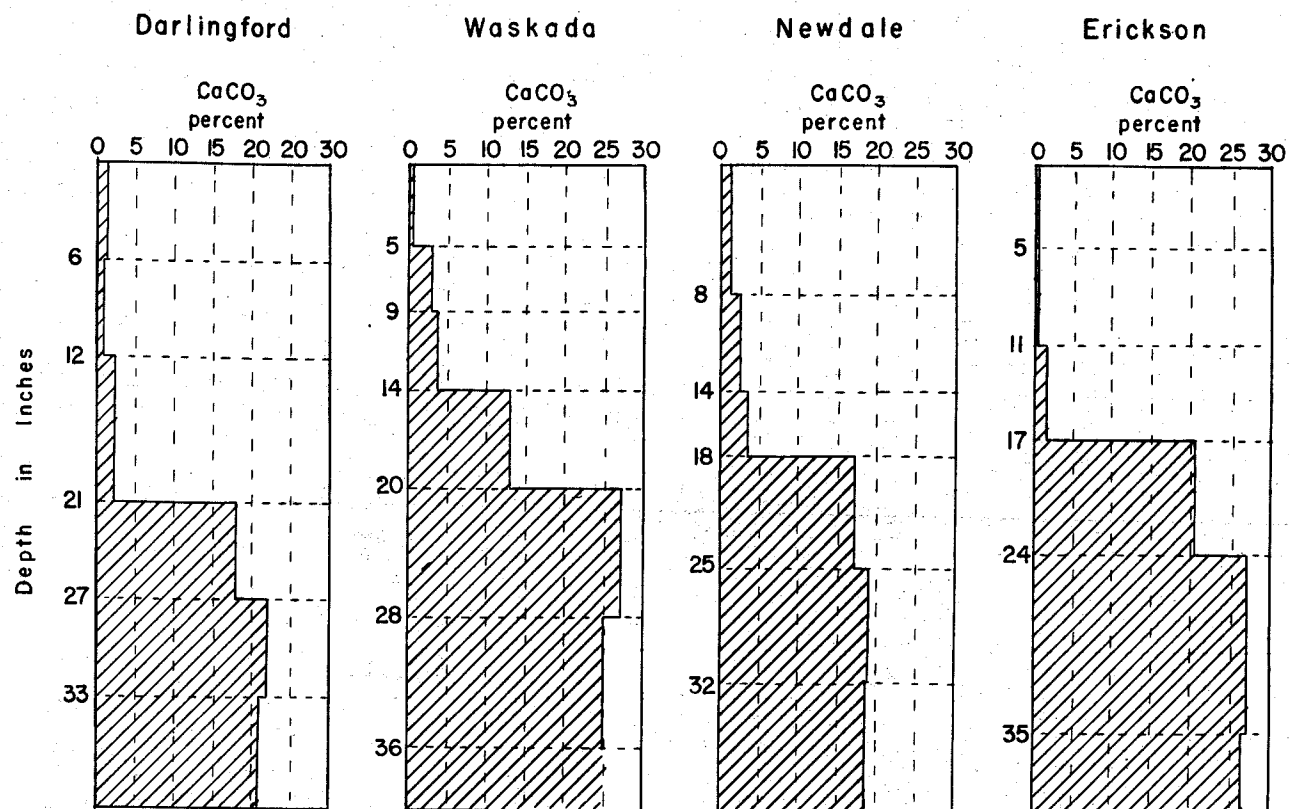
TABLE NO. 9.

HYDROGEN ION CONCENTRATION\* OF DARLINGFORD, WASKADA,  
NEWDALE AND ERICKSON PHYTOMORPHIC ASSOCIATES.

Depth in Inches	Darlingford	Waskada	Newdale	Erickson
0-3"	7.40	6.60	6.70	
3-6"	7.45	6.85	6.55	6.15
6-9"	7.45	6.80	6.60	
9-12"	7.55	6.75	6.95	6.70
12-15"	7.50	7.15	7.55	
15-18"	7.20	7.90	7.85	7.75
18-21"	7.20	8.00	8.20	
21-24"	7.55	8.25	8.35	8.75
24-27"	7.45	8.60	8.55	
27-30"	7.50	8.35	8.65	
30-33"	7.85	8.45	8.80	8.85
33-36"	7.60	8.30	8.70	
36-39"	7.65			8.80
39-42"	7.85			

\* Determined by glass electrode.

Chart No. 3 CALCIUM CARBONATE CONTENT OF SOIL PROFILES  
STUDIED, EXPRESSED AS PERCENT





(b) Data:

Tables No. 4, 5, 6, 7, 8 & 9.  
Chart No. 3.

(c) Discussion of Results:

1. Darlingford Phytomorphic Associate (Table No. 4).

The results indicated a downward movement of lime from the upper portion of the Darlingford profile. Calcium carbonate content was high in the profile below the twenty-one inch level; with a slight accumulation at twenty-seven inches.

The percentage of silica varied from 75.78 percent in the surface horizon to 60.20 percent in the subsoil. There had been no apparent movement of sesquioxides within the profile. The amount of calcium oxide increased with depth, to a maximum of 16.69 percent in the subsoil. The quantity of magnesium was variable; probably due to the deposition of the parent material. The alkalies were very low in quantity and fairly constant throughout the profile. Manganese and sodium were also very low in quantity. Sodium showed a slight increase in the B horizon.

These results showed that there had been very little weathering of the parent material. The condition of the minerals also indicated lack of decomposition.

2. Waskada Phytomorphic Associate (Table No. 5).

The calcium carbonate determination showed a downward movement, but not as severe as in the other soil profiles. The increase with depth was gradual, reaching a maximum of 27.83 percent in the horizon immediately below the twenty inch level.

The silica content of the B horizon of the Waskada profile was very high. The results also showed a slight increase in percentage of sesquioxides in this horizon; but this increase

was probably due to deposition rather than movement, as the reaction does not favor decomposition. The alkali earths increased with depth. The alkalies, manganese and sulphur were relatively low in quantity.

The surface horizons of the Waskada profile were slightly acid in reaction (Table No. 9).

### 3. Newdale Phytomorphic Associate (Table No. 6)

The pattern of lime content for the Newdale profile resembled that of the Darlingford profile, with the exception that the accumulation was at a higher level. In the Newdale soil the downward movement of lime has been greater than in the Waskada profile.

The silica content of the Newdale soil ranged from 79.76 percent in the surface horizon to 64.46 percent in the lower part of the profile. The percentage of alkali earths was lower in the surface horizon of this profile than in the surface horizons of the Darlingford and Waskada soils. However, the percentage of the horizon immediately below (8" - 14") was considerably higher; indicating a downward movement of alkali earths.

The surface horizons of the Newdale profile were slightly acid in reaction (Table No. 9).

### 4. Erickson Phytomorphic Associate (Tables Nos. 7 & 8)

Of the soil profiles studied, the Erickson profile showed the greatest movement of lime from the upper horizons. As a result of this movement the upper horizons were acid in reaction (Table No. 9).

The silica content of the Erickson soil ranged from 77.87 percent to 60.64 percent. The calcium oxide content of

the lower portion of the profile was very high. The analysis showed a slight accumulation of magnesium in the B horizon.

These results indicated that the Erickson profile has undergone more intensive weathering than the other soil profiles studied.

#### B. ORGANIC MATTER AND NITROGEN:

A study was made of the organic matter content and the nitrogen percentage of the soil profiles.

##### (a) Methods:

In the determination of carbon, a wet combustion method, adopted from methods by Adam (1) and Waynick (61) was used. The organic carbon was obtained by subtracting the amount of inorganic carbon from the total carbon. The amount of organic matter was calculated by multiplying the amount of organic carbon by the factor 1.724.

The amount of nitrogen was determined by the Kjeldahl-Gunning-Arnold Method (29). In this method the quantity was determined volumetrically, by titrating with standard alkali, using methyl red as an indicator.

##### (b) Data:

Tables No. 10 & 11.  
Chart No. 4.

##### (c) Discussion of Results:

The results indicated that the organic carbon, organic matter and nitrogen content of these soils decreased with increasing depth. The Darlingford soil contained larger quantities of organic matter and nitrogen than the other soils. Therefore, the conditions under which the Darlingford soil was developed were more favorable for the accumulation of organic matter than were those of the other soils.

TABLE No. 10

ORGANIC MATTER AND NITROGEN CONTENT, CARBON-NITROGEN  
RELATIONSHIP, OF THE SOILS STUDIED.

DARLINGFORD Phytomorphic Associate:

Sample Depth	Organic Carbon	Organic Matter (Organic carbon x 1.742 )	Nitrogen Percent	Carbon-Nitrogen (C:N) Ratio
0- 6"	7.84	13.52	.589	13.31 : 1
6-12"	5.89	10.15	.448	13.15 : 1
12-21"	1.93	3.33	.205	9.41 : 1
21-27"	1.57	2.71	.115	13.65 : 1
27-33"	1.10	1.90	.089	12.36 : 1
33-42"	.85	1.46	.026	32.69 : 1

WASKADA Phytomorphic Associate:

0- 5"	6.28	10.83	.563	11.15 : 1
5- 9"	2.19	3.78	.217	10.09 : 1
9-14"	1.21	2.09	.141	8.58 : 1
14-20"	.78	1.34	.077	10.13 : 1
20-28"	.47	.81	.077	6.10 : 1
28"+	.50	.86	.030	16.66 : 1

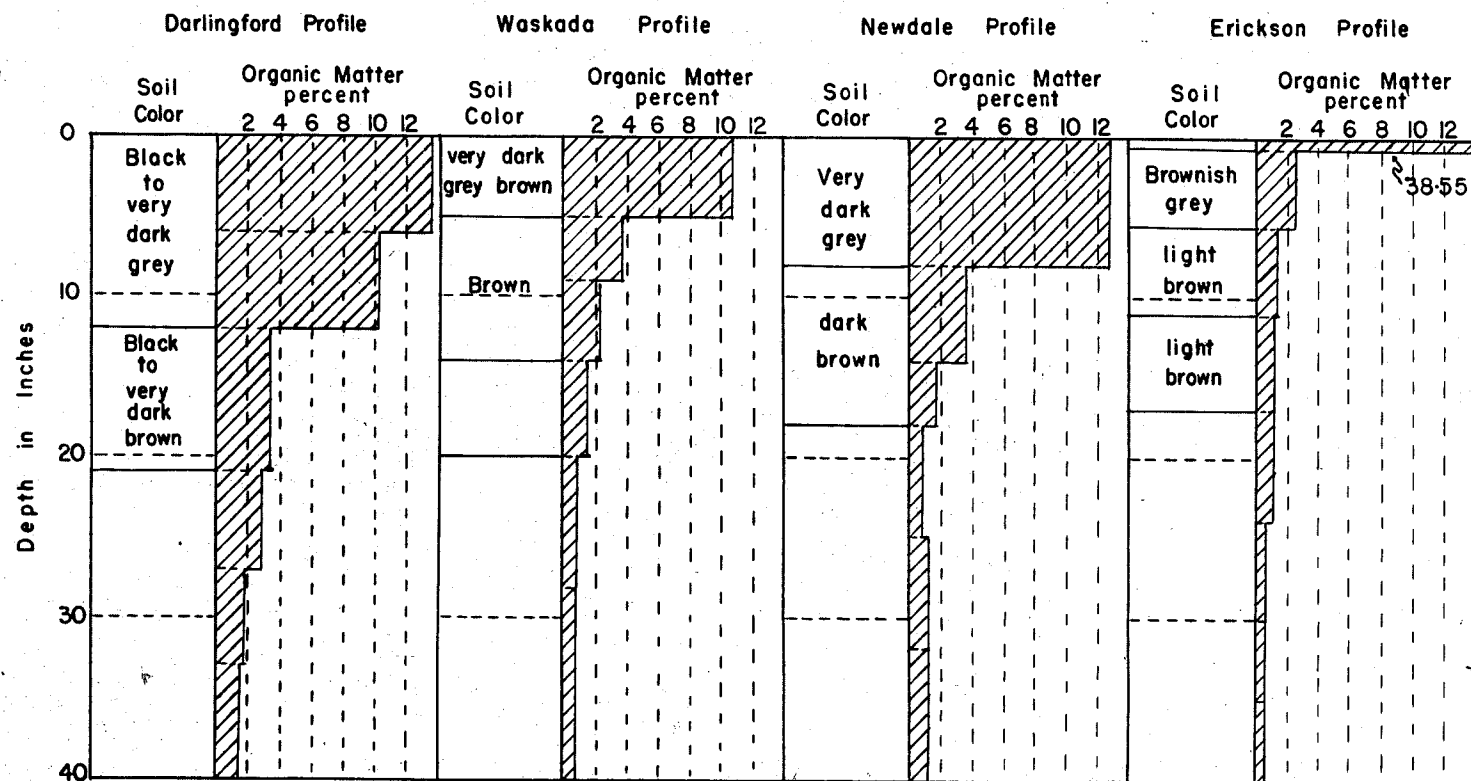
NEWDALE Phytomorphic Associate:

0- 8"	7.38	12.72	.550	13.42 : 1
8-14"	2.03	3.50	.192	10.57 : 1
14-18"	.98	1.69	.153	6.40 : 1
18-25"	.42	.72	.089	4.72 : 1
25-32"	.59	1.02	.038	15.53 : 1
32"+	.60	1.03	.038	15.79 : 1

ERICKSON Phytomorphic Associate:

0- $\frac{1}{2}$ "	22.36	38.55	1.13	19.79 : 1
$\frac{1}{2}$ -5 $\frac{1}{2}$ "	1.38	2.38	.120	11.51 : 1
5 $\frac{1}{2}$ -11"	.71	1.23	.034	21.03 : 1
11-17"	.60	1.04	.022	27.45 : 1
17-24"	.61	1.05	.022	27.77 : 1
24-35"	.34	.59	.028	12.21 : 1
35-45"	.35	.61	.022	16.00 : 1

Chart No. 4 ORGANIC MATTER CONTENT OF SOIL PROFILES STUDIED



The relationship of the organic matter content was established when the total amounts of organic matter were estimated for each profile. This relationship is shown in Table No. 11.

TABLE NO. 11

Total Organic Content of the Soil Profiles  
Expressed as Pounds per Acre \*

<u>Soil</u>	<u>Organic Matter</u>	<u>Comparative ratings</u>
Darlingford	638,370 lbs.	100
Waskada	303,360 "	47.5
Newdale	449,820 "	70.5
Erickson	155,826 "	24.4

\* Hopkins (22).

The Darlingford soil contained approximately one and one quarter times as much total organic matter as the Newdale soil; twice as much as the Waskada soil; and four times as much as the Erickson soil.

Chart No. 4 showed the distribution of organic matter within the profiles. The patterns of the content in the Darlingford and Newdale profiles were similar, with the exception that the organic matter content decreased more rapidly with increasing depth in the Newdale soil. The Waskada profile was relatively low in organic matter and the decrease with increasing depth was greater than for the other blackearth profiles studied. The organic matter content of the leaf mat of the Erickson profile was very high; while the content of the remainder of the profile was low.

Total organic content and the mineral portion of the soil

have a bearing on soil coloration (52). As the minerals in the soils of the blackearth zone are not strongly weathered, the coloration would be due mainly to the organic content.

It was observed that with decreasing degrees of intensity of soil color, (from black, through brown to grey), the total organic content decreased.

(d) The Carbon-Nitrogen Relationship:

The carbon-nitrogen ratio has been used by some writers as a basis for differentiation of certain soils.

Leighty and Shorey (30) showed that the carbon-nitrogen ratio was quite variable. With few exceptions, it was widest in surface soils, and narrowest at lower levels. This was found to be the case in the blackearth soils of Manitoba, in the portion of the profiles above the horizon of calcium carbonate accumulation. The carbon-nitrogen ratios in the carbonate horizons were not significant due to the low percentage of organic carbon and nitrogen, and to the errors in determination caused by the high concentration of carbonates. The ratios obtained are shown in Table No. 10. These results showed minor variations, but were not significant to give cause for differentiating the subtypes of blackearth soils in Manitoba.

The carbon-nitrogen ratio was wider for the Erickson soil profile than it was for the blackearth soils. This can probably be attributed to variation in the composition of vegetative matter which was deposited on the surface in the form of leaf mat.

C. BASE EXCHANGE AND SOLUBILITY PRODUCTS:

The method used in the determination of exchangeable

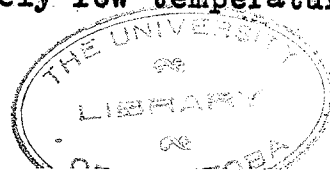
base was a modification of that of Kelly and Chapman (25). This method consists essentially of the replacement of the exchangeable bases of the soil by ammonia, which is accomplished by leaching with a neutral, normal solution of ammonium acetate. The excess of ammonium acetate was removed by washing with methyl alcohol, and the amount of absorbed ammonia was determined by the Gunning-Hibbard method. (38)

(a) Modified Method Used:

Seventy-five grams of soil were placed in a shaker bottle and 500 c.c.'s of neutral normal ammonium acetate were added. The bottle was stoppered, shaken in a mechanical shaker for thirty minutes and then allowed to stand over-night.

After standing, the solution was filtered from the soil by the use of No. 40 Whatman's filter paper and the soil washed by decantation with ammonium acetate solution until 700 c.c.'s were leached through. The filtrate was made up to 750 c.c.'s and analysed for the cations and anions brought into solution. The soil residue was washed with methyl alcohol until any further washing would cause colloidal material to move through the filter paper. The ammonia in the soil sample was then determined by distilling the ammonia into standard acid by the use of a kjeldahl distilling apparatus.

Ammonium acetate was used in this determination because ammonium rarely occurs in quantity as a major soil base, but can function as such under laboratory conditions; is easily determinable, and the acetates of all soil bases are readily soluble. Moreover, it has the outstanding analytical advantage of being almost completely volatile at a comparatively low temperature.





Every trace can be removed by ignition or treatment with suitable reagents. A solution of high purity is easily prepared from inexpensive reagent chemicals. About its only defects in application to base exchange work on soils are, the difficulty in titrating an excess of acid in a large volume of the strong solution, and its solvent effect on calcareous material. In the leaching process not only bases but also soluble salts are removed. Therefore, both cation and anion determinations are necessary.

The filtrate was analysed for calcium, magnesium and sulphates by A.O.A.C. analytical methods (38). The calcium was determined by precipitation as calcium oxalate and ignited to calcium oxide; the magnesium was ignited and weighed as pyrophosphate; and the sulphates weighed as barium sulphate.

The soluble carbonates which were dissolved from the soils were determined in the filtrate by the method of Emerson (14). In this method the carbonate was determined by titrating with a dilute solution of hydrochloric acid using methyl orange as an indicator.

The soluble chlorides were determined by the method of Emerson (14) by titrating with silver nitrate solution using potassium chromate as an indicator.

The replaceable sodium and potassium were determined in the filtrate by the Ottawa method (53). In this method an aliquot was treated with sodium cobaltinitrate for potassium, and another with magnesium uranyl acetate solution for sodium. The respective precipitates were collected in gooch crucibles, dried and weighed.

A portion of the aliquot was evaporated to dryness and then treated with hydrofluoric acid in the determination of soluble silica. The loss in weight represents the amount of silica.

The replaceable hydrogen was determined by a method outlined by Brown (8) making use of the glass electrode to determine the hydrogen ion concentrations of both the original extracting reagent and the filtrate after leaching.

The quantity of cations and anions replaced by ammonia or brought into solution by the action of ammonium acetate salt was expressed as milli-equivalents. A milli-equivalent is defined as chemical equivalents expressed in milligrams (Kelly and Brown 1924) and is calculated by multiplying the milligrams of the ion determined per 100 grams of soil, by its valency and dividing the product by its atomic weight.

(b) Data:

Tables Nos. 12, 13, 14, 15, 16 & 17.  
Chart Nos. 5, 6, & 7.

(c) Discussion of Results:

The ammonium acetate method of determining exchange capacity and exchangeable bases in soil was used by Prianishnikov<sup>(51)</sup> and later investigated by Schollenberger (51). The writer showed that ammonium acetate in solution has an effect upon the surface tension of water. Therefore, its wetting and penetrating powers are superior to many salts. This aids in the removal of the exchangeable cations by leaching; and carries the exchange of bases to an equilibrium in a minimum of time and with a minimum volume of solution. It was also found that at sufficiently high concentrations aqueous ammonium acetate did

TABLE NO. 12

DARLINGFORD PHYTOMORPHIC ASSOCIATE

EXCHANGEABLE BASES. HYDROGEN AND SOLUBILITY PRODUCTS, EXPRESSED AS MILLI-EQUIVALENTS.  
Extracted by Neutral Normal Ammonium Acetate Solution.

Depth in Inches	Bases and Hydrogen							Solubility Products				
	Ca	Mg	Na	K	H	Total	NH <sub>4</sub>	SiO <sub>2</sub>	CO <sub>3</sub>	SO <sub>4</sub>	Cl	Total
						Bases & Hydrogen						
0- 6"	61.393	7.919	.258	1.40	4.3	75.270	50.57	14.32	1.0	.882	0.0	16.202
6-12"	48.565	7.451	.137	.53	4.8	61.483	44.93	11.44	2.0	.780	0.0	14.220
12-21"	37.834	7.780	.176	.38	3.2	49.370	37.41	9.36	24.0	1.105	0.0	34.465

TABLE NO. 13

EXCHANGEABLE AND SOLUBLE BASES AND HYDROGEN, AS PERCENT OF TOTAL  
BASES AND HYDROGEN EXTRACTED.

Depth	Ca	Mg	Na	K	H
0 -6"	81.56	10.52	.350	1.88	5.71
6-12"	78.99	12.12	.218	.862	7.81
12-21"	76.63	15.76	.356	.774	6.48

TABLE NO. 14

WASKADA PHYTOMORPHIC ASSOCIATE

EXCHANGEABLE BASES. HYDROGEN AND SOLUBILITY PRODUCTS, EXPRESSED AS MILLI-EQUIVALENTS.  
Extracted by Neutral Normal Ammonium Acetate Solution.

Depth in Inches	Bases and Hydrogen								Solubility Products				
	Ca	Mg	Na	K	H	Total		NH <sub>4</sub>	SiO <sub>2</sub>	CO <sub>3</sub>	SO <sub>4</sub>	Cl	Total
						Bases & Hydrogen	Absorbed						
0- 5"	37.035	7.903	.148	1.13	6.4	52.616	40.42		4.68	4.0	.514	0.0	9.194
5- 9"	17.220	7.253	.125	.50	4.8	29.898	30.08		7.15	11.0	.917	0.0	19.067
9-14"	19.566	7.056	.043	.23	1.6	28.495	24.44		8.90	16.0	.745	0.0	25.645

TABLE NO. 15

EXCHANGEABLE AND SOLUBLE BASES AND HYDROGEN, AS PERCENT OF TOTAL  
BASES AND HYDROGEN EXTRACTED.

Depth	Ca	Mg	Na	K	H
0- 5"	70.39	15.02	.280	2.15	12.16
5- 9"	57.60	24.26	.420	1.67	16.05
9-14"	68.66	24.76	.163	.817	5.61

TABLE NO. 16

NEWDALE PHYTOMORPHIC ASSOCIATE

EXCHANGEABLE BASES. HYDROGEN AND SOLUBILITY PRODUCTS, EXPRESSED AS MILLI-EQUIVALENTS.  
Extracted by Neutral Normal Ammonium Acetate Solution.

Depth in Inches	Bases and Hydrogen							Solubility Products				
	Ca	Mg	Na	K	H	Total	NH <sub>4</sub>	SiO <sub>2</sub>	CO <sub>3</sub>	SO <sub>4</sub>	Cl	Total
						Bases & Hydrogen	Absorbed					
0-8"	45.021	8.816	.114	1.26	6.4	61.611	44.74	20.96	11.0	.771	0.0	32.731
8-14"	27.552	9.268	.078	.54	3.2	40.638	32.52	12.88	16.0	1.114	0.0	29.994
14-18"	22.161	10.000	.092	.41	.5	33.163	29.70	8.53	14.0	1.225	0.0	23.755

TABLE NO. 17

EXCHANGEABLE AND SOLUBLE BASES AND HYDROGEN, AS PERCENT OF TOTAL  
 BASES AND HYDROGEN EXTRACTED.

Depth	Ca	Mg	Na	K	H
0- 8"	73.074	14.31	.186	2.04	10.39
8-14"	67.80	22.81	.190	1.33	7.87
14-18"	66.82	30.15	.280	1.24	1.51

# CATIONS EXTRACTED

Chart No. 5

Darlingford Phytomorphic Associate

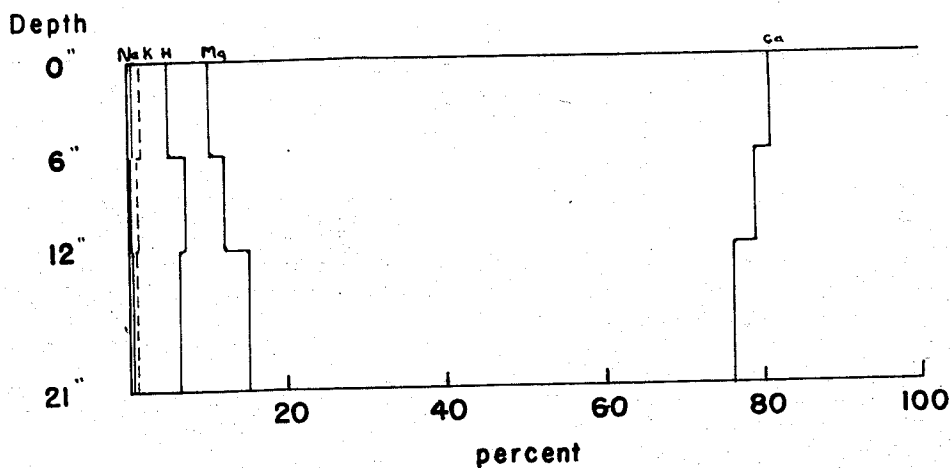


Chart No. 6

Waskada Phytomorphic Associate

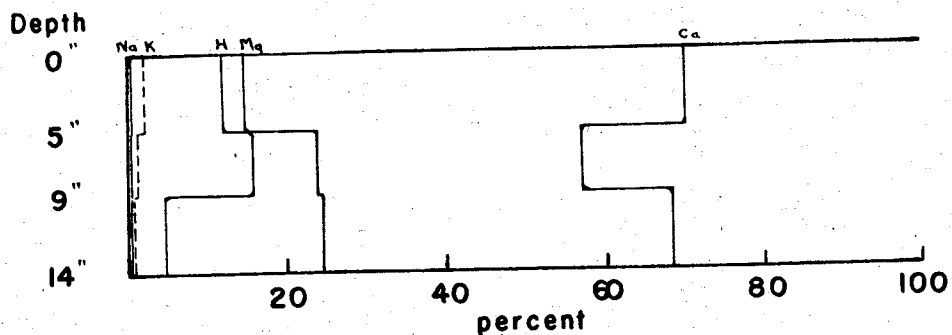
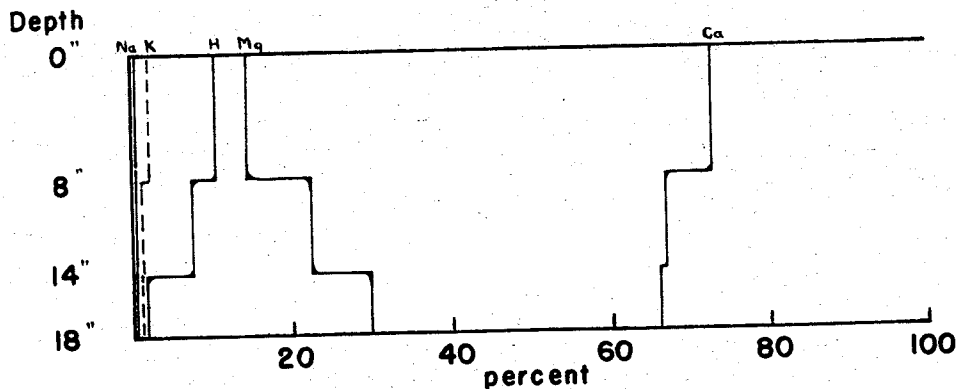


Chart No. 7

Newdale Phytomorphic Associate



not cause dispersion of the soil colloids. Furthermore leaching was not noticeably slower than with dilute acid or other salt solutions. These writers stressed that a neutral salt, which did not have the tendency to hydrolyze, should be used for the determination of exchangeable bases.

In the determination of exchangeable bases, soils, which are high in calcium carbonate content, offer an additional problem. Kelly and Chapman (25) state that the reaction which takes place between the absorbed bases in the exchange complex and the electrolytes in solution is characterized by an exchange of ions. Certain minerals that occur in soils yield bases to salt solutions as a result of decomposition and ordinary solution processes. Calcium carbonate is soluble in solutions of ammonium salts. Thus, when calcareous soils are being investigated, the calcium equivalent from the dissolved carbonate may equal, or even exceed, the replaceable calcium.

Gedroiz (16) attempted to overcome this difficulty by determining the carbonate content of the soil, before and after neutral salt extraction, and thereby affording a basis for calculating the extent to which calcium carbonate affected the results. Kelly and Brown (27) found that this method is accurate if the soil does not also contain magnesium carbonate. They also found that base exchange was incomplete when the carbonate content was over one percent. Thus, the universal application of the Gedroiz correction is doubtful as most carbonates are soluble or partially soluble in ordinary salt solutions.

In carbonate free soil the base absorption capacity, expressed as the sum of total replaceable bases plus replaceable

hydrogen, does not agree with the total capacity as expressed by ammonia absorption. Ammonia will not replace exchangeable hydrogen when the latter is low in quantity. De Sigmond and Di Sleria (10) and Parker (40) found that only a portion of the hydrogen was replaced in the colloidal complex. Kelly (26) noted that the difference between the total absorption capacity and the bases removed by the ammonium chloride method was equal to the exchangeable hydrogen.

Gedroiz (17) believed that in the chernozem or black-earth soils the absorption complex is completely saturated with divalent ions (calcium and magnesium), and that calcium predominates in all but exceptional cases. He also stated that chernozem soils contain no absorbed hydrogen. De Sigmond (11) showed that these soils can contain absorbed hydrogen, sodium, and potassium; and therefore, they are not completely saturated with divalent ions.

The results of the investigation carried out on the Manitoba blackearth soils confirm De Sigmond's findings. While calcium and magnesium predominated in the exchange complex, with a large potential reserve in the carbonate horizon, there were replaceable ions of sodium, potassium and hydrogen present. The figures given in Tables No. 13, 15 and 17 showed that in the Manitoba profiles calcium and magnesium were over eighty per-cent of the total exchangeable bases.

Turmin (58) found that there was no absorbed hydrogen in any horizon containing carbonates. He stated that the presence or absence of hydrogen depended upon the physiographic position of the soil within the chernozem region.



Neustreuv (37) and Gedroiz (17) believed that sodium was important in the exchange complex of certain soils. Rosov (48) found that the morphological characteristics of chernozem soils (e.g. granular structure) do not agree with the theory of sodium saturation.

The results of the base exchange determination on the blackearth soils, herein reported, showed a very low content of sodium; indicating that sodium does not play an important role in the exchange complex of these soils.

According to McGeorge (33) and Page and Williams (39) the cation absorption capacity decreases with depth; the decrease being chiefly due to the decrease in organic matter content. In the Manitoba soils studied, the absorption capacity and the organic matter content were highest at the surface of the profiles, and decreased with increasing depth. The base absorption capacity dropped more rapidly in the Waskada and Newdale profiles. The same condition was found on examination of the organic matter content (see page 38).

Of the three soil profiles studied, the Darlingford was found to have the largest base absorption capacity throughout the profile; and the Waskada, the smallest capacity. The cation exchange capacity of the Newdale soil was intermediate between the other two soils.

The percentage of absorbed hydrogen was highest in the B horizon of the Waskada profile. The absorbed monovalent ions (sodium and potassium) were found to be low in quantity and only incidental in all three soils. The sodium was below one milliequivalent in all cases. The potassium was also very low with the greatest concentration at the surface. This condition was

probably due to the cycle whereby potassium was transported to the aerial portion of plants, and then deposited on the surface when the plants died.

## II. PHYSICAL STUDIES:

The physical studies of the blackearth soils of Manitoba included mechanical analysis, aggregate or structural analysis, and the determination of the moisture equivalents.

### A. Mechanical Analysis:

#### (a) Method:

The method of mechanical analysis used in the present studies was developed in the University of Manitoba Soils Laboratory. It is a modification and combination of the Troell Dispersion method and the Olmstead Pipette method.

Five grams of oven dry soil was weighed into a 400 c.c. beaker, treated with 25 c.c. water and gently boiled until nearly dry. The damp soil was then treated with 50 c.c. NaBrO solution, mixed intermittently for two hours, and then treated with a further 50 c.c. aliquot. After having stood over-night, the mixture was gently boiled in a fume chamber with 6 gms. ammonium chloride until all the excess bromine had been driven off. Filtration was then carried out through Whatman No. 40 filter paper, washed with N/10 sodium chloride and water, and the soil transferred to a shaker bottle of one litre capacity. Ten c.c. of three percent sodium carbonate solution was added to the soil mixture, and made up to about 600 c.c. with water. After shaking for 30 minutes the sand in the soil was separated from the silt and clay by passing the soil mixture through a small 300 mesh sieve placed on a litre graduated cylinder. The

soil mixture was added, a little at a time, and washed with the aid of a soft rubber policeman. Washing was continued until the water passing through the sieve was clear.

The sands were dried after removal from the sieve, weighed, transferred to a weighed crucible and gently ignited to remove undecomposed plant fibre. The sand was then sieved into fractions and each fraction weighed.

The solution containing the silt and clay was then made up to one litre with water. The solution was stirred and a 10 c.c. aliquot was removed immediately by means of a 10 c.c. pipette with the tip 10 cm. below the solution surface. This aliquot contained both silt and clay. The solution was then allowed to settle \* and an aliquot removed when all the coarse silt had settled below 10 cm, and again when all the fine silt with a diameter greater than .002 had settled below 10 cm.

The aliquots were removed in weighed crucibles, dried at 110°C, weighed and then ignited and reweighed.

1st aliquot = silt and clay

2nd aliquot = fine silt and clay

3rd aliquot = clay <.002

\* Time of settling calculated from Stokes formula (54).

(b) Data:

Tables No. 18, 19, & 20.  
Charts No. 8, 9, & 10.

(c) Discussion of Results:

The procedure outlined was found to be the most satisfactory for conditions prevailing in Manitoba soils.

The results of this investigation are shown in tables Nos. 18, 19, and 20. These tables showed that the percentage

TABLE NO. 18.  
MECHANICAL ANALYSIS

Percentages Of Soil Fractions Based On Oven Dry Weight.

Weight of soil fractions and loss = 100%.

Sample	F.Gr.	C.S.	M.S.	F.S.	V.F.S.	C. Silt	F. Silt	Clay	Loss
Depth	2.0-1.0	1.0-0.5	0.5-.25	.25-.1	.1-.05	.05-.005	.005-.002	<.002	

DARLINGFORD Phytomorphic Associate:

0- 6"	1.40	1.85	3.63	7.48	3.92	33.2	12.0	29.6	6.92
6-12"	1.89	3.01	5.81	6.28	5.01	35.2	9.8	29.2	3.80
12-21"	1.32	2.33	4.10	8.12	4.25	24.2	9.0	45.8	.88
21-27"	1.08	2.01	3.04	6.50	3.70	22.6	9.2	34.8	17.07
27-33"	2.47	2.33	3.34	6.36	3.59	20.6	8.4	36.2	16.71
33-42"	.94	2.35	3.25	6.64	4.28	19.8	9.2	35.4	18.14

WASKADA Phytomorphic Associate:

0- 5"	.86	2.30	4.69	10.01	8.56	38.4	6.2	18.2	10.78
5- 9"	3.04	4.24	8.21	14.97	7.32	24.2	3.0	27.8	7.22
9-14"	4.00	6.51	11.05	17.06	5.43	24.4	3.2	27.4	.95
14-20"	3.86	7.86	13.76	22.42	7.16	16.4	3.0	13.2	12.34
20-28"	1.20	2.34	4.65	10.72	8.05	23.4	6.6	30.0	13.04
28"+	1.89	2.99	5.98	14.29	8.85	23.4	8.0	19.4	15.20

NEWDAL Phytomorphic Associate:

0- 8"	1.51	2.80	6.40	11.44	6.87	32.2	10.2	22.2	6.38
8-14"	1.15	4.12	7.71	13.93	8.35	24.6	5.8	34.0	.34
14-18"	1.23	4.08	7.69	15.57	8.76	23.2	4.8	33.4	1.27
18-25"	1.61	3.45	7.07	11.84	9.17	21.6	5.0	27.6	12.66
25-32"	2.18	3.84	6.57	11.52	9.13	19.4	7.2	23.6	16.56
32"+	2.25	4.01	6.74	12.89	8.16	22.4	4.8	22.2	16.55

TABLE NO. 19.

MECHANICAL ANALYSIS

Sand + Silt + Clay + Ignition Loss + Loss = 100%  
 Percentage on ignited basis.

Sample Depth	Total Sand	Silt And Clay	Loss on ignition of sand	Loss on ignition of Silt and Clay	Loss
<u>DARLINGFORD</u> Phytomorphic Associate:					
0- 6"	18.28	60.6	.59	14.2	6.33
6-12"	22.00	62.6	.55	11.6	3.25
12-21"	20.12	70.6	.19	8.4	.69
21-27"	16.31	60.8	.47	5.8	16.62
27-33"	18.09	60.0	.51	5.2	16.20
33-42"	17.46	58.2	.38	6.2	17.76

WASKADA Phytomorphic Associate:

0-5"	26.43	51.6	1.26	11.2	9.51
5-9"	37.77	53.4	.40	1.6	6.82
9-14"	44.05	50.2	.33	4.8	.62
14-20"	55.06	29.8	.62	2.8	11.72
20-28"	26.96	54.0	1.05	6.0	11.99
28"+	34.00	46.8	.58	4.0	14.62

NEWDAL Phytomorphic Associate:

0- 8"	29.02	51.6	.80	13.0	5.58
8-14"	35.26	57.8	.21	6.6	.13
14-18"	37.33	56.2	.21	5.2	1.06
18-25"	33.14	50.4	.69	3.8	11.97
25-32"	33.24	45.2	.32	5.0	16.24
32"+	34.05	45.6	.55	3.8	16.00

TABLE NO. 20.

MECHANICAL ANALYSIS.

Sand + Silt + Clay = 100%.

Percentage on oven dry basis (sand ignited).

Sample Depth	Total Sand	Total Silt	Clay	Texture
	2.0-.05	.05-.002	<.002	*

DARLINGFORD Phytomorphic Associate:

0- 6"	19.64	48.45	31.69	HCL
6-12"	22.87	46.78	30.35	HCL
12-21"	20.30	33.49	46.21	C
21-27"	19.67	38.35	41.98	HCL
27-33"	21.71	34.82	43.47	HCL
33-42"	21.33	35.43	43.24	HCL

WASKADA Phytomorphic Associate:

0- 5"	29.62	49.98	20.40	CL
5- 9"	40.71	29.32	29.97	CL
9-14"	44.47	27.86	27.67	CL
14-20"	62.81	22.13	15.06	FSL
20-28"	29.91	35.04	35.05	HCL
28"+	40.09	37.03	22.88	CL

NEWDALÉ Phytomorphic Associate:

0- 8"	31.00	45.29	23.71	CL
8-14"	35.38	30.50	34.12	HCL
14-18"	37.81	28.36	33.83	HCL
18-25"	37.94	30.45	31.61	HCL
25-32"	39.84	31.88	28.28	CL
32"+	40.80	32.59	26.61	CL

\* (Based on modified chart from Davis and Bennet, U.S.D.A. Circ. #39.)

## MECHANICAL ANALYSIS

percentage by weight on ignited basis

Chart No. 8 Darlingford Phytomorphic Associate

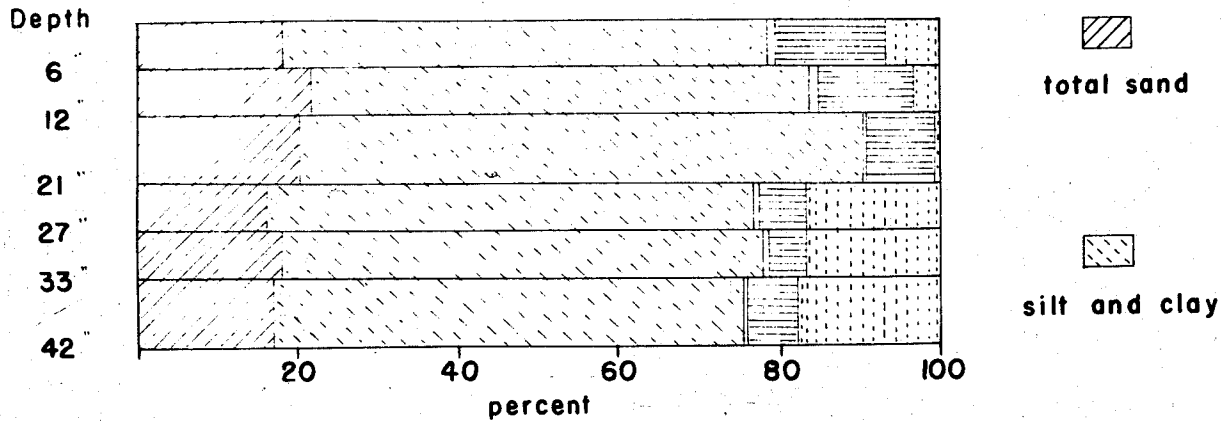


Chart No. 9 Waskada Phytomorphic Associate

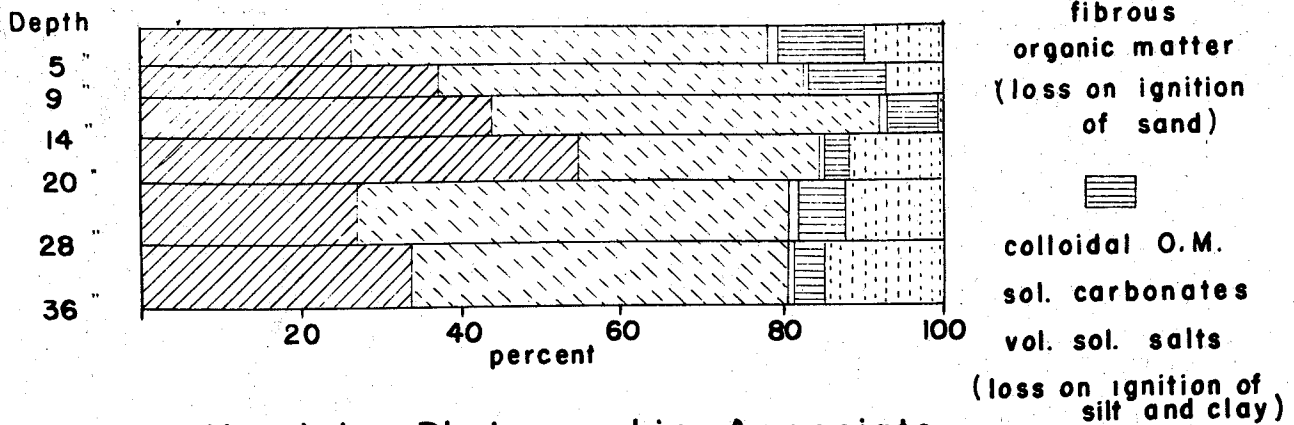
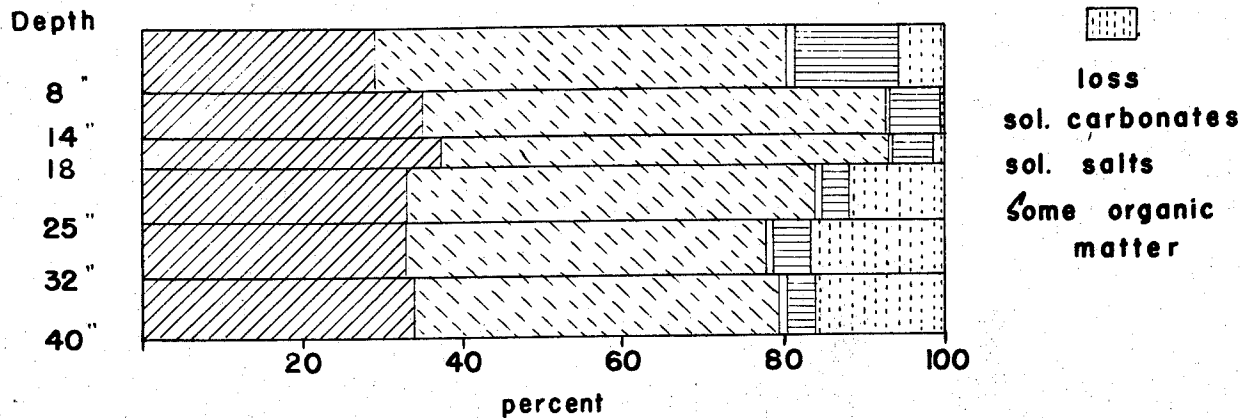


Chart No. 10 Newdale Phytomorphic Associate



of sand in the Darlingford profile was comparatively low in comparison with those of the Waskada and Newdale profiles. For the clay and silt content, the situation was reversed, with the Darlingford having the highest percentage.

The Waskada profile showed a wide variation in mechanical composition. Table No. 19 indicated a sand content of 26.43 percent in the surface horizon, and a maximum content of 50.06 percent in the horizon from fourteen to twenty inches. This variation was probably due to the deposition of the parent material as there were no indications of severe erosion or illuviation.

The mechanical analysis also showed that there had been very little, if any, downward movement of the colloidal organic matter. The loss on ignition of silt and clay was used as a measure of the colloidal organic matter. However, this may not give a true picture of the colloidal organic matter as the loss on ignition also included soluble carbonates and volatile soluble salts.

In Tables Nos. 18 and 19, the column "loss" included soluble carbonates, soluble salts and some organic matter. This loss was at a minimum in the B horizon of all profiles. The loss was slightly higher in the A horizon due to some loss of organic matter.

The textures of the various horizons were determined by inserting the percentage compositions into the triangle chart (13). The results (Table No. 20) showed that the textural class of the Darlingford profile was dominantly heavy clay loam. With the exception of a horizon of fine sandy loam, the textural class of the Waskada soil was clay loam. The texture of the



Newdale soil profile varied from clay loam to heavy clay loam.

B. MOISTURE EQUIVALENTS:

The moisture equivalent is one of the most frequently used determination for characterizing the moisture relations of soil. It has been used as an indirect measure of the wilting point by Briggs and Shantz (7). Fisher (15) states that the moisture equivalent measures the water held in the small pores as well as that imbibed by the soil colloids.

(a) Method (5):

Air dry soil was ground and passed through a 2 m.m. sieve. Duplicated samples were soaked in water for an hour, excess water removed, the samples covered with a damp cloth and allowed to temper overnight. The samples were centrifuged at 2440 R.P.M. for 40 minutes, transferred to a tared can, weighed, and dried for eight hours at 108°C. Loss of water was calculated as percentage of dry soil.

(b) Data:

Table No. 21.

(c) Discussion of Results:

The results of the moisture equivalent determination showed the highest values for the Darlingford soil; and the lowest values for the Waskada profile. The 14 to 20 inch horizon of the Waskada soil had a very low value; due to the high percentage of sand in relation to silt and clay content. The moisture equivalent values for the Newdale soil were intermediate between the other two soils.

TABLE NO. 21

MOISTURE EQUIVALENTS OF DARLINGFORD, WASKADA,  
AND NEWDALE PHYTOMORPHIC ASSOCIATES.

Based on oven dry weight.

DARLINGFORD PHYTOMORPHIC ASSOCIATE:

<u>Depth</u>	<u>M.Eq.</u>
0 - 6"	36.6
6 -12"	32.8
12-21"	28.9
21-27"	27.7
27-33"	27.2
33-42"	27.2

WASKADA PHYTOMORPHIC ASSOCIATE:

<u>Depth</u>	<u>M.Eq.</u>
0 - 5"	30.1
5 - 9"	21.4
9 -14"	19.1
14-20"	12.4
20-28"	27.1
28"+	21.7

NEWDALE PHYTOMORPHIC ASSOCIATE:

<u>Depth</u>	<u>M.Eq.</u>
0 - 8"	35.6
8 -14"	34.5
14-18"	23.2
18-25"	22.6
25-32"	22.0
32"+	22.1

C. AGGREGATE OR STRUCTURAL ANALYSIS:

The chernozems or blackearth soils are noted for their high state of aggregation. Jenny (23) states that this condition is due to the large amount of organic matter in the soil profile and to the climate under which these soils are developed. The low rate of precipitation limits the amount of weathering brought about by leaching.

Water stable aggregate analysis was carried out on the blackearth soils under investigation.

(a) Method: (49)

The soil material was broken down to lumps less than 5 m.m. in size and kept in a humid atmosphere overnight. It was then slaked in water for twenty-four hours and transferred to the sieves. Three m.m., 2 m.m., 1 m.m.,  $\frac{1}{2}$  m.m. and 60 mesh sieves were used in a four litre beaker with the upper sieve immersed to a depth of half an inch in water. Separation was obtained by 200 quick vertical motions (a few cms.). The separates were then transferred to weighed beakers, dried at 105°C, weighed and expressed as percent of total oven dry weight. After the sieves had been removed from the 4-litre beaker, the suspension was allowed to settle for five minutes. The water was then drawn off using a suction pump and the sediment dried and weighed. The soil material removed with the water was calculated as "loss".

(b) Data:

Table No. 22.

(c) Discussion of Results:

Baver (4) stated that the percentage of aggregates in

TABLE NO. 22

AGGREGATE ANALYSIS

(water stable aggregates)

Percent by weight.

Size of  
Aggregates   2 m.m.   1 m.m.    $\frac{1}{2}$  m.m.   > 60 mesh   < 60 mesh   loss

DARLINGFORD Phytomorphic Associate:

A						
Horizon	2.39	9.59	13.04	35.54	28.30	11.14
B						
Horizon	5.41	17.87	21.43	26.20	19.97	9.12

-----  
WASKADA Phytomorphic Associate:

A	4.18	8.49	7.35	28.44	37.23	14.31
B	10.66	15.16	14.44	20.84	28.02	10.88

-----  
NEWDALE Phytomorphic Associate:

A	4.16	9.38	8.59	30.56	35.14	12.17
B	8.36	15.44	16.54	24.54	25.80	9.32

-----

a given weight of soil was a maximum in semi-arid regions where the chernozem-like soils were located.

Puri and Rai (43) found that the water stable aggregates in the soil represented more or less permanent structures, which were dependent on the ultimate mechanical composition of the soil, and thus represented fundamental characteristics which were not likely to change from day to day.

Martin and Waksman (32) observed that the growth of micro-organisms led to a binding together of soil particles. Tiulin (56), working on the genesis of soil structure, found that the penetration of roots and the burrowing of animals caused pressure forcing the particles together. Russel (50) suggested the formation of some by-product during the decay of the root system which cemented the particles together.

Yoder (62) investigated the effect of wetting and drying. He attributed the "fracturation" and fragmentation to the pressure exerted by trapped air and to the unequal swelling caused by rapid intake of water.

Water stable aggregates were determined on the A and B horizons of each of the Manitoba blackearth profiles under investigation. The results showed a high state of aggregation in all the soil profiles, with the B horizon better aggregated than the A horizon in each profile. The Darlingford had the highest percentage of aggregation in relation to the amount of sample used.

Although there were minor variations, there was no cause for profile differentiation on the basis of water stable aggregation.

8. GENERAL SUMMARY:

Chemical and physical studies of the blackearth soils were undertaken to ascertain what chemical and physical determinations can be made in the laboratory which will correlate with the morphological features observed in the field; and to ascertain if the data from such determinations can be used as criteria in the differentiation and classification of the blackearth soils in Manitoba.

The blackearth soils used in this investigation were representative of the phytomorphic (or well-drained) associates of the Darlingford, Waskada and Newdale soil associations. These soil associations were selected because they have been developed on similar parent material. Hence it was assumed that variations in the results obtained from the analysis of the respective soil profiles would reflect the soil-forming processes. The typical Darlingford soil profile was obtained from the area designated as the "blackearth soil zone;" the typical Waskada soil profile was obtained from the area designated as the "dark brown-blackearth transition soil zone;" and the typical Newdale soil profile was obtained from the area designated as the "northern blackearth soil zone." An additional soil profile (which showed grey-wooded characteristics) was obtained from the wooded area of the Riding Mountains, and was used in the studies herein reported, for comparison and contrast.

Morphological descriptions of these soils were made at the time of sampling. Variations were found in color, texture, structure, consistence, intrusions and concretions, and reaction. Special note was made of the soil color, because it varied by

horizons and between the three profiles.

Climatic data from the stations located nearest to the respective sites from which the soil profiles were secured, were used to indicate the climatic conditions under which the various soils had been developed. The precipitation-effectivity index values indicate that the climatic conditions under which the Waskada soil was developed, were slightly more arid than those of the other two soils. The total amount of precipitation for the area from which the Newdale soil profile was obtained, was similar to that for the Waskada soil area; however, the more limited temperature data for the Newdale area implies somewhat cooler conditions than those which prevail in the Darlingford and Waskada areas.

The respective soil profiles studied were sampled by horizon depth and subjected to a number of chemical and physical determinations. The chemical studies involved total analysis by the fusion method; the determination of reaction, organic matter, and nitrogen content; and the determination of exchangeable bases and solubility products. The results of the fusion analysis indicated that the soils under investigation were very calcareous and alkaline in reaction, and appear to be developed on geological parent materials similar in chemical composition, which originally contained large amounts of calcium carbonate as pulverized limestone.

Under the soil forming processes to which the parent materials have been subjected, decalcification, with different degrees of intensity, has taken place in all of the soil profiles studied. However, the removal of calcium carbonate from the surface horizons was not as close to completion in the

Waskada soil as in the Darlingford or Newdale profiles; the lime carbonate patterns were similar for the latter soils, with the exception that the horizon of accumulation in the Darlingford profile was at a lower depth.

Slight variation was noted in the reaction of the surface horizons of the respective soil profiles. The horizons in the solum of the Darlingford profile were neutral to slightly alkaline in reaction; those of the Newdale and Waskada profiles were neutral to slightly acid in reaction.

The results of the determination of organic matter showed variation in the amount and distribution of organic matter within the soil profile. Of the blackearth soils investigated, the Darlingford soil had the highest organic content; the Waskada soil had the lowest content; while that of the Newdale soil was intermediate between the other two soils. The decrease in organic content with increasing depth was most gradual in the Darlingford profile, and it is obvious that a relationship exists between the quantity of organic matter and the soil color;- the higher the organic content, the darker the color of the soil.

The results of the determination of exchangeable bases indicated that calcium and magnesium dominated the base exchange complex in the solum of each profile. In all cases the amount of exchangeable calcium was greater than the amount of exchangeable magnesium, and the calcium-magnesium ratios in all soils narrowed with depth.

A direct relationship was noted between the total base absorption capacity and the organic matter content. The base absorption capacity was highest for the surface horizons of the profiles, and decreased with increasing depth.



The physical studies undertaken included mechanical analysis, aggregate or structural analysis, and the determination of the moisture equivalents. The results of the analysis showed slight variation in the mechanical composition of the parent materials. The textural class of the Darlingford soil was dominantly heavy clay loam. With the exception of a fine sandy loam horizon at 14 to 20 inches, the textural class of the Waskada soil was clay loam. The texture of the Newdale soil ranged from clay loam to heavy clay loam.

The moisture equivalents of the soil profiles indicated that the Darlingford soil had the highest water retention capacity. The retention capacity of the Waskada profile was the lowest of the soils investigated; while that of the Newdale soil profile was intermediate between the other soil profiles.

The results of the aggregate analysis showed a very high state of aggregation for all the soil profiles studied. However, the variation in the percentage of water-stable aggregates for the soils was only slight; and therefore, was not significant.

9. CONCLUSIONS:

The following conclusions have been drawn from laboratory studies and field observations of representative black-earth soil profiles selected from the three sub-zones; deep black (Darlingford), brown-black (Waskada) and northern black (Newdale).

(i) The depth of the solum varied from the respective soil profiles. The depth to the lime carbonate horizon of the blackearth soil profile was twenty-one inches; to the lime carbonate horizon of the northern blackearth soil profile, eighteen inches; and to the lime carbonate horizon of the dark brown-blackearth soil profile, fourteen inches.

(ii) A direct relationship was found between the soil color and the organic content of the respective soils. The soil horizons that were brown in color contained lower amounts of organic matter than those that were black in color.

(iii) The decrease of organic content with increasing depth was more gradual in the Darlingford profile than in the Waskada and Newdale soil profiles.

(iv) The amount of organic matter varied in the three typical blackearth profiles. The total amount of organic matter per acre in the solum of the Darlingford soil was 638,370 pounds; in the solum of the Newdale soil, 449,820 pounds; and in the solum of the Waskada soil, 303,360 pounds.

(v) The results showed that calcium carbonate has been leaching from the upper portion of all the soil profiles, and has been accumulating at different depths. There was more

residual carbonate present in the upper horizons of the Waskada soil than in the other soils studied which indicates that leaching has not been as intense. The pattern of lime carbonate accumulation was similar for the Newdale and Darlingford soil profiles, with the exception that the horizon of maximum accumulation in the Darlingford profile was at a lower depth.

(vi) The divalent ions (calcium and magnesium) dominated the base exchange complex. Calcium was the dominant cation in all the blackearth soil profiles. The calcium-magnesium ratio decreased with depth, and differed between profiles.

Further investigation should be undertaken to ascertain if this variation in the calcium-magnesium ratios is a sub-zonal characteristic, or if it has been effected by a variation in the parent material.

(vii) The mechanical analysis showed variations in the clay content of the soil profiles. These differences are due, in part, to the variation in texture of the boulder till which forms the parent material of the soils. However, a somewhat higher content of clay below the uppermost horizon of each profile suggests that there may have been a very slight illuviation of clay in each case, or the surface may have been affected by wind before it was tied down by vegetation.

(viii) The results of the analysis, and the fresh appearance of the minerals in the sand fractions, indicated that these minerals have not been strongly weathered under the soil-forming processes that have prevailed. Hence, the slight variations in the sesquioxide content, together with the wide

variations in the silica content, are more likely to be due to the composition of the parent material, than to illuviation in the weathering processes.

(ix) The sub-zones of the blackearth soil zones can be differentiated by variations in the depth of the solum, the soil color of the A and B horizons, the structure of the B horizon, and the quantity and pattern of organic content.

The depth of the solum, the dark soil color, and the high organic content in the Darlingford soil profile indicate that it was developed under favourable climatic conditions. The characteristics of the A horizon of the Newdale soil profile indicate a climatic condition comparable to that of the Darlingford soil area. However, the brown coloration and the structure of the B horizon of the Newdale profile, in contrast to the Darlingford profile, are characteristic of a more arid condition. This variation is due to a lower organic content. The climate of the Waskada soil area is more arid than that of the Darlingford and Newdale soil areas. This condition is indicated by the shallow solum, the brown coloration (due to a lower organic content), and the structural development of the B horizon in the Waskada soil profile.

BIBLIOGRAPHY:

1. Adams, J. E.  
"Determination of Total Carbon in Soils by the Wet Combustion Method"  
Journ. Ind. and Eng. Chem., Anal. Ed. Vol. 6: p.227. 1934.
2. Barshad, I.  
"A Pedologic Study of California Prairie Soils"  
Soil Sc. 61: 423-443. 1946.
3. Bayer, L. D.  
"Aggregation of Soils and Calcium Ion Saturation"  
The American Soil Survey Association Bull. XVII, Report of the 16th Annual Meeting.
4. Bayer, L. D.  
"Soil Physics"  
John Wiley & Sons Inc., New York. 1948.
5. Briggs, L. J., and McLane, J. W.  
"Moisture Equivalent Determination and Its Application"  
Am. Soc. of Agron., Vol. 2: p. 139.
6. Briggs, L. J., and McLane, J. W.  
"The Moisture Equivalent of Soils"  
U.S.D.A. Bur. Soils Bull. 45, 1907.
7. Brigg, L. J., and Shantz, H. J.  
"The Wilting Coefficient for Different Plants and Its Indirect Determination"  
U.S.D.A. Bur. Plant Ind. Bull. 230, 1912.
8. Brown, I. C.  
"A Rapid Method of Determining Exchangeable Hydrogen and Total Exchangeable Bases of Soils"  
Soil Sc. 56, p. 353-359. 1943.
9. Clark, N. A., and Ogg, C. L.  
"A Wet Combustion Method for Determining Total Carbon in Soils"  
Soil Sc. 1:53, p. 27. 1942.

10. DeSigmond, A.A.J., and Di Gleria, T.  
"The Different Degrees of Saturation of the Absorbing Complex, Humus-Zeolites, of the Soil, and Method of Their Determination"  
Proceedings of the First Int. Congress of Soil Science, Vol. II, p. 155. 1928.
11. DeSigmond, A.A.J.  
"The Principles of Soil Science"  
Thomas Murby & Co. London. 1938.
12. Ellis, J. H.  
"A Field Classification of Soils for Use in Soil Survey"  
Sci. Agri. Vol. 12, p. 338. 1938.
13. Ellis, J. H.  
"Soils of Manitoba"  
Economic Survey Board, Province of Manitoba. 1938.
14. Emmerson, P.  
"Soil Characteristics"  
McGraw-Hill Book Co. Inc., New York. 1925.
15. Fisher, E. A.  
"Remarks and Observations on Imbibitional Soil Moisture"  
J. Agri. Sci. 14: 204-220. 1924.
16. Gedroiz, K. K.  
"Contribution to the Method of Determining the Zeolitic Bases in the Soil"  
Comm. I Chem. Laboratory of Forestry Department, Petrograd. 1918.
17. Gedroiz, K. K.  
"The Soil Absorbing Complex and the Absorbed Soil Cations as a Base of Genetic Soil Classification"  
Nossov Agri. Exp. Station, Paper 28, Leningrad. 1925
18. Glinka, K. D.  
"Dokuchaiev's Ideas in the Development of Pedology and Cognate Sciences"  
Russian Pedological Investigation, Leningrad. 1927.
19. Glinka, K. D.  
"The Great Soil Groups of the World and Their Development"  
Translation by Marbut. 1927.  
Edwards Brothers Ann Harbor, Mich. 1927.

20. Hilgard, E. W.  
"Soils"  
The MacMillan Company, New York. 1912.
21. Hillebrand, W. F., and Lundell, C. E. F.  
"Applied Inorganic Analysis"  
John Wiley & Sons Inc., New York. 1929.
22. Hopkins, C. G.  
"Soil Fertility and Permanent Agriculture"  
Ginn and Co., New York, p. 59. 1910.
23. Jenny, H.  
"A Study on the Influence of Climate Upon the Nitrogen  
and Organic Matter Content of Soil"  
Missouri Agri. Exp. Station, Research Bull. 152.  
1930.
24. Joffe, J. S.  
"Pedology"  
Rutger's University Press. 1936.
25. Kelly, H. D., and Chapman, W. P.  
"The Determination of the Replaceable Bases and the Base-  
Exchange Capacity of Soils"  
Soil Sc. 30: 391-407. 1930.
26. Kelly, W. P.  
"A General Discussion of Base Exchange in Soil"  
Journ. Amer. Soc. of Agronomy, Vol. 18, p. 450. 1926.
27. Kelly, W. P., and Brown, S. M.  
"Replaceable Bases in Soils"  
University of California publications, Tech. paper  
No. 15. 1924.
28. Kilmer, V. S., and Alexander, L. T.  
"Methods of Making Mechanical Analyses of Soil"  
Soil Sc. 68: 15-25. 1949.
29. Kjeldahl-Gunning, Arnold Method  
"Methods of Analysis"  
A. O. A. C. 3rd Ed. 1930.
30. Leighty, W. R., and Shorey, E. C.  
"Some Carbon-nitrogen Relations in Soils"  
Soil Sc. 30: 257-266. 1930.

31. Lutz, H. J., and Chandler, R. F.  
"Forest Soils"  
John Wiley and Sons Inc., New York. 1946.
32. Martin, J. P., and Waksman, S. A.  
"Influence of Micro-organisms in Soil Aggregation and Erosion"  
Soil Sc. 50: 29-47. 1940.
33. McGeorge, W. T.  
"The Base Exchange Property of Organic Soils"  
Arizona Agri. Exp. Station, Tech. Bull. No. 31.  
1930.
34. Methods of Chemical and Physical Examination of Soils.  
Department of Soils, University of Manitoba.  
(unpublished)
35. Millar, C. E., and Turk, L. M.  
"Fundamentals of Soil Science"  
J. Wiley & Sons Inc., New York. 1943.
36. Moore, R. E.  
"Water Conduction from Shallow Water Tables"  
Hilgardia 12: 383-426. 1939.
37. Neustruev, S. S.  
"Genesis of Soils"  
Russian Pedological Investigations. 1927.
38. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists.  
A.O.A.C. Washington, 1925.
39. Page, H. J., and Williams, W.  
"Proceedings of the International Society of Soil Science"  
Rome, Vol. I: p. 172. 1925.
40. Parker, F. W.  
"Methods for the Determination of the Amount and Acidity of Exchangeable Hydrogen in Soils"  
Proceedings of the First International Congress of Soil Sc. Vol. II, p. 164. 1928.
41. Peele, T. C., and Beale, O. W.  
"Influence of Microbial Activity upon Aggregation and Erodibility of Lateritic Soils"  
Soil Sc. Soc. Am. Proc: 5: 33-35. 1940.



42. Piper, C. S.  
"Soil and Plant Analysis"  
The University of Adelaide. 1940.
43. Puri, A. N., and Rai, B.  
"Physical Characteristics of Soils"  
Soil Sc. 5: 57. 1944.
44. Robinson, G. W.  
"Note on the Mechanical Analysis of Humus Soils"  
J. Agri. Sci. 12: 287-291. 1922.
45. Robinson, G. W.  
"Soils: Their Origin, Constitution and Classification"  
London. 1932.
46. Robinson, W. O.  
"Method and Procedure of Soil Analysis Used in the  
Division of Soil Chemistry and Physics"  
U.S.D.A. Circ. 139. 1930.
47. Robinson, W. O.  
"The Fusion Analysis of Soils"  
Soil Sc. 1: 59, p. 7-13.
48. Rosov, L. P.  
"Solonetzous Processes at Amelioration"  
Transactions of Sixth Commission of International  
Society of Soil Science, Russia, Vol. A, p. 30, 1929.
49. Rowles, W.  
"Physical Properties Related to Structure of St. Rosalie  
Clay and Their Seasonal Variation"  
MacDonald College. Sci. Agric. 28: 558-573.
50. Russel, E. W.  
"Soil Structure"  
Imp. Bur. Soil Sci. Tech. Commun. 37. 1938.
51. Schollenberger, C. J.  
"Exchangeable Hydrogen and Soil Reaction"  
Science 65 (1692 n.s.) 552-553. 1927.
52. Shorey, E. C.  
"Some Methods for Detecting Differences in Soil Organic  
Matter"  
U.S.D.A. Tech. Bull. 211, p. 25. 1930.

53. Soil Analysis for Soil Survey Samples - Ottawa (unpublished)
54. Stokes, G. C.

"On the Effect of the Internal Friction of Fluids on the Motion of Pendulums"  
Trans. Cambridge Phil. Soc. 9: 8-106. 1851.
55. Thornthwaite, C. W.

"The Climates of North America According to a New Classification"  
Geological Review, p. 633-656. The American Geological Society of New York. 1931.
56. Tiulin, A. F.

"Questions on Soil Structure"  
Aggregate Analysis as a Method for Determining Soil Structure. Report 2, p. 77-122. Perm. Agr. Exp. Sta. Div. Agri. Chem. 1928.
57. Truog, E., and Associates

"Procedure for Special Type of Mechanical and Mineralogical Soil Analysis"  
Soil Sc. Soc. Am. Proc. 1: 101-112. 1936.
58. Tumin, G. M.

"Chernozem Soils of the European Part of the U.S.S.R."  
Proceedings of the Second International Congress of Soil Science, Vol. 5, p. 261.
59. Unpublished Data - Manitoba Soil Survey.
60. Van Slyke, L. L.

"Fertilizers and Crop Production"  
Orange Judd Pub. Co. New York. 1932.
61. Waynick, D. D.

"A Simplified Wet Combustion Method for the Determination of Carbon in Soils"  
Journ. Ind. and Eng. Chem., Vol. II, No. 7, p. 634. 1919.
62. Yoder, R. E.

"A Direct Method of Aggregate Analysis and a Study of the Physical Nature of Erosion Losses"  
J. Am. Soc. Agron. 28: 337-351. 1936.