REPORT

of

COMMITTEE ON THESIS

THE undersigned, acting as a committee of the Graduate School, have read the accompanying thesis submitted by Paul Raymond McMiller for the degree of Master of Science They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

F. J. Alway
Chairman

C. P. Fostrup

Frank F. Grout

June 1st 1915.

A Thesis submitted to the Faculty of

The University of Minnesota for the degree

of

Master of Science

by

P. R. McMiller

1915

A STUDY OF THE GLACIAL AND LOESSIAL SOILS OF THE MOST SOUTHERLY TIER OF COUNTIES IN MINNESOTA.

by

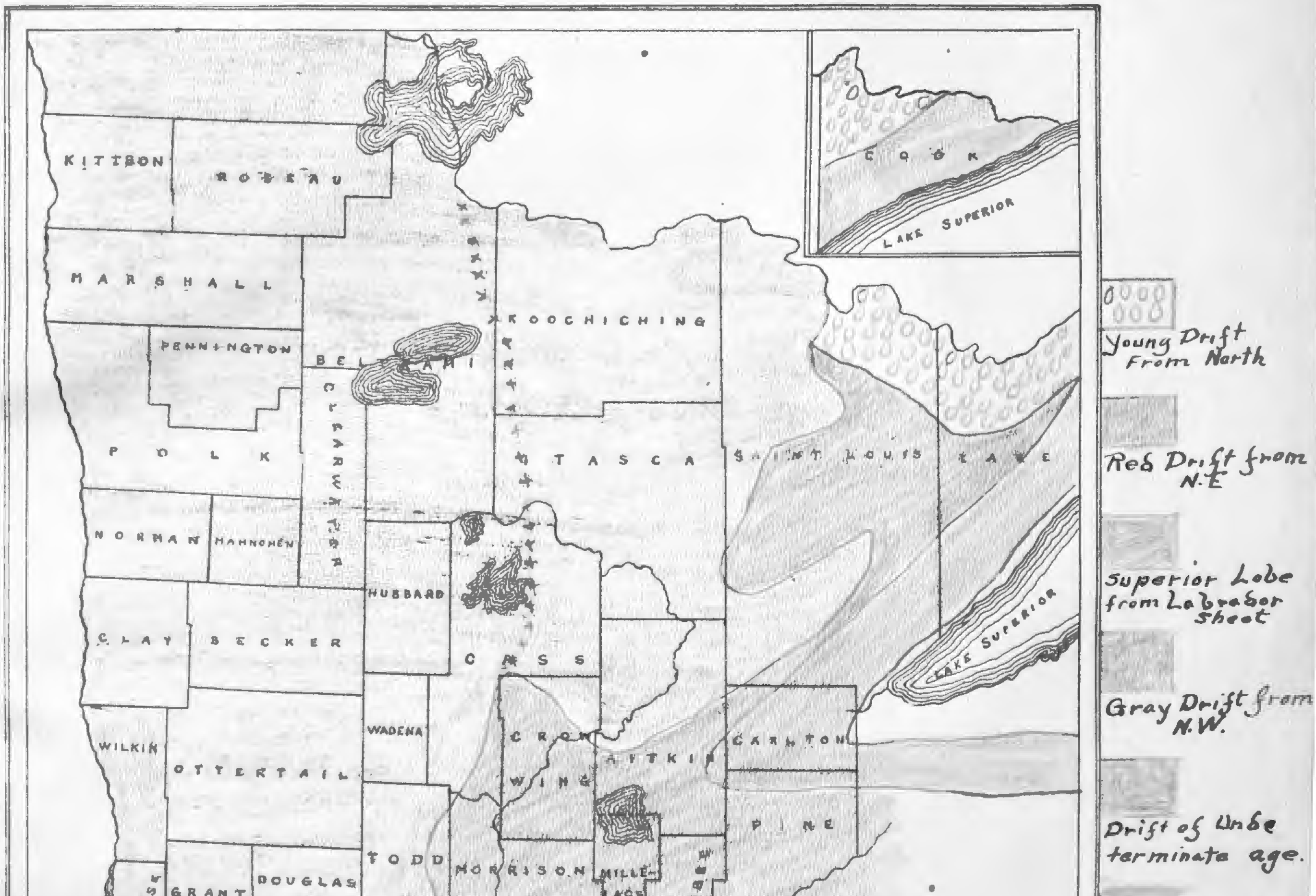
P. R. McMILLER.

CONTENTS.

INTRODUCTION

According to Leverett of the United States Geological Survey there are exposed in the most southerly tier of counties in Minnesota drift sheets from two distinct glacial invasions and also a drift sheet which appears to belong to an intermediate glaciation. In addition to these drift exposures there are deposits of loess over the driftless area in southeastern Houston county, over the Kansan glaciation in Houston and Fillmore counties and also over the Kansan glaciation in Nobles and Rock counties.

The earliest glaciation which affected this section of Minnesota is the Pre-Kansan of which no surface exposure has yet been definitely identified. Next followed the Kansan glaciation, now covered by loess in western Houston, the greater part of Fillmore, the western edge of Nobles and the greater portion of Rock. However, the Kansan remains exposed in the western part of Fillmore and in most of Mower. The most recent glacier that has passed over these southern counties is termed the Late Wisconsin, or, in so far as Minnesota is concerned, the Late Gray Drift. The drift from this covers the western part of Mower, all of Freeborn, Faribault, Martin, Jackson and the greater part of Nobles. Crossing part of Nobles in a southeasterly and northwesterly direction is a glaciation of undetermined age, geologists being inclined to consider it earlier than the Late Wisconsin. The boundaries of the drift areas are shown on the accompanying map.



Map after F. LEVERETT
Bulletin 12 - U of Minn.

Map of Minnesota showing location of the different fields (indicated thus,) sampled, as well as the geological formations on which they lie. Dotted lines show the extent of the moraines.

These different glaciers in their passage over the country deposited vast amounts of debris, ranging in thickness from a few to several hundred feet. This till, or boulder clay, as it is called, consists of a mixture of boulders, rocks, pebbles, sand and rock flour in varying proportions with no evidences of any sorting. It is the material carried along beneath the ice sheet and left there as a ground moraine when the glacier retreated. Throughout this glaciated area terminal moraines occur. These moraines are wide strips of more or less assorted glacial till which gathered where the retreat of the ice sheet was delayed or where re-advances occurred and were left there as low hills or ridges, ranging in width from several hundred feet to several miles. These moraines are especially noticeable in Mower, Freeborn, Faribault, Martin, Jackson and Nobles.

The topography of the country embraced in this study varies considerably. In southeastern Minnesota it varies from undulating to rough and hilly in many places, the topography being characterized by deep, wide valleys and long ridges. Exposures of limestone are abundant and nearly every small stream is banked by limestone ledges.

The topography of the counties which comprise the Late Wisconsin glaciation might be termed undulating though there are large flat areas many square miles in extent. Owing to the fact that the glaciation is a late one, good drainage has not been established. The surface is pitted with depressions, large and small, which have no outlet and in these water stands the year around. Small lakes are numerous and peat bogs are not uncommon.

The topography of the country which is covered by the drift of undetermined age may also be termed undulating, but resulting from an earlier glaciation natural drainage is well established and there is an absence of lakes and depressions.

The topography of the loess covered area in southwestern Minnesota in general has a surface that is broadly undulating. In many portions the prairie extends like a broad, level plain broken now and then by gently undulating slopes through which small streams flow.

It would be well at this point to briefly consider the general character of the soils in these southern counties. As stated before both the southeastern and southwestern parts of the state are covered with a deposit of loess, a peculiar deposit, the origin or formation of which is not definitely known. Large areas of this loess soil are found in China and there its formation is regarded to be largely aeolian, due to the action of the wind in transporting the material for long distances and depositing it among the grass where it was held by the plants, accumulating in some cases to a depth of over several hundred feet. Whether the loess in Minnesota is of similar origin is an open question, very probably not, as the aeolian theory fails to satisfactorily explain all the existing conditions and there seems to be little doubt but that it represents in large part the fine silt, the glacial flour, brought down by the ice of the glacial period, borne southward by streams, and deposited in water just sufficiently in motion to carry the fine clay further away.

The soil of the Kansan glaciations is lighter in color and coarser in texture. In general the drift is of stony clay or till. Stones of all sizes and kinds are dessiminated through it.

The soils on the Late Wisconsin drift consist principally of clay loams. These contain a considerable proportion of sand and gravel and occasionally of stones and boulders. In the flat areas the soil is principally clayey, heavily charged with organic matter to a depth of two or three feet. There is an abundance of peat which is found in the most of the marshes.

The soils on the drift of undetermined age consist of till, not unlike that of the Late Wisconsin. Many of the pebbles, stones, and boulders contained in it, however, are in an almost complete state of disintegration showing that the age of the drift is much older than that of the Late Wisconsin. Lakes, peat bogs, and depressions are rare, and nearly all of the land is tillable.

The object of this study of the glacial and loessial soils of the most southerly tier of counties in Minnesota was to determine what marked differences, if any, exist in the chemical composition and the physical characteristics of the soils which have developed on the different geological formations mentioned above. A lithological examination has been made of the pebbles found in the samples collected from the first, second and third feet of soil. Determinations have been made of the total nitrogen, carbon dioxide, total potash and total phosphoric acid. The texture as represented by the hygroscopic coefficient or moisture equivalent has been determined in the case of all the samples collected except some from the surface six inches.

In this investigation considerable time and work was necessary in the collection of the soil samples and acknowledgment is due Mr. G. R. McDole and Mr. J. E. Chapman who assisted in the work. Credit is also due Mr. C. O. Rost who assisted in making part of the acidity determinations, Mr. P. M. Harmer for assistance rendered in the determination of carbon dioxide, and to Mr. J. C. Russel who made the greater portion of the moisture equivalent determinations.

The writer is especially indebted to Dr. F. J. Alway under whose direction the investigation has been carried out.

TABLE I.

VEGETATION AND LEGAL DESCRIPTION OF FIELDS WHERE SAMPLES WERE OBTAINED.

VIRGIN FIELDS.

Area	Field	Vegetation	Owner		Section	Twp.	Range.
Caledonia	I	Forest	Jacob Schauble	E½ of SW¼	16	103	5
"	II	"	Mrs. E. Wilhelm	SW¼ of SW¼	20	103	5
"	III	"	P. Mullany	SE of SE¼	32	103	5
"	IV	"	E.A. & R.O.Sprague	E½ of SW¼	1	102	6
"	V	"	J. P. Lommen	NE¼ of SW¼	14	102	6
Preston	I	Forest	Wm. A. Olson	NW¼ SW¼	18	102	10
"	II	"	Theo. Deobbert	E½ Sec. 30		102	10
"	III	"	Staner Oelson	W½ NE¼	31	102	10
"	IV	"	Wm. C. Marsholf	Near Center	7	102	10
"	V	"	B. Bendeckson	Center Sec.	22	102	10
Spring V.	I	Forest	John Beyers	NW¼ Sec.	30	103	13
"	II	"	Tom Fryer	NE¼ of SW¼	25	103	14
"	III	"	G. H. Churchill	SW¼ SW¼	19	103	13
"	IV	"	A. Harland	SE¼ of SE¼	30	103	13
"	V	"	Geo. Warner	W½ SE¼	21	103	13
Albert Lea	I	Forest	C. Nelson	SE¼ SE¼	30	102	21
"	II	"	J. M. Engbloom	SE¼ SW¼	20	102	21
"	III	"	Wm. Schneider	N½ SW¼	15	102	22
"	IV	"	C. Lens	NW¼ of NE¼	15	102	22
Wells	I	Prairie	W. E. Billington	W½ SW¼	31	104	24
"	II	"	Hans Gilbertson	W½ SW¼	19	103	24
"	III	"	Anton Miller	SW¼ SE¼	18	103	24
"	IV	"	L. Larson	NW¼ SE¼	17	102	24
"	V	"	John Kulba	SW¼ SE¼	30	104	24

AINED.

Twp.	Range
103	5
103	5
103	5
102	6
102	6
102	10
102	10
102	10
102	10
102	10
103	13
103	14
103	13
03	13
103	13
02	21
02	21
02	22
02	22
04	24
03	24
03	24
02	24
4	24

TABLE I. (Continued)

Area	Field	Vegetation	Owner		Section	TWP.	Range
Fairmont	I	Forest	J. Welchin	SW¼	24	102	30
"	II	Prairie	John Prafke	SW¼ SW¼	23	102	30
"	III	"	Fair Grounds	NE¼ SE¼	8	102	30
"	IV	"	A. L. Ward	SW¼ SE¼	8	102	30
"	V	"	Mr. Burman	SE¼ NW¼	15	102	30
Jackson	I	Prairie	H. Valden	NW¼ SW¼	32	103	34
"	II	"	C.H.Washburn	SW¼ SW¼	8	102	34
"	III	"	C. Ruchen	SE¼ SE¼	16	102	34
"	IV	"	H. A. Holland	S½ SE¼	17	102	34
"	V	"	Hutchinson & Strong	NW¼ NE¼	19	102	34
Worthington	I	Prairie	John Webster	SW¼ NW¼	33	102	39
"	II	"	L. M. Fogg	S½ NW¼	31	102	39
"	III	"	J. M. Walnen	SW¼ SE¼	18	102	40
"	IV	"	J.W.Walnen	NE¼ NE¼	20	102	40
"	V	"	R. H. Sykes	NW¼ NE¼	22	102	40
Adrian	I	Prairie			1	102	43
"	II	"		NE¼	24	102	43
"	III	"	John Pasture	N½	13	102	43
"	IV	"	Mr. Slade	N½ NE¼	23	102	43
"	V	"	E. G. Cross	E½	16	102	43
Luverne	I	Prairie		NE¼	3	101	45
"	II	"		Between 9 & 16		101	45
"	III	"	Mr. Fogg	NE¼	29	102	44

TABLE I. (Continued)

Area	Field	Vegetation	Owner		Section	Twp.	Range
Luverne	V	Prairie		NE¼	8	101	45

LONG CULTIVATED FIELDS.

Area	Field	Owner		Section	Twp.	Range
Caledonia	I	Sprague Brothers	SE¼	12	102	6
"	II	Sprague Brothers	N½	22	102	6
"	III	John Keefe	N½ NE¼	22	102	6
"	IV	Tony Rosch	NE¼	28	102	6
"	V	Sprague Brothers	SE¼	24	102	6
Preston	I	W. A. Olson	NW¼ SW¼	18	102	10
"	II	Theo. Deobbert	E½	30	102	10
"	III	Wm. C. Marzlof		7	102	10
"	IV	F. C. Wood	SE NE¼	9	102	11
"	V	E. S. Holton	S½ NE¼	4	102	11
Spring V.	I	C. G. Stoddard	N½	29	103	13
" "	II	Thornhill Bros.	E½ NE¼	25	103	14
" "	III	T. Fryer	SW¼	25	103	14
" "	IV	Herbert Fowler	SW¼	32	103	13
" "	V	T. Wilkins	SW SW¼	30	103	13
Luverne	I	C. H. Linnel	SW¼	8	101	45
"	II	W. Wiggens	W½ SW¼	9	101	45
"	III	John Linsch	NW¼	34	102	45
"	IV	B. E. Sluck	SE¼	22	102	45
"	V	Pat Jancey	S½ SE¼	5	101	45

PREVIOUS WORK.

Snyder[1] has reported the analyses of about 34 soils, part surface and part sub soils from long cultivated fields in several of the southern counties. The analyses were made by digestion with hydrochloric acid for 24 hours. Owing to the analyses reported in this thesis having been made by different methods, the analyses of Snyder's are not comparable except in the case of nitrogen and carbon dioxide. In Table II. these analyses are reported.

1 Bulletins 30, 41, and 65. Agricultural Experiment Station, University of Minnesota.

TABLE II.

SNYDER'S ANALYSIS OF CULTIVATED MINNESOTA SOILS

	Soil	Weight Per Cu.Ft.	Fine Earth	Insoluble Matter	Potash	Soda	Lime
		HOUSTON COUNTY					
Houston	Surface	100	100	86.10	.34	.52	.42
"	Sub-soil	100	100	86.64	.32	.52	.40
"	Surface	78.1	94.8	87.02	.83		.59
"	Sub-soil	83.2		88.10	.43		.48
		FILLMORE COUNTY					
Twp.101	Surface		100	82.23	.41	.31	.45
" "	Sub-soil		100	83.07	.46	.33	.27
		MOWER COUNTY					
Austin	Surface	68	98	82.28	.32	.34	.48
"	Sub-soil	76	99	84.22	.08	.31	.21
Waltham	Surface		93.8	77.95	.37		.49
"	Sub-soil		89.0	78.01			.46
Brownsdale	Surface		95.1	77.80	.50	.30	.56
"	Sub-soil		95.6	81.61	.53	.19	.37
		FREEBORN COUNTY					
Albert Lea	Surface		99.5	77.29	.54	.22	.61
" "	Sub-soil			80.60	.54	.26	.44
" "	Surface		98.5	82.57	.46	.26	.67
" "	Sub-soil			83.83	.47	.19	.59
Moscow	Surface		99	83.25	.42	.48	.52
"	Sub-soil		98	84.52	.48	.23	.30
London	Surface		93	85.88	.27	.18	.60
"	Sub-soil		95	87.15	.26	.17	.49
Oakland	Surface		100	65.15	.35	.45	2.40

Magnesia	Ferric O and Aluminia	Phosphoric Acid	Sulfuric Anhydride	Carbon Dioxide	Volatile Matter	Humus	Nitrogen
.47	6.04	.22	.05	.03	5.97	2.27	.20
.47	7.54	.23	.05	.04	3.90		.07
.37	5.89	.26	.06	none	4.37	1.67	.10
.38	5.01	.19	.01	none	4.71		.10
.66	8.95	.12	.03	.06	6.18	2.15	.22
.36	11.30	.24	.05	.05	4.34		.04
.45	7.58	.38	.15	1.40	6.56	3.73	.30
.61	7.70	.30	.10	1.43	5.00		.15
.33	9.90	.19	.12	.08	11.53	5.55	.32
.29	12.98	.09	.05	.02	5.93		.15
.19	9.16	.18	.11	.03	9.41	3.89	.29
.20	11.42	.12	.05	.05	4.89		.12
.53	8.34	.27	.13	.06	10.14	6.60	.39
.68	7.77	.21	.10	.12	8.24		
	6.52	.25	.08	.04	8.97	3.78	.29
..65	8.01	.15	.04	.13	6.04		.15
.29	7.46	.18	.06	.15	7.52	3.63	.23
.26	9.44	.15	.08	.16	5.01		
.46	5.48	.26	.10	.22	6.55		
.53	6.50	.25	.09	.20	4.07		
.25	11.66	.27	.20	1.25	15.66		

TABLE II. (Concluded)

	Soil	Weight Per Cu.Ft.	Fine Earth	Insoluble Matter	Potash	Soda	Lime
		FREEBORN COUNTY					
Oakland	Sub-soil		100	71.67	.39	.27	2.43
"	Surface		99.8	62.34			2.36
"	Sub-soil		100	69.74	.40	.32	4.96
"	Surface		96	73.70	.29	.42	1.94
"	Sub-soil		94	72.67	.40	.56	4.40
		MARTIN COUNTY					
Fairmont	Surface	72.2	97	82.20	.57	.37	.93
"	Sub-soil	78.8	97	82.60	.39	.65	2.08
Welcome	Surface	72	99	81.65	.31	.12	.58
"	Sub-soil	74	99	82.02	.24	.27	.58
		FARIBAULT COUNTY					
Wells	Surface	75	97.0	77.64	.36	.41	1.10
"	Sub-soil	79	98.0	81.60	.30	.35	.80
		NOBLES COUNTY					
Worthington	Surface	72	100	74.68	.36	.28	1.06
"	Sub-soil	75	100	61.81	.22	.44	11.33

Magnesia	Ferric O and Aluminia	Phosphoric Acid	Sulfuric Anhydride	Carbon Dioxide	Volatile Matter	Humus	Nitrogen
.42	11.65	.21	.16	1.26	11.21		
.77	11.81	.29	.18	1.51	20.47		
.75	10.01	.22	.15	3.93	8.75		
6.12	6.87	.22	.35	.19	17.81		
2.06	5.77	.17	.09	3.96	8.57		
.76	7.35	.11	.06	.29	7.43	3.28	.22
.84	7.69	.12	.03	1.21	4.77		.09
.19	8.03	.25	.08	.21	8.73	2.54	.26
.25	8.69	.29	.22	.12	7.20		.11
.99	6.01	.25	.16	.56	12.40	4.17	.37
.68	8.60	.24	.16	.75	6.50		.20
.82	7.93	.65	.21	.37	13.19	4.39	.37
1.72	10.74	.25	.08	10.94	1.56		.01

EXPERIMENTAL WORK

COLLECTION OF SAMPLES

Five fields that had never grown crops were selected in each of the ten areas chosen to represent the soils. In every field two sets of samples were collected, each from five borings to a depth of three feet, samples being taken from each foot section. Great care was taken in sampling the second and third feet to prevent the samples becoming contaminated with soil from the overlying foot sections. The soil from each foot section of the five borings was thoroughly mixed in the field, put in sacks, and at once tagged. This method of sampling gave us duplicate samples of each foot section, each representing five borings.

The tools used in sampling were a 1½ inch and a 2 inch auger. The latter was used on the first foot, the former on the second foot, the hole being cleaned out with the 2 inch auger down to the third foot. Finally the last sample was taken with the 1½ inch auger.

In order to study the nitrogen content six-inch samples were collected from part of the fields that had previously been sampled. In this case three sets of samples were taken from a field, each representing ten borings. In the case of each of the twenty long cultivated fields a composite sample from thirty borings was prepared.

The samples from the first, second, and third feet from the ten areas were collected in the months of October and November, 1913 while the six-inch samples, both from the virgin and long cultivated fields, were taken in October 1914.

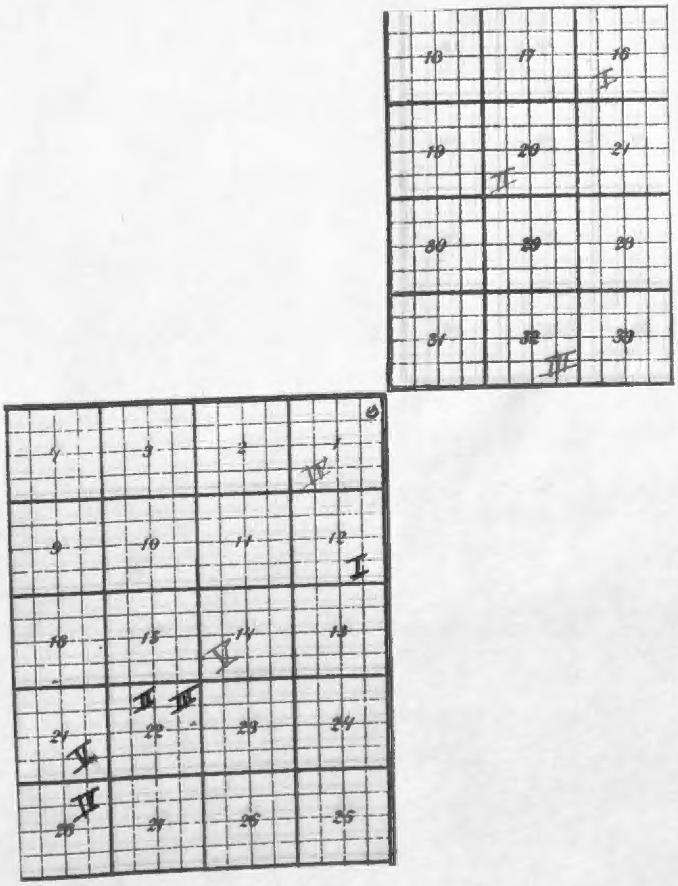
When the soils reached the laboratory they were put through a ¼ inch sieve to remove pebbles, dried and placed in jars. Where there were pebbles remaining on the sieve, these were placed in separate jars, their number and composition being later determined.

Composites were made from the samples of the first, second and third feet of each area, so each foot sample from an area represented a composite of fifty borings. These were placed in jars. The greater number of the chemical determinations were made on these "area composites".

The location of the fields sampled is indicated on the map, page 3 and the legal description of each is given in Table I. On the latter is shown the natural vegetation of the different fields. It will be seen that only four fields were sampled at Albert Lea instead of five. This was due to the fact that weather conditions were unfavorable at the time for the completion of the set. In 1914, however, the fifth field was sampled but the work todate has not included these samples.

On the following pages are maps of each area showing the location of fields sampled. These will serve to show the distribution of the fields in each area. Where the samples were collected from moraines the maps have been shaded with cross lines.

It was the intention at the time the samples were taken to obtain photographs of all the fields, but owing to unfavorable weather conditions this plan had to be abandoned and only photographs of several of the areas were taken. These will serve to show, in a general way, the areas selected to represent the fields. These photographs are shown on pages 33 to 40 inclusive.

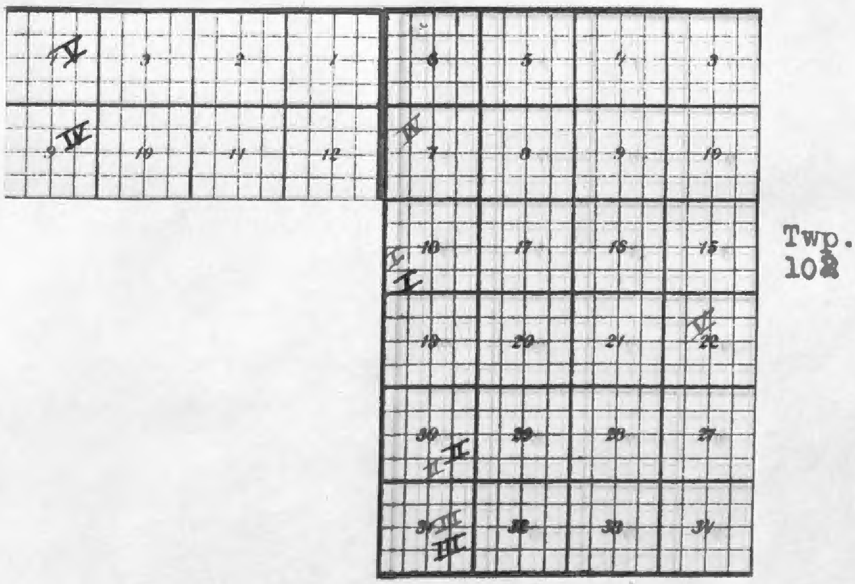


Twp.
103

Twp.
102

R 6 CALEDONIA AREA R 5

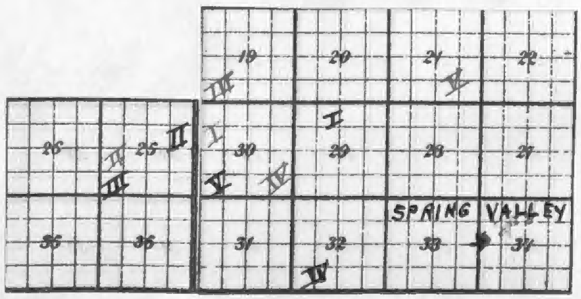
Cultivated Fields are shown in Black.
Virgin Fields are shown in Red.



R 11 R 10

PRESTON AREA

Cultivated Fields are shown in Black.
Virgin Fields are shown in Red.

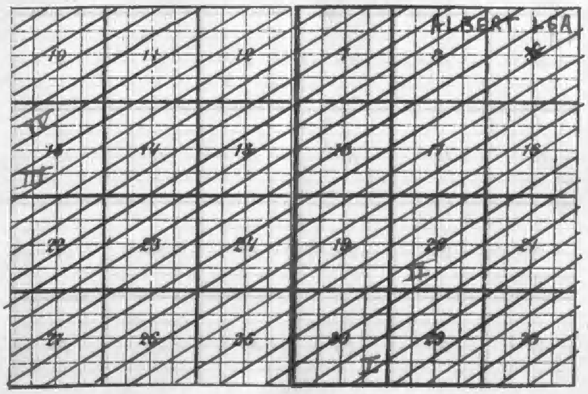


Twp.
103

R 14 R 13

SPRING VALLEY AREA

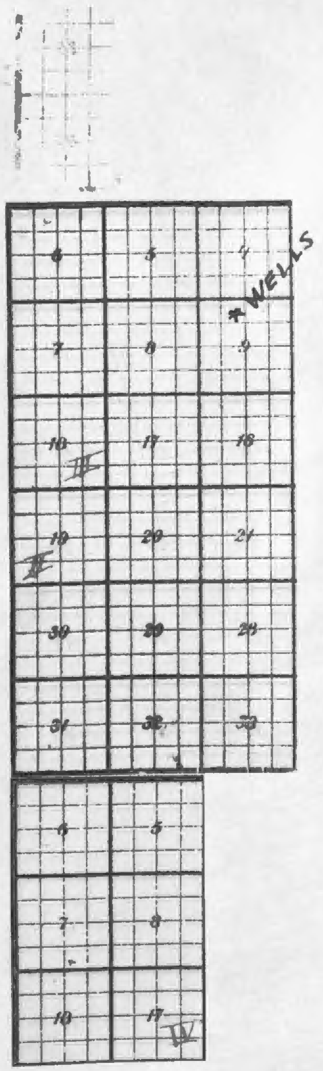
Cultivated Fields are shown in Black.
Virgin Fields are shown in Red.



Twp. 102

R 22 R 21

ALBERT LEA AREA



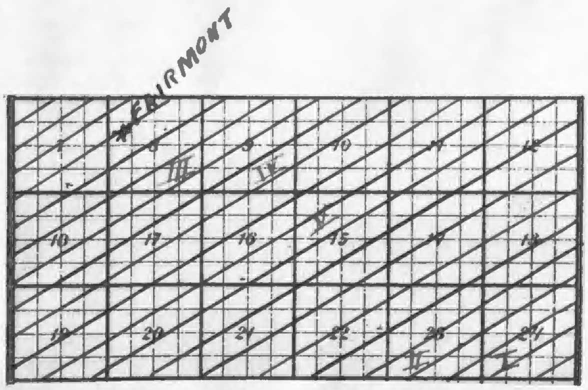
Twp. 104.

Twp. 103.

Twp. 102.

R 24

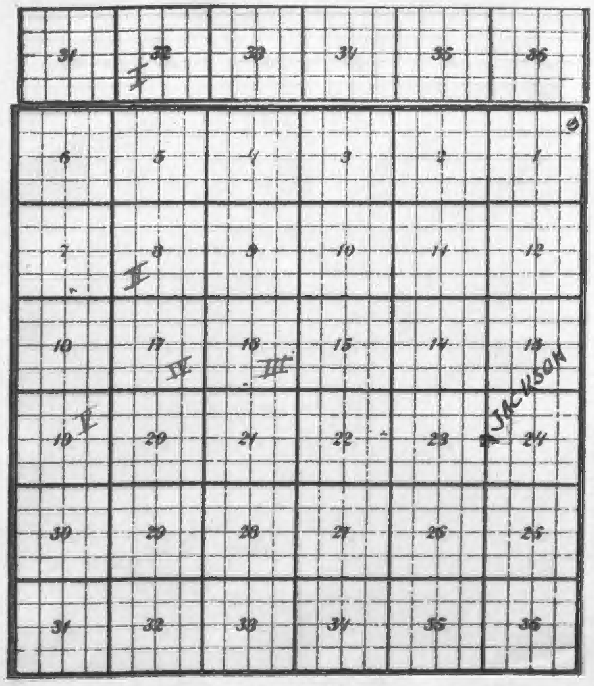
WELLS AREA



Twp. 102

R 30

FAIRMONT AREA

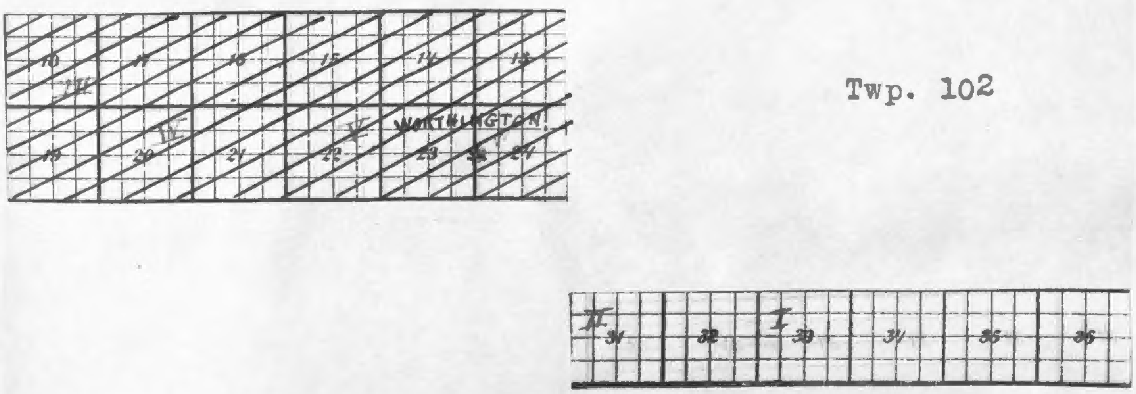


Twp. 103.

Twp. 102

R 34

JACKSON AREA

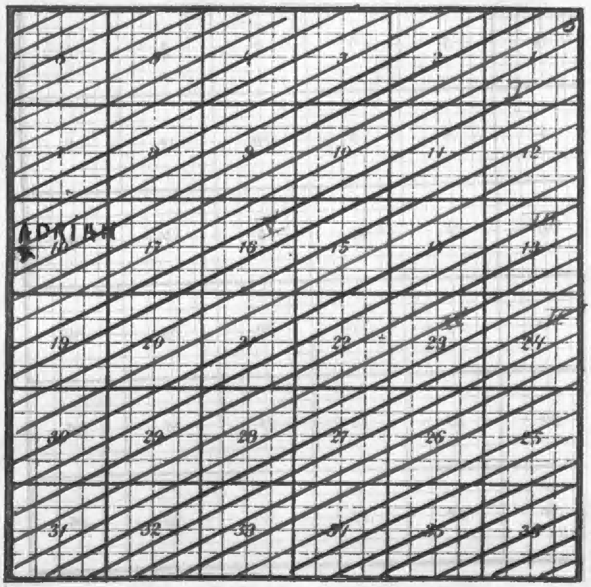


Twp. 102

R 40

R 39

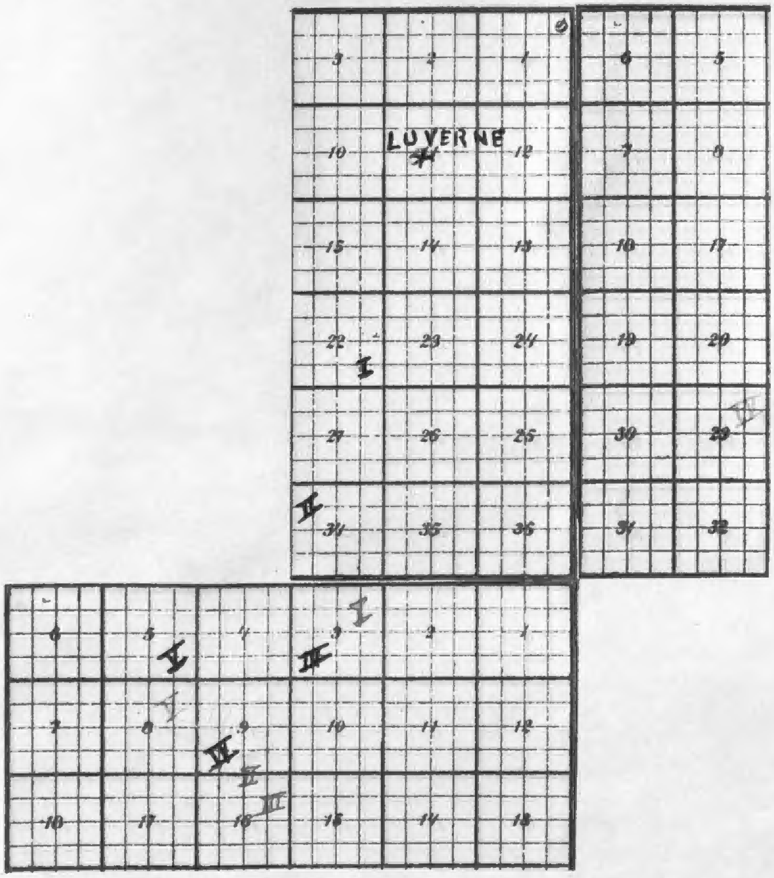
WORTHINGTON AREA



Twp.
102

R 43

ADRIAN AREA



Twp. 102

Twp. 101

R 45 R 44

LUVERNE AREA

Cultivated Fields are shown in Black.
Virgin Fields are shown in Red.

CALEDONIA AREA VIRGIN FIELD II.

CALEDONIA AREA VIRGIN FIELD III.

CALEDONIA AREA VIRGIN FIELD IV.

CALEDONIA AREA VIRGIN FIELD V.

PRESTON AREA VIRGIN FIELD I.

PRESTON AREA VIRGIN FIELD II.

PRESTON AREA VIRGIN FIELD III.

PRESTON AREA VIRGIN FIELD IV.

PRESTON AREA VIRGIN FIELD V.

PRESTON AREA CULTIVATED FIELD I.

PRESTON AREA CULTIVATED FIELD II.

PRESTON AREA CULTIVATED FIELD III.

PRESTON AREA CULTIVATED AREA IV.

PRESTON AREA CULTIVATED FIELD V.

SPRING VALLEY AREA VIRGIN FIELD I.

SPRING VALLEY AREA VIRGIN FIELD II.

PEBBLES AND COARSE GRAVEL FOUND IN THE SAMPLES.

In Table III. are shown the relative quantities of calcareous and non-calcareous pebbles, in percentage by weight, in the samples from the different fields. This permits of the calculation of the weight of pebbles per acre foot.

Table IV. gives the average distribution in the first, second, and third feet of the ten areas.

Table V. shows the number and the percentages of both calcareous and non-calcareous pebbles with the average percentages by weight in the first, second and third feet of the ten areas. This table permits of the calculation of the numbers of pebbles per cubic foot or per acre foot.

Table VI. gives the average distribution in the first, second and third feet of the ten areas.

The data regarding the pebbles is summarized as follows:

Caledonia and Preston Areas,

No pebbles were present in the soils from these

TABLE III. RELATIVE QUANTITIES OF CALCAREOUS AND NON-CALCAREOUS PEBBLES IN THE FIELD SAMPLES.

		Weight of soil and pebbles.				Percentage of pebbles.		
Field	Depth Foot	Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Total P.ct.	Calc. P.ct.	Others P.ct.
				SPRING VALLEY AREA				
I.	1	none	none	none	none	.00	.00	.00
"	2	5155	14.5	5169.5	"	.28	.00	.28
"	3	4560	18.6	4578.6	"	.40	.00	.40
II.	1	2000	15.8	2015.8	"	.78	.00	.78
"	2	4200	72.7	4272.7	"	1.72	.00	1.72
"	3	5350	26.6	5376.6	"	.49	.00	.49
III.	1	none	none	none	none	.00	.00	.00
"	2	4610	72.7	4682.7	"	1.55	.00	1.55
"	3	4710	127.2	4837.2	"	2.63	.00	2.63
IV.	1	2040	32.6	2072.6	"	1.59	.00	1.59
"	2	4170	122.5	4292.5	"	2.85	.00	2.85
"	3	1620	22.1	1642.1	"	1.35	.00	1.35
V.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	3940	105.8	4045.8	"	2.62	.00	2.62
AVERAGE	1				none	.47	.00	.47
"	2				"	1.28	.00	1.28
"	3				"	1.49	.00	1.49

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of Soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
			ALBERT LEA AREA					
I.	1	none	none	none	none	.00	.00	.00
"	2	2270	7.2	2277.2	"	.31	.00	.31
"	3	4295	21.9	4316.9	"	.51	.00	.51
II.	1	2070	7.8	2077.8	none	.37	.00	.37
"	2	3895	50.2	3945.2	1.6	1.32	.04	1.67
"	3	2060	28.7	2088.7	17.7	1.37	.85	.52
III.	1	none	none	none	none	.00	.00	.00
"	2	4135	34.1	4169.1	"	.82	.00	.82
"	3	2140	30.5	2170.5	"	1.41	.00	1.41
IV.	1	none	none	none	none	.00	.00	.00
"	2	1825	8.2	1833.2	"	.45	.00	.45
"	3	1760	13.2	1773.2	"	.74	.00	.74
AVERAGE	1					.09	.00	.09
"	2					.72	.01	.71
"	3					1.01	.21	.80

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
				WELLS AREA				
I.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
II.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	3300	17.3	3317.3	7.5	.52	.22	.30
III.	1	none	none	none	none	.00	.00	.00
"	2	1850	45.3	1895.3	33.3	2.39	1.75	.64
"	3	3050	23.0	3073.0	11.8	.75	.38	.37
IV.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	1620	8.7	1628.7	4.5	.53	.27	.26
V.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
AVERAGE	1					,00	.00	.00
"	2					.48	.35	.13
"	3					.36	.17	.19

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
				FAIRMONT AREA				
I.	1	none	none	none	none	.00	.00	.00
"	2	2100	10.9	2110.9	"	.52	.00	.52
"	3	4150	27.4	4177.4	1.4	.65	.03	.62
II.	1	2575	23.5	2598.5	11.3	.91	.43	.48
"	2	3700	31.9	3731.9	11.9	.85	.32	.53
"	3	3600	50.8	3650.8	28.2	1.39	.77	.62
III.	1	none	none	none	none	.00	.00	.00
"	2	3950	72.9	4022.9	3	1.80	.07	1.73
"	3	3925	57.3	3982.3	42.4	1.45	1.06	.39
IV.	1	1650	8.2	1658.2	none	.49	.00	.49
"	2	4100	29.2	4129.2	"	.71	.00	.71
"	3	4600	99.0	4699.0	31.5	2.10	.67	1.43
V.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	1800	10.5	1810.5	6.	.58	.33	.25
AVERAGE	1					.28	.09	.17
"	2					.78	.10	.68
"	3					1.23	.57	.66

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
				JACKSON AREA				
I.	1	none	none	none	none	.00	.00	.00
"	2	1670	17.6	1687.6	3.1	1.04	.18	.86
"	3	none	none	none	none	.00	.00	.00
II.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	3400	20.4	3420.4	17.2	.59	.50	.09
III.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	3550	17.8	3367.8	16.1	.53	.48	.05
IV.	1	1200	12.3	1212.3	12.3	1.01	1.01	.00
"	2	none	none	none	none	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
V.	1	none	none	none	none	.00	.00	.00
"	2	1600	44.8	1644.8	9.3	2.92	.55	2.17
"	3	3300	30.7	3330.7	13.1	.92	.39	.53
AVERAGE	1					.20	.20	.00
"	2					.79	.15	.64
"	3					.41	.27	.14

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
			WORTHINGTON AREA					
I.	1	1850	9.0	1859.0	1.1	.48	.06	.42
"	2	none	none	none	none	.00	.00	,00
"	3	3580	33.9	3613.9	17.1	.94	.47	.47
II.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	1970	18.1	1988.1	14.0	.91	.70	.21
III.	1	none	none	none	none	.00	.00	.00
"	2	2050	28.8	2078.8	2.4	1.39	.11	1.28
"	3	1550	12.2	1562.2	3.5	.78	.22	.56
IV.	1	none	none	none	none	.00	.00	.00
"	2	2150	12.3	2162.3	.8	.57	.04	.53
"	3	4225	55.2	4280.2	24.4	1.29	.57	.72
V.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	3650	27.3	3677.3	17.6	.74	.48	.26
AVERAGE	1					.10	.01	.09
"	2					.39	.03	.36
"	3					.93	.49	.44

TABLE III. (Continued)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentabe of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
					ADRIAN AREA			
I.	1	none	none	none	none	.00	.00	.00
"	2	1225	10.	1235	"	.81	.00	.81
"	3	2780	26.8	2806.8	8.5	.95	.30	.65
II.	1	none	none	none	none	.00	.00	.00
"	2	1650	33.4	1683.4	"	1.98	.00	1.98
"	3	3130	42.7	3172.7	14.1	1.35	.44	.00
III.	1	none	none	none	none	.00	.00	.00
"	2	1300	10.4	1310.4	8.2	.79	.63	.16
"	3	2555	27.0	2582.0	1.1	1.04	.04	1.00
IV.	1	1220	6.1	1226.1	none	.50	.00	.50
"	2	1550	11.2	1561.2	.8	.72	.05	.67
"	3	1550	30.3	1580.3	3.3	1.91	.21	1.70
V.	1	none	none	none	none	.00	.00	.00
"	2	1600	12.1	1612.1	10.6	.75	.66	.09
"	3	2742	115.4	2857.4	77.3	4.04	2.71	1.33
AVERAGE	1					.10	.00	.10
"	2					1.01	.27	.74
"	3					1.86	.74	1.12

TABLE III. (Concluded)

Field	Depth Foot	Weight of soil and pebbles. Weight of soil grams	Weight of pebbles grams	Total Weight grams	Weight Calc. pebbles grams	Percentage of pebbles. Total P.ct.	Calc. P.ct.	Others P.ct.
				LUVERNE AREA				
I.	1	535	4.5	539.5	1.3	.83	.24	.59
"	2	none	none	none	none	.00	.00	.00
"	3	560	8.8	568.8	6.5	1.55	1.14	.41
II.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
III.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
IV.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00
V.	1	none	none	none	none	.00	.00	.00
"	2	"	"	"	"	.00	.00	.00
"	3	"	"	"	"	.00	.00	.00

TABLE IV. SUMMARY OF RELATIVE QUANTITIES OF CALCAREOUS AND NON-CALCAREOUS PEBBLES IN THE FIELD SAMPLES.

AVERAGE PERCENTAGE OF ALL PEBBLES.

Area	First foot.	Second foot.	Third foot.
Spring Valley	.47	1.28	1.49
Albert Lea	.09	.72	1.01
Wells	.00	.48	.36
Fairmont	.28	.78	1.23
Jackson	.20	.79	.41
Worthington	.10	.39	.93
Adrian	.10	1.01	1.86

AVERAGE PERCENTAGE OF CALCAREOUS PEBBLES.

Area	First foot.	Second foot.	Third foot.
Spring Valley	.00	.00	.00
Albert Lea	.00	.01	.21
Wells	.00	.35	.17
Fairmont	.09	.10	.57
Jackson	.20	.15	.27
Worthington	.01	.03	.49
Adrian	.00	.27	.74

TABLE V. DISTRIBUTION, NUMBER AND COMPOSITION OF PEBBLES CONTAINED IN FIELD SAMPLES.

Field	Depth Foot	Number of pebbles			Weight of pebbles			Percentage by weight	
		Calc.	Others	Total	Calc. grams	Others grams	Total grams	Calc. P.ct.	Others P.ct.
				SPRING VALLEY AREA					
I.	1	none	none	none	none	none	none	.00	.00
"	2	"	13	13	"	14.5	14.5	.00	100.00
"	3	"	17	17	"	18.6	18.6	.00	100.00
II.	1	"	1	1	"	15.8	15.8	.00	100.00
"	2	"	14	14	"	72.7	72.7	.00	100.00
"	3	"	33	33	"	26.6	26.6	.00	100.00
III.	1	"	none	none	"	none	none	.00	.00
"	2	"	47	47	"	72.7	72.7	.00	100.00
"	3	"	54	54	"	128.2	127.2	.00	100.00
IV.	1	"	31	31	"	32.6	32.6	.00	100.00
"	2	"	34	34	"	122.5	122.5	.00	100.00
"	3	"	19	19	"	22.1	22.1	.00	100.00
V.	1	"	none	none	"	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	60	60	"	105.8	105.8	.00	100.00
AVERAGE	1	"	6.4	6.4	"	9.6	9.6	.00	100.00
"	2	"	19.8	19.8	"	56.5	56.5	.00	100.00
"	3	"	36.6	36.6	"	60.1	60.1	.00	100.00

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles: Calc.	Others	Total	Weight of pebbles: Calc. grams	Others grams	Total grams	Percentage by weight: Calc. P.ct.	Others P.ct.
				ALBERT LEA AREA					
I.	1	none	none	none	none	none	none	.00	.00
"	2	"	7	7	"	7.2	7.2	.00	100.00
"	3	"	11	11	"	21.9	21.9	.00	100.00
II.	1	"	7	7	"	7.8	7.8	.00	100.00
"	2	3	21	24	1.6	48.6	50.2	3.1	96.8
"	3	10	11	21	17.7	11.0	28.7	61.7	38.3
III.	1	none	none	none	none	none	none	.00	.00
"	2	"	32	32	"	34.1	34.1	.00	.00
"	3	"	16	16	"	30.5	30.5	.00	100.00
IV.	1	none	none	none	none	none	none	.00	.00
"	2	"	4	4	"	8.2	8.2	.00	100.00
"	3	"	12	12	"	13.2	13.2	.00	100.00
AVERAGE	1	none	1.7	1.7	none	1.9	1.9	.00	100.00
"	2	0.8	16.0	16.8	.4	24.5	24.9	1.6	98.4
"	3	2.5	12.5	15.0	4.7	19.1	23.8	19.7	80.2

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles Calc.	Others	Total	Weight of pebbles Calc. grams	Others grams	Total grams	Percentage by weight Calc. P.ct.	Others P.ct.
				WELLS AREA					
I	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
II	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	5	7	12	7.5	9.8	17.3	43.3	56.6
III	1	none	none	none	none	none	none	.00	.00
"	2	2	1	3	33.3	12.0	45.3	73.6	26.5
"	3	6	14	20	11.8	11.2	23.0	51.3	48.7
IV	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	3	4	7	4.5	4.2	8.7	51.7	48.2
V	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
AVERAGE	1	none	none	none	none	none	none	.00	.00
"	2	.4	.2	.6	6.6	2.4	9.0	73.2	26.7
"	3	.3	5.	.8	4.7	5.0	9.7	48.4	51.5

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles Calc.	Others	Total	Weight of pebbles Calc. grams	Others grams	Total grams	Percentage by weight Calc. P.ct.	Others P.ct.
				FAIRMONT AREA					
I.	1	none	none	none	none	none	none	.00	.00
"	2	"	17	17	"	10.9	10.9	.00	100.00
"	3	2	13	15	1.4	26.0	27.4	5.1	94.9
II.	1	9	11	20	11.3	12.2	23.5	48.1	51.9
"	2	13	20	33	11.9	20.0	31.9	37.3	62.7
"	3	12	23	35	28.2	22.6	50.8	55.5	44.5
III.	1	none	none	none	none	none	none	.00	.00
"	2	1	38	39	3.	69.9	72.9	4.1	95.9
"	3	43	23	66	42.4	14.9	57.3	74.0	26.0
IV.	1	none	5	5	none	8.2	8.2	.00	100.00
"	2	"	19	19	"	29.2	29.2	.00	100.00
"	3	19	36	55	31.5	67.5	99.0	31.8	69.2
V.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	3	5	8	6.	4.5	10.5	57.1	42.9
AVERAGE	1	1.8	3.2	5.0	2.2	4.1	6.3	34.8	65.1
"	2	3.0	18.8	21.8	3.	26.0	29.0	10.4	89.6
"	3	16.0	20.0	36.0	21.9	27.1	49.0	44.6	55.3

TABLE V. (Continued)

FIELD	Depth Foot	Number of pebbles Calc.	Others	Total	Weight of pebbles Calc. grams	Others grams	Total grams	Percentage by weight Calc. P.ct.	Others P.ct.
				JACKSON AREA					
I.	1	none	none	none	none	none	none	.00	.00
"	2	1	6	7	3.1	14.5	17.6	17.0	82.6
"	3	none	none	none	none	none	none	.00	.00
II.	1	none	none	none	none	none	none	.00	.00
"	2	none	none	none	none	none	none	.00	.00
"	3	10	2	12	17.2	3.2	20.4	84.3	15.7
III.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	14	1	15	16.1	1.7	17.8	90.4	9.5
IV.	1	1	none	1	12.3	none	12.3	100.00	.00
"	2	none	"	none	none	"	none	.00	.00
"	3	"	"	"	"	"	"	.00	.00
V.	1	none	none	none	none	none	none	.00	.00
	2	1	7	8	9.3	35.5	44.8	20.7	79.2
	3	9	21	30	13.1	17.6	30.7	42.6	57.3
AVERAGE	1	.2	none	.2	2.4	none	2.4	100.00	.00
	2	.4	2.6	3.0	2.5	10	12.5	20.0	80.0
	3	6.6	5	11.6	9.3	7.1	16.4	56.6	43.3

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles Calc.	Others	Total	Weight of pebbles Calc. grams	Others grams	Total grams	Percentage by weight Calc. P.ct.	Others P.ct.
				WORTHINGTON AREA					
I.	1	1	14	15	1.1	7.9	9.0	12.2	87.7
"	2	none	none	none	none	none	none	.00	.00
"	3	19	24	43	17.1	16.8	33.9	50.4	49.5
II.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	7	2	9	14.0	4.1	18.1	77.3	22.6
III.	1	none	none	none	none	none	none	.00	.00
"	2	2	8	10	2.4	26.4	28.8	8.4	91.3
"	3	2	3	5	3.5	8.7	12.2	28.7	71.3
IV.	1	none	none	none	none	none	none	.00	.00
"	2	3	18	21	.8	11.5	12.3	6.5	93.5
"	3	11	33	44	24.4	30.8	55.2	44.2	55.8
V.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	12	5	17	17.6	9.7	27.3	64.4	35.5
AVERAGE	1	.2	3.	3.2	2.2	1.8	2.0	10.0	90.0
"	2	1.0	5.1	6.1	.6	8.2	8.8	6.8	92.0
"	3	10.2	13.4	23.6	15.3	14.0	29.3	52.2	47.7

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles: Calc.	Others	Total	Weight of pebbles: Calc. grams	Others grams	Total grams	Percentage by weight: Calc. P.ct.	Others P.ct.
				ADRIAN AREA					
I.	1	none	none	none	none	none	none	.00	.00
"	2	"	1	1	"	10.	10.	.00	100.00
"	3	15	13	28	8.5	18.3	26.8	31.6	68.3
II.	1	none	none	none	none	none	none	.00	.00
"	2	"	5	5	"	33.4	33.4	.00	100.00
"	3	12	11	23	14.1	28.6	42.7	33.0	66.9
III.	1	none	none	none	none	none	none	.00	.00
"	2	4	1	5	8.2	2.2	10.4	78.8	21.1
"	3	2	21	23	1.1	25.9	27.0	4.1	95.9
IV.	1	none	6	6	none	6.1	6.1	.00	100.00
"	2	1	12	13	.8	10.4	11.2	7.1	92.8
"	3	6	9	15	3.3	27.0	30.3	10.8	89.1
V.	1	none	none	none	none	none	none	.00	.00
"	2	9	3	12.	10.6	1.5	12.1	87.6	12.4
"	3	66	20	86	77.3	38.1	115.4	66.8	33.1
AVERAGE	1	none	1.2	1.2	none	1.2	1.2	.00	100.00
		2.8	4.4	7.2	3.9	11.5	15.4	25.3	74.7
		20.2	15.	35.2	20.8	27.2	48.0	43.3	56.7

TABLE V. (Continued)

Field	Depth Foot	Number of pebbles Calc.	Others	Total	Weight of pebbles Calc. grams	Others grams	Total grams	Percentage by weight Calc. P.ct.	Others P.ct.
				LUVERNE AREA					
I.	1	2	2	4	3.2	1.3	4.5	71.2	28.8
"	2	none	none	none	none	none	none	.00	.00
"	3	7	6	13	6.5	2.3	8.8	73.8	26.1
II.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
III.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
IV.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
V.	1	none	none	none	none	none	none	.00	.00
"	2	"	"	"	"	"	"	.00	.00
"	3	"	"	"	"	"	"	.00	.00
AVERAGE	1	.4	.4	.8	.6	.3	.9	66.8	33.2
"	2	none	none	none	none	none	none	.00	.00
"	3	1.4	1.1	2.5	1.3	.5	1.8	72.2	27.8

TABLE VI. SUMMARY OF DISTRIBUTION, NUMBER AND COMPOSITION OF PEBBLES CONTAINED IN THE FIELD SAMPLES.

AREA	Average Weight of Pebbles. First Foot Gr.	Second Foot Gr.	Third Foot Gr.	Total Gr.
SPRING VALLEY	9.6	56.5	60.1	126.2
ALBERT LEA	1.9	24.9	23.8	50.6
WELLS	.0	9.0	9.7	18.7
FAIRMONT	6.3	29.0	49.0	84.3
JACKSON	2.4	12.5	16.4	31.3
WORTHINGTON	2.0	8.8	29.3	40.1
ADRIAN	1.2	15.4	48.0	64.6

AREA	Average Percentage of Calcareous Pebbles. First Foot P.ct.	Second Foot P.ct.	Third Foot P.ct.	Average Per Cent
SPRING VALLEY	.00	.00	.00	.00
ALBERT LEA	.00	1.6	19.7	9.9
WELLS	.00	73.2	48.4	60.4
FAIRMONT	34.8	10.4	44.6	32.1
JACKSON	100.0	20.0	56.6	45.3
WORTHINGTON	10.0	6.8	52.2	40.2
ADRIAN	.00	25.3	43.3	38.2
LUVERNE	66.8	.00	72.2	70.2

loess coverēd areas.

Spring Valley Area,

In all of the five fields pebbles were found but none were calcareous. Pebbles were found in the first foot of fields II. and IV., only one in the former and 31 in the latter. In the second foot pebbles were found in all the fields except one, viz. V., the number ranging from 13 to 47. In the third foot pebbles were found in all five fields, the smallest number being 17 and the largest 60.

Albert Lea Area,

Pebbles were found in all of the four fields. Calcareous pebbles were found in only Field II. and in this field there were 3 in the second and 10 in the third; the percentage of calcareous pebbles in the second foot being 3.1, while that in the third was as high as 61.7. Only Field II. showed pebbles which were found in the first foot, and in the second foot pebbles were present in all, the number ranging from 4 to 32, and in the third foot pebbles were also present in all, ranging in number from 11 to 21.

Wells Area,

Pebbles were found in only three out of the five fields. In the three there were none in the first foot and in only one were pebbles found in the second foot. This sample contained three pebbles, two being calcareous, the percentage of calcareous by weight being 73.6 In the third foot of the three, the number varied from 7 to 20 and the percentage of calcareous from 43.3 to 51.7.

Fairmont Area,

Pebbles were found in all five fields. Calcareous ones were present in all. In the first foot pebbles were found in two fields, II and IV, and the number ranging from 5 to 20. In Field IV. there were no calcareous stones and in the other 48.1 per cent by weight. In the second foot, one field, V., had no pebbles, while the number present in the others ranged from 17 to 39, the percentage of calcareous material ranging from 4.1 to 37.3. Two fields, I. and IV. had no calcareous pebbles present in the second foot. In the third foot both calcareous and other pebbles were present in all five fields, the total number present ranging from 8 to 66, the percentage of calcareous ranging from 5.1 to 74.0.

Jackson Area,

Pebbles were found in all five fields, calcareous as well as others. In the first foot pebbles were found in only Field IV. in which a single pebble was found, a calcareous one weighing about 12 grams. In the second foot, pebbles were found in two fields, I. and V., seven in one and eight in the other, the percentages of calcareous ones being 17 and 21. In the third foot pebbles were found in three fields, II., III., and V., the number ranging from 12 to 30. The percentages of the calcareous material were 84.3, 90.4 and 42.6.

Worthington Area,

Pebbles were found in all five fields. In only Field I. were there pebbles found in the first foot and this contained 12.2 per cent calcareous material. In the second foot pebbles were found in two fields, III. and IV., ten in the former and 21 in the latter and the percentages of calcareous material being 8.4 and 6.5. Pebbles were found in the third foot of all the fields, the number ranging from 5 to 44, from 28.7 to 77.3 per cent consisting of calcareous material.

Adrian Area,

Pebbles were found in all five fields. In the first foot of only one, Field IV., were any found and in this no calcareous ones were present. In the second foot pebbles were found in all of the fields. In one field, I., a single non-calcareous pebble was found and in II., five, all being non-calcareous. In Field III. five were found, the calcareous ones amounting to 78.8 per cent. In Field IV. 13 were present, the calcareous ones amounting to 7.1 per cent. In Field V. 12 pebbles were present, 87.6 per cent being calcareous. In the third foot there were pebbles in all the fields, the number ranging from 15 to 86 and the percentages of calcareous ones ranging from 4.1 to 66.8.

Luverne Area,

This area represents loess deposits over the glacial till. Pebbles were found in only Field I., in both the first and third foot. In the first, four pebbles were found, two being calcareous, and the percentage 71.2 while in the third foot 13 were found, 7 being calcareous ones and forming 73.8 per cent. As pebbles were found in only one field it is probable that these had been brought up from the underlying till by burrowing animals.

CHARACTER OF PEBBLES IN THE DRIFT.

A lithological examination was made of all the pebbles that did not pass through the quarter inch seive. The data from this examination, given in Table VII., shows that except in the carbonate fragments no sharp line can be drawn between any two of the drift sheets; the Kansan shows the greatest number of pebbles and they rank in the order of basalts, granites, quartz. On the Late Wisconsin from which 725 pebbles were examined the order was, limestone, granite and basalts. On the drift of Undetermined Age from which 217 pebbles were examined, these arranged in order of number, were: limestones, granites, and basalts. In the five areas on the Late Wisconsin there appears to be no general agreement as to the preponderance of either granites or basalts. In one area granites will predominate while in the next basalts

TABLE VII. CHARACTER OF PEBBLES IN TILL SHOWING PERCENTAGES BY NUMBER.

	Number present	Lime-stone P.ct.	Granite P.ct.	Weathered Granite P.ct.	Basalt P.ct.	Syenite P.ct.
			KANSAN DRIFT			
Spring Valley	323	.00	25.7	4.0	31.2	.6
			LATE WISCONSIN DRIFT.			
Albert Lea	134	9.7	33.6	2.2	10.5	1.5
Wells	42	38.1	19.0	.0	31.0	.0
Fairmont	312	32.7	32.1	1.6	20.8	1.3
Jackson	73	49.5	13.7	.0	15.1	2.7
Worthington	164	34.7	30.5	.0	22.0	2.4
AVERAGE		32.9	25.8	1.9	19.9	1.9
			DRIFT OF UNDETERMINED AGE			
Adrian	217	53.0	26.3	.0	17.5	.0

Gneiss	Schist	Felsite	Shale	Sandstone	Chert	Quartz
P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.
.6	1.5	8.6	3.2	1.5	8.0	14.8
2.2	7.5	9.7	1.5	3.0	7.5	11.2
.0	.0	.0	2.4	.0	7.1	2.4
.0	.0	1.0	3.1	2.9	2.6	1.9
2.7	.0	2.7	2.7	.0	2.7	8.2
.6	.6	.0	1.8	4.3	1.2	1.8
1.8	4.0	4.5	1.9	3.4	4.2	5.1
.5	.0	.0	.9	.0	1.4	.5

LABORATORY METHODS EMPLOYED.

In making the lithological examination the pebbles were usually broken in fragments and these examined and classified without the use of the microscope. The moisture equivalent determinations were made according to the method devised by Briggs and McLane. Soil acidity was determined by two methods, the litmus test using the Kellerman modification, which consists in placing strips of red and blue litmus paper in the bottom of a petri dish; over these are laid four thicknesses of filter paper and on the latter is placed the soil to be tested. Enough neutral water is added to saturate the soil on the filter paper. The dish is covered and allowed to stand for one hour when the reaction is noted. The Hopkins method consists in shaking 100 grams of the soil with a normal solution of potassium nitrate and allowing it to stand over night. Then 125 cc of the clear solution is decanted and titrated with a standard solution of sodium hydroxide using phenalphthalein as the indicator.

Nitrogen determinations were made according to the A. O. A. C. method.[3]

Total potash was determined by fusing 1 gram of soil with 1 gram of ammonium chloride and 8 grams of calcium carbonate in a Lawrence Smith crucible when the melt was extracted with hot water and the calcium precipitated with ammonium carbonate. The calcium carbonate filtered off and the potash determined in the filtrate according to the method of W.A. Davis.*

Phosphoric acid was determined gravimetrically by solution of the soil in hydrofluoric acid.[5]

3. Bulletim 107 (Revised) Bureau of Chemistry P.7 (1910).

5. Washington. The Chemical Analysis of Rocks. (1906) Page 152.

*Journal Agricultural Science. Oct. 1912. Vol.V. Part I.

Carbon dioxide was determined by the usual method of treating the soil with dilute hydrochloric acid and absorbing the liberated carbon dioxide in caustic potash.

All determinations reported in this study were made in duplicate, the average of concordant determinations being used. Table XIII. shows the maximum difference between accepted duplicates as well as the average difference for the different constituents.

TABLE XIII. MAXIMUM AND AVERAGE DIFFERENCES BETWEEN ACCEPTED DUPLICATES.

Constituent	Maximum difference between accepted duplicates. Per cent.	Average difference between accepted duplicates. Per cent.
Nitrogen	.012	.005
Potash	.010	.004
Phosphoric acid	.040	.010
Carbon dioxide	.510*	.067

* In only three cases was the maximum difference as high as this and in these cases the carbon dioxide content was over 5%.

PHYSICAL CONSTANTS.

Moisture Equivalents.

One characteristic physical property of a soil is its capacity to retain moisture. This is influenced chiefly by its texture and has an important bearing on the production of crops. The texture of a soil is usually determined by a mechanical analysis, which separates the soil particles into groups which are dependant upon the size of the grains. Owing to the tediousness of the method, which requires several days for its completion, it is expensive to use where a large number of soils are being examined. Briggs and McLane have devised a method of measuring the relative moisture retentiveness of soils which is rather rapid in execution. This method is termed the Moisture Equivalent Method and is described by

Briggs and McLane in an article published 1910.[1]
The moisture equivalents were determined on all the foot sections collected in this investigation and the resluts are reported in Table VIII. which shows the moisture equivalents of individual samples from five borings with the averages for each foot for each area. By taking the average of Sets 1 and 2 from each field in each area and tabulating the results in Table IX. we have the moisture equivalents expressed from ten borings. In some cases it will be seen that there is a marked difference between Sets 1 and 2 from the same field. These differences are tabulated in Table X. where it will be noted that the average differences of the areas grow less from the first foot to the third foot.

The eastern loess from the Caledonia and Preston

1. Proceedings American Society of Agronomy. Vol.II P.138(1910).

TABLE VIII. MOISTURE EQUIVALENTS OF INDIVIDUAL SAMPLES FROM FIVE BORINGS.

	FIELD I. Set 1.	FIELD I. Set 2.	FIELD II. Set 1.	FIELD II. Set 2.	FIELD III. Set 1.	FIELD III. Set 2.	FIELD IV. Set 1.	FIELD IV. Set 2.	FIELD V. Set 1.	FIELD V. Set 2.	Average
CALEDONIA AREA											
1st Ft.	22.2	21.8	24.2	23.3	23.1	24.6	25.0	23.7	23.7	23.6	23.5
2nd Ft.	24.1	23.9	25.5	24.6	25.4	25.8	25.3	25.3	24.6	25.1	25.0
3rd Ft.	25.5	25.4	26.5	26.1	26.4	26.4	25.9	25.7	25.6	24.9	25.8
PRESTON AREA											
1st Ft.	23.9	22.8	22.7	24.6	23.2	24.4	24.3	23.3	21.7	21.4	23.2
2nd Ft.	24.1	24.3	23.7	24.3	23.8	24.1	25.3	25.2	23.9	23.2	24.2
3rd Ft.	25.3	25.1	24.5	24.2	24.5	24.5	25.2	25.3	24.9	24.7	24.8
SPRING VALLEY AREA											
1st Ft.	22.8	24.0	29.4	30.0	22.5	21.7	17.2	20.6	25.0	25.0	23.8
2nd Ft.	19.8	19.4	24.4	24.4	18.3	17.4	14.6	15.1	21.3	21.1	19.6
3rd Ft.	16.8	18.5	21.8	22.2	16.1	14.4	11.4	11.3	17.1	16.0	16.6
ALBERT LEA AREA											
1st Ft.	28.5	27.8	27.5	32.3	20.8	23.1	20.0	18.4			24.8
2nd Ft.	25.5	24.5	27.4	28.9	19.8	21.5	16.7	16.6			22.6
3rd Ft.	26.0	25.3	27.2	28.2	21.2	22.1	15.2	15.2			22.4
WELLS AREA											
1st Ft.	38.8	43.0	35.4	38.4	36.3	39.0	41.5	39.7	36.5	39.9	38.9
2nd Ft.	32.4	33.0	30.4	28.7	28.6	30.3	33.6	32.0	31.2	32.4	31.3
3rd Ft.	28.8	30.5	27.0	26.7	27.0	27.7	28.8	28.2	29.0	31.7	28.5
FAIRMONT AREA											
1st Ft.	29.8	22.8	26.2	29.4	26.0	26.0	23.7	24.0	28.1	25.8	26.2
2nd Ft.	26.6	20.4	23.8	23.6	23.6	24;1	21.4	22.4	25.3	25.0	23.6
3rd Ft.	21.8	20.1	22.2	21.5	21.6	22.4	20.7	20.9	26.2	23.0	22.0

TABLE VIII. (Concluded)

	FIELD I. Set 1.	FIELD I. Set 2.	FIELD II. Set 1.	FIELD II. Set 2.	FIELD III. Set 1.	FIELD III. Set 2.	FIELD IV. Set 1.	FIELD IV. Set 2.	FIELD V. Set 1.	FIELD V. Set 2.	Average
JACKSON AREA											
1st Ft.	32.2	34.2	35.2	34.5	30.0	29.2	34.6	31.7	29.1	29.5	32.0
2nd Ft.	24.9	29.7	29.9	30.0	27.1	27.6	28.5	29.8	27.1	26.4	28.1
3rd Ft.	23.3	26.0	25.4	25.1	24.9	25.2	24.3	24.9	24.7	24.7	24.9
WORTHINGTON AREA											
1st Ft.	29.2	31.1	34.9	35.0	37.0	26.2	26.3	27.4	33.0	32.1	31.2
2nd Ft.	28.0	28.3	33.3	31.5	32.0	25.0	22.9	24.7	31.3	32.2	28.9
3rd Ft.	24.9	22.6	31.7	32.2	31.3	22.4	21.3	21.1	24.2	28.3	26.0
ADRIAN AREA											
1st Ft.	32.7	31.0	28.7	30.7	22.5	24.3	30.7	27.4	24.0	23.8	27.6
2nd Ft.	30.9	29.6	25.2	28.6	15.6	15.9	28.9	27.1	20.3	21.3	24.3
3rd Ft.	24.4	24.9	21.9	24.4	16.6	13.8	26.0	25.7	17.7	16.3	21.2
LUVERNE AREA											
1st Ft.	31.3	30.0	31.0	31.1	33.1	34.3	32.1	32.8	31.5	30.6	31.9
2nd Ft.	28.4	24.3	27.2	28.8	28.8	30.0	30.5	30.9	28.0	26.5	28.4
3rd Ft.	24.9	20.6	23.2	25.4	26.1	27.0	27.1	27.0	23.6	23.7	24.9

TABLE IX. MOISTURE EQUIVALENTS OF SAMPLES FROM TEN BORINGS.

Depth Foot	Field I.	Field II.	Field III.	Field IV.	Field V.	Average.
			CALEDONIA AREA			
1	22.0	23.8	23.9	24.4	23.7	23.5
2	24.8	25.1	25.6	25.3	24.9	25.0
3	25.5	26.3	26.4	25.8	25.3	25.8
			PRESTON AREA			
1	23.4	23.7	23.8	23.8	21.6	23.2
2	24.2	24.0	24.0	25.3	23.6	24.2
3	25.2	24.4	24.5	25.3	24.8	24.8
			SPRING VALLEY AREA			
1	23.4	29.7	22.1	18.9	25.0	23.8
2	19.6	24.4	17.9	14.9	21.2	19.6
3	17.7	22.0	15.3	11.4	16.6	16.6
			ALBERT LEA AREA			
1	28.2	29.9	22.0	19.2		24.8
2	25.0	28.2	20.7	16.7		22.6
3	25.7	27.7	21.7	15.2		22.4
			WELLS AREA			
1	40.9	36.9	37.7	40.6	38.2	38.9
2	32.7	29.6	30.0	32.8	31.8	31.3
3	29.7	26.9	27.4	28.5	30.4	28.5

TABLE IX. (Concluded)

Depth Foot	Field I.	Field II.	Field III.	Field IV.	Field V.	Average
			FAIRMONT AREA			
1	26.3	27.8	26.0	23.9	27.0	26.2
2	23.5	23.7	23.9	21.9	25.2	23.6
3	21.0	21.9	22.0	20.8	24.6	22.0
			JACKSON AREA			
1	33.2	34.9	29.6	33.2	29.3	32.0
2	27.3	30.0	27.4	29.2	26.8	28.1
3	24.7	25.3	25.1	24.6	24.7	24.9
			WORTHINGTON AREA			
1	30.2	35.0	31.6	26.9	32.6	31.2
2	28.2	32.4	29.0	23.8	31.8	28.9
3	23.8	32.0	26.9	21.2	26.3	26.0
			ADRIAN AREA			
1	31.9	29.7	23.4	29.1	23.9	27.6
2	30.3	26.9	15.8	28.0	20.8	24.3
3	24.7	23.2	15.2	25.9	17.0	21.2
			LUVERNE AREA			
1	30.7	31.1	33.7	32.5	31.1	31.9
2	26.4	28.0	29.4	30.8	27.3	28.4
3	22.8	24.3	26.6	27.1	23.7	24.9

TABLE X. DIFFERENCES BETWEEN MOISTURE EQUIVALENTS OF DUPLICATE SAMPLES FROM THE SAME DEPTH IN THE SAME FIELD.

Depth Foot	Field I.	Field II.	Field III.	Field IV.	Field V.	Average
			CALEDONIA AREA			
1	.4	.9	1.5	1.3	.1	.8
2	.2	.9	.4	.0	.5	.4
3	.1	.4	.0	.2	.7	.3
			PRESTON AREA			
1	1.1	1.9	1.2	1.0	.3	1.1
2	.2	.6	.3	.1	.7	.4
3	.2	.3	.0	.1	.2	.2
			SPRING VALLEY AREA			
1	1.2	.6	.8	3.4	.0	1.2
2	.4	.0	.9	.5	.2	.4
3	1.7	.4	1.7	.1	1.1	1.0
			ALBERT LEA AREA			
1	.7	4.8	2.3	1.6	[illegible]	2.3
2	1.0	1.5	1.7	.1	[illegible]	1.1
3	.7	1.0	.9	.0	[illegible]	.6
			WELLS AREA			
1	4.2	3.0	2.7	1.8	3.4	3.2
2	.6	1.7	1.7	1.6	1.2	1.4
3	1.7	.3	.7	.6	2.7	1.2

TABLE X. (Concluded)

Depth Foot	Field I.	Field II.	Field III.	Field IV.	Field V.	Average
			FAIRMONT AREA			
1	7.0	3.2	.0	.3	2.3	2.6
2	6.2	.2	.5	1.0	.3	1.6
3	1.7	.7	.8	.2	3.2	1.3
			JACKSON AREA			
1	2.0	.7	.8	2.9	.4	1.4
2	5.2	.2	.5	1.3	.7	1.6
3	2.7	.3	.3	.6	.0	.8
			WORTHINGTON AREA			
1	1.9	.1	10.8	1.1	.9	3.0
2	.3	1.8	7.0	1.8	.9	2.4
3	2.3	.5	8.9	.2	4.1	3.2
			ADRIAN AREA			
1	1.7	2.0	1.8	3.3	.2	1.8
2	1.3	3.4	.3	1.8	1.0	1.6
3	.5	2.5	2.8	.3	1.4	1.5
			LUVERNE AREA			
1	1.3	.1	1.2	.7	.9	.8
2	4.1	1.6	1.2	.3	1.5	1.7
3	4.3	2.2	.9	.1	.1	1.5

areas is very uniform in texture, averaging 24.4 for the first, second and third feet with a maximum of 26.4 and a minimum of 21.7. As will be seen there is no great variation between the individual fields, the texture in all cases being practically uniform. The texture of the western loess is somewhat finer, having an average of 28.4 for the first, second and third feet, with a maximum of 34.3 and a minimum of 20.6. The third foot samples average almost the same as those from the eastern loess. The high equivalents of the first and second feet can be explained by the fact that the organic matter is much higher in the western area. The soils from the eastern loess were obtained from wooded areas where no vegetation was growing while the western loess has a heavy growth of prairie grass. Taking this fact into consideration it may be safe to state that the loess, both eastern and western is of practically uniform texture.

The average texture of the soils on the Kansan glaciation is the coarsest of all as would be expected from the sandy condition of the drift. Here we have a maximum of 30.0 and a minimum of 11.3.

The soils on the Late Wisconsin glaciation present cases that are difficult to interpret. As will be seen the texture is very variable, the moisture equivalent ranging all the way from 15.2 to 41.5. The flat, poorly drained areas of Wells and Jackson, where the organic content is high, naturally show the highest equivalent. The only explanation of the varying results of the samples from the other areas is that different soil types are represented in the samples that were collected.

The soils on the glaciation of Undetermined Age show a texture very similar to those on the Late Wisconsin.

HYGROSCOPIC COEFFICIENTS.

In addition to the moisture equivalent for expressing the relative texture of soils, there is a method which was long ago developed by Hilgard, termed the hygroscopic coefficient. Briefly stated, this represents the percentage of water found when a dry soil has been placed in a saturated atmosphere and allowed to stand until equilibrium is established. Briggs and Shantz[2] have found that there exists a relationship between the two methods, this being expressed by the formula $H.C. = \frac{M.E.}{2.71}$ Using this factor, the hygroscopic coefficients have been determined from the moisture equivalents shown in Table VIII. These results are given for each set for each field in Table XI.. Table XII. reports the results for each field from ten borings.

(2) Bulletin 230. Bureau of Plant Industry. U.S.D.AG.

TABLE XI. HYGROSCOPIC COEFFICIENTS* OF INDIVIDUAL SAMPLES FROM FIVE BORINGS.

Depth Foot	FIELD I. Set1	Set 2	Av.	FIELD II. Set 1	Set 2	Av.	FIELD III. Set 1	Set 2	Av.
				CALEDONIA AREA					
1	8.2	8.1	8.2	9.0	8.6	8.8	8.5	9.1	8.8
2	8.9	8.8	8.9	9.4	9.1	9.3	9.4	9.5	9.5
3	9.4	9.4	9.4	9.8	9.7	9.8	9.8	9.8	9.8
				PRESTON AREA					
1	8.8	8.4	8.6	8.4	9.1	8.8	8.6	9.0	8.8
2	8.9	9.0	9.0	8.8	9.0	8.9	8.8	8.9	8.9
3	9.4	9.3	9.4	9.1	9.0	9.1	9.1	9.1	9.1
				SPRING VALLEY AREA					
1	9.4	8.9	9.2	10.9	11.1	11.0	8.3	8.0	8.2
2	7.3	7.2	7.3	9.0	9.0	9.0	6.8	6.4	6.6
3	6.2	6.8	6.5	8.1	8.2	8.2	6.0	5.3	5.7
				ALBERT LEA AREA					
1	10.5	10.3	10.4	10.2	11.9	11.1	7.7	8.5	8.6
2	9.4	9.1	9.3	10.1	10.7	10.4	7.3	8.0	7.7
3	9.6	9.4	9.5	10.1	10.4	10.3	7.8	8.2	8.0
				WELLS AREA					
1	14.4	15.9	15.2	13.1	14.2	13.7	13.4	14.4	13.9
2	12.0	12.2	12.1	11.2	10.6	10.9	10.6	11.2	10.9
3	10.7	11.3	11.0	10.0	9.8	9.9	10.0	10.2	10.1

*Hygroscopic Coefficients calculated from the Moisture Equivalents using the factor .37 as given by Briggs and Shantz.

FIELD IV.			FIELD V.			
Set 1	Set 2	Av.	Set 1	Set 2	Av.	Av. for Area
9.2	8.8	9.0	8.8	8.7	8.8	8.7
9.4	9.4	9.4	9.1	9.3	9.2	9.2
9.6	9.5	9.6	9.5	9.2	9.3	9.5
9.0	8.6	8.8	8.0	7.9	8.0	8.6
9.4	9.3	9.4	8.8	8.6	8.7	9.0
9.3	9.4	9.4	9.2	9.1	9.2	9.2
6.4	7.6	7.0	9.2	9.2	9.2	8.8
5.4	5.6	5.5	7.9	7.8	7.9	7.3
4.2	4.2	4.2	6.3	5.9	6.1	6.1
7.4	6.8	7.1				9.2
6.2	6.1	6.2				8.4
5.6	5.6	5.6				8.3
15.4	14.7	15.1	13.5	14.8	14.2	14.4
12.4	11.8	12.1	11.5	12.0	11.7	11.6
10.7	10.4	10.6	10.7	11.7	11.2	10.5

TABLE XI. (Continued)

Depth Foot	FIELD I. Set 1	Set 2	Av.	FIELD II. Set 1	Set 2	Av.	FIELD III. Set 1	Set 2	Av.
				FAIRMONT AREA					
1	11.0	8.4	9.7	9.7	10.9	10.3	9.6	9.6	9.6
2	9.8	7.5	8.7	8.8	8.7	8.8	8.7	8.9	8.8
3	8.1	7.4	7.8	8.2	8.0	8.1	8.0	8.3	8.2
				JACKSON AREA					
1	11.9	12.6	12.3	13.0	12.8	12.9	11.1	10.8	11.0
2	9.2	11.0	10.1	11.1	11.1	11.1	10.0	11.2	10.6
3	8.6	9.6	9.1	9.4	9.3	9.4	9.2	9.3	9.3
				WORTHINGTON AREA					
1	10.8	11.5	11.2	12.9	13.0	13.0	13.7	13.4	13.5
2	10.4	10.5	10.5	12.3	11.7	12.0	11.9	9.2	10.6
3	9.2	8.4	8.8	11.7	11.9	11.8	11.6	8.3	10.0
				ADRIAN AREA					
1	12.1	11.5	11.8	10.6	11.4	11.0	8.3	9.0	8.7
2	11.4	11.0	11.2	9.3	10.6	10.0	5.8	5.9	5.9
3	9.0	9.2	9.1	8.7	9.0	8.9	6.1	5.1	5.6
				LUVERNE AREA					
1	11.6	11.1	11.4	11.5	11.5	11.5	12.2	12.7	12.8
2	10.5	9.0	9.8	10.1	10.7	10.4	10.7	11.1	10.9
3	9.2	7.6	8.4	8.6	9.4	9.0	9.7	10.0	9.9

FIELD IV.			FIELD V.			
Set 1	Set 2	Av.	Set 1	Set 2	Av.	Av. for Area
9.8	8.9	9.4	10.4	9.5	10.0	9.7
7.9	8.3	8.1	9.4	9.3	9.4	8.7
7.6	7.7	7.7	9.7	8.5	9.1	8.1
12.8	11.7	12.3	10.8	10.9	10.9	11.8
10.5	11.0	10.8	10.0	9.7	9.9	10.4
9.0	9.2	9.1	9.1	9.1	9.1	9.2
9.6	10.1	9.9	12.2	11.9	12.1	11.5
8.5	9.1	8.8	11.6	11.9	11.8	10.7
7.9	7.8	7.9	8.9	10.5	9.7	9.6
11.4	10.1	10.8	8.9	8.8	8.9	10.2
10.7	10.0	10.4	7.5	7.9	7.7	9.0
9.6	9.5	9.6	6.5	6.0	6.3	7.8
11.9	12.1	12.0	11.7	11.3	11.5	11.8
11.3	11.4	11.4	10.4	9.8	10.1	10.5
10.1	10.0	10.1	8.7	8.8	8.8	9.2

TABLE XII. HYGROSCOPIC COEFFICIENTS OF SAMPLES FROM TEN BORINGS*

Depth Feet	FIELD I.	FIELD II.	FIELD III.	FIELD IV.	FIELD V.	Average
			CALEDONIA AREA			
1	8.2	8.8	8.8	9.0	8.8	8.7
2	8.9	9.3	9.5	9.4	9.2	9.2
3	9.4	9.8	9.8	9.6	9.4	9.5
			PRESTON AREA			
1	8.6	8.8	8.8	8.8	8.0	8.6
2	9.0	8.9	8.9	9.4	8.7	9.0
3	9.4	9.1	9.1	9.4	9.2	9.2
			SPRING VALLEY AREA			
1	9.2	11.0	8.2	7.0	9.2	8.8
2	7.3	9.0	6.6	5.5	7.9	7.3
3	6.5	8.2	5.8	4.2	6.1	6.1
			ALBERT LEA AREA			
1	10.4	11.1	7.8	7.1		9.2
2	9.3	10.4	7.7	6.2		8.4
3	9.5	10.3	8.0	5.6		8.3
			WELLS AREA			
1	15.2	13.7	13.9	15.1	14.2	14.4
2	12.1	10.9	10.9	12.1	11.8	11.6
3	11.0	9.9	10.1	10.6	11.2	10.5

*Hygroscopic Coefficients calculated from the Moisture Equivalents using the factor .37 as given by Briggs and Shantz.

TABLE XII. (Concluded)

Depth Foot	FIELD I.	FIELD II.	FIELD III.	FIELD IV.	FIELD V.	Average
			FAIRMONT AREA			
1	9.7	10.3	9.6	9.4	10.0	9.7
2	8.9	8.8	8.8	8.1	9.4	8.7
3	7.8	8.1	8.2	7.7	9.1	8.1
			JACKSON AREA			
1	12.3	12.9	11.0	12.3	10.9	11.8
2	10.1	11.1	10.6	10.8	9.8	10.4
3	9.1	9.4	9.3	9.1	9.1	9.2
			WORTHINGTON AREA			
1	11.2	13.0	13.8	9.9	12.1	11.5
2	10.5	11.5	10.6	8.8	11.8	10.7
3	8.8	11.8	10.0	7.9	9.7	9.6
			ADRIAN AREA			
1	11.8	11.0	8.7	10.8	8.9	10.2
2	11.2	10.0	5.9	10.4	7.7	9.0
3	9.1	8.9	5.6	9.6	6.3	7.8
			LUVERNE AREA			
1	11.4	11.5	12.5	12.0	11.5	11.8
2	9.8	10.4	10.9	11.4	10.1	10.5
3	8.4	9.0	9.8	10.1	8.7	9.2

SOIL ACIDITY.

All samples collected in the first year were tested for acidity by both litmus, using the Kellerman modification and by the Hopkins quantitative method for the lime requirement.

The results obtained by both methods are unsatisfactory as recent work done in this laboratory on both methods seems to have shown them unreliable.

Table XIV. reports the results obtained by the two methods, and by treatment with dilute hydrochloric acid, all the samples being from the surface foot. It will be seen in the case of the samples from the fields of the Caledonia Area that all except one are neutral by the litmus test, that according to the Hopkins test lime is required on all of the fields and that none of the samples showed any action with dilute hydrochloric acid.

TABLE XIV. COMPARISON OF RESULTS OBTAINED BY ACIDITY TESTS ON THE FIRST FOOT FROM THE DIFFERENT FIELDS.

CALEDONIA AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	30	330	45	45	15
Litmus Test	0	0	0	0	2
Action of Hydrochloric Acid	0	0	0	0	0

PRESTON AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	none	none	none	none	none
Litmus Test	0	0	0	0	0
Action of Hydrochloric Acid	0	0	0	0	0

SPRING VALLEY AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	15	150	30	30	30
Litmus Test	0	0	0	1	1
Action of Hydrochloric Acid	0	0	0	0	0

ALBERT LEA AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	30	30	30	60	
Litmus Test	0	0	0	0	
Action of Hydrochloric Acid	0	0	0	0	

KEY

Litmus method 0 = neutral, 1=very sl. acid, 2=sl. acid, 3=distinctly acid

Action of hydrochloric acid 0= no action, 1=very sl. action, 2=slight action, 3=strong action.

TABLE XIV. (Continued)

WELLS AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	none	none	none	none	none
Litmus Test	0	0	0	0	0
Action of Hydrochloric Acid	0	1	3	3	2

FAIRMONT AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	15	none	none	none	45
Litmus Test	0	0	0	0	0
Action of Hydrochloric Acid	0	3	0	0	0

JACKSON AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	none	none	none	none	30
Litmus Test	0	0	0	0	0
Action of Hydrochloric Acid	3	1	1	2	0

WORTHINGTON AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	none	none	none	21	none
Litmus Test	2	0	2	3	3
Action of Hydrochloric Acid	1	1	0	0	1

TABLE XIV. (Continued)

ADRIAN AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	6	36	36	60	0
Litmus Test	3	3	3	3	2
Action of Hydrochloric Acid	0	0	0	0	0

LUVERNE AREA

	Field I.	Field II.	Field III.	Field IV.	Field V.
Pounds Lime Required by Hopkins	none	none	60	30	none
Litmus Test	2	0	2	3	3
Action of Hydrochloric Acid	1	1	0	0	0

In the Preston Area all the fields according to the litmus test are neutral, none by the Hopkins determination show a lime requirement and none showed any action with dilute hydrochloric acid.

At Spring Valley three fields were found to be neutral and two slightly acid by litmus. By the Hopkins determination all fields were found to require lime and none of the soils showed any action with dilute hydrochloric acid.

At Albert Lea all four fields were neutral according to he litmus test and the Hopkins determination indicated that lime was required on all of them. None of the samples showed any action with dilute hydrochloric acid.

At Wells all five fields, according to the litmus test were neutral and the Hopkins determination showed no lime requirement in the case of any. All except one showed a distinct action with dilute hydrochloric acid.

At Jackson all five fields were neutral according to the litmus test, while by the Hopkins determination one requires lime. Four of the samples showed an action with dilute hydrochloric acid.

At Worthington, by the litmus test, one field was found neutral and four acid while by the Hopkins determination only one was found to require lime. Three of the samples effervesced with dilute hydrochloric acid.

In the Adrian Area all five fields, by the litmus test, appeared acid, while by the Hopkins determination four fields were found to require lime. None of the samples reacted with dilute hydrochloric acid.

At Luverne four fields with litmus reacted acid and one was neutral, while according to the Hopkins determination two fields required lime. Three of the samples reacted with dilute hydrochloric acid.

The six-inch samples, three composites from each field from the areas of Caledonia, Preston, Spring Valley and Luverne, were later subjected to the two acidity methods and as will be seen from Table XV. every soil was acid by the litmus test and, with one exception, all were found by the Hopkins determination to require liming. The lime requirement for the three samples from each field differed widely in many cases, some of the fields showing a close agreement, such as those at Luverne, while in others as at Caledonia, one sample showed a lime requirement of 360 pounds per acre, while another, which was taken less than ten rods away, showed a lime requirement of 3600 pounds per acre.

A word of explanation is in place concerning the use of litmus paper in making the litmus test. By using a cheap quality it is almost impossible to get a reaction by the end of an hour and often ten hours fail to show a reaction. In case of thefirst foot

TABLE XV. COMPARISON OF RESULTS OBTAINED BY ACIDITY TESTS ON THE SURFACE SIX-INCHES.

FIELD I.		FIELD II.		FIELD III.	
Pounds Lime Required	Acidity by Litmus	Pounds Lime Required	Acidity by Litmus	Pounds Lime Required	Acidity by Litmus
		CALEDONIA AREA			
1350	2	3600	2	2010	2
3600	2	360	2	1800	2
960	1	360	2	1980	1
		PRESTON AREA			
180	2	240	2	180	1
420	2	210	2	180	2
180	2	150	1	180	2
		SPRING VALLEY AREA			
720	2	450	3	180	3
2820	3	420	3	420	2
540	3	150	2	180	3
		LUVERNE AREA			
60	3	60	3	60	3
60	3	60	3	60	3
90	3	60	3	90	3

KEY

1 = very slightly acid

2 = slightly acid

3 = acid

FIELD IV. Pounds Lime Required	FIELD IV. Acidity by Litmus	FIELD V. Pounds Lime Required	FIELD V. Acidity by Litmus
	CALEDONIA AREA		
90	2	150	2
90	1	300	2
150	2	960	2
	PRESTON AREA		
240	1	210	2
330	2	150	3
210	1	2400	3
	SPRING VALLEY AREA		
90	3	360	3
90	3	90	3
90	3	210	2
	LUVERNE AREA		
60	3	30	2
none	2	60	3
60	3	60	3

samples Bausch and Lamb's litmus paper was used, while Squibbs', a more sensitive grade, was used on the six-inch samples.

TOTAL NITROGEN

Nitrogen determinations were made on only the samples from the first six inches and from the first foot. The nitrogen content of the first foot from each virgin field is given in Table XVI. with the average for the area. Table XVII. shows the nitrogen content in each set from each field with the difference and with the average for each field. The soils of the Late Wisconsin glaciation are far richer in nitrogen than those of the forest covered fields on the loess areas of Caledonia and Preston and the soils on the Kansan glaciation at Spring Valley. On the prairies on the western loess the virgin fields show twice as high a nitrogen content. The average nitrogen content of the soils on the drift of Undetermined Age, those of the Adrian Area, is very close to that of those on the Late Wisconsin. It will be seen that in the case of some fields there is a wide difference between the percentages of nitrogen in the two samples from the same

TABLE XVI. NITROGEN IN SURFACE FOOT OF VIRGIN SOIL.

	FIELD I. P.ct.	FIELD II. P.ct.	FIELD III. P.ct.	FIELD IV. P.ct.	FIELD V. P.ct.	AVERAGE P.ct.
CALEDONIA AREA	.094	.142	.119	.167	.148	.134
PRESTON AREA	.127	.138	.111	.107	.089	.114
SPRING VALLEY AREA	.157	.294	.186	.144	.168	.190
ALBERT LEA AREA	.269	.274	.197	.195		.234
WELLS AREA	.421	.399	.331	.450	.401	.400
FAIRMONT AREA	.279	.290	.234	.212	.223	.247
JACKSON AREA	.330	.337	.305	.412	.308	.338
WORTHINGTON AREA	.288	.348	.303	.255	.282	.295
ADRIAN AREA	.289	.307	.251	.285	.219	.270
LUVERNE AREA	.262	.300	.299	.271	.282	.283

TABLE XVII. NITROGEN IN SURFACE FOOT OF VIRGIN SOILS.

FIELD I.				FIELD II.				FIELD III.			
S.1 P.ct.	S.2 P.ct.	Diff. P.ct.	Av. P.ct.	S.1 P.ct.	S.2 P.ct.	Diff. P.ct.	Av. P.ct.	S.1 P.ct.	S.2 P.ct.	Diff. P.ct.	Av. P.ct.
CALEDONIA AREA											
.099	.088	.011	.094	.161	.122	.039	.142	.107	.130	.023	.119
PRESTON AREA											
.139	.114	.025	.127	.114	.161	.047	.138	.109	.113	.004	.111
SPRING VALLEY AREA											
.145	.168	.023	.159	.289	.298	.009	.294	.200	.171	.029	.186
ALBERT LEA AREA											
.278	.260	.018	.269	.236	.312	.076	.274	.182	.211	.029	.197
WELLS AREA											
.404	.438	.034	.421	.379	.418	.039	.399	.356	.306	.050	.331
FAIRMONT AREA											
.298	.259	.039	.279	.295	.285	.010	.290	.243	.224	.019	.234
JACKSON AREA											
.329	.330	.001	.330	.332	.341	.009	.337	.292	.317	.025	.305
WORTHINGTON AREA											
.283	.293	.010	.288	.310	.385	.075	.348	.349	.257	.092	.303
ADRIAN AREA											
.302	.275	.027	.289	.314	.299	.015	.307	.252	.250	.002	.251
LUVERNE AREA											
.272	.252	.020	.262	.319	.280	.039	.300	.291	.306	.015	.299

FIELD IV.				FIELD V.			
S.1 P.ct.	S.2 P.ct.	Diff. P.ct.	Av. P.ct.	S.1 P.ct.	S.2 P.ct.	Diff. P.ct.	Av. P.ct.
.188	.145	.043	.167	.146	.149	.003	.148
.114	.099	.015	.107	.087	.091	.004	.089
.144	.144	.	.144	.167	.169	.003	.168
.206	.184	.022	.195				
.478	.421	.057	.450	.412	.390	.022	.401
.209	.215	.006	.212	.217	.229	.012	.223
.427	.396	.031	.412	.309	.307	.002	.308
.246	.264	.018	.255	.292	.271	.021	.282
.301	.268	.033	.285	.203	.235	.030	.219
.261	.281	.020	.271	.258	.305	.047	.282

field, the extreme being shown by Field III. of the Worthington Area where the two samples contained .349 and .257 per cent respectively, a difference of .092, or 35 per cent of the lower. These samples differ markedly in texture, their moisture equivalents being 37.0 and 26.2, respectively. This difference in texture may account for the wide difference in nitrogen in these two samples. But on the other hand in Field II. of the Caledonia Area, where the texture of the duplicate samples is practicallythe same the nitrogen content of these is .161 and .122 per cent, respectively, a difference of .039, or 32 per cent of the latter. In other fields in which the duplicate samples are similar in texture, the nitrogen content differs greatly, for example Field IV. of the Wells Area where the nitrogen content of the duplicate samples is .478 and .421 per cent, a difference of .057, Field II of the Worthington Area whsre the nitrogen percentages are .385 and .310 with a difference of

.075. There the difference in texture fails to account for the difference in nitrogen content of duplicate samples from the same virgin field.

In an investigation carried on by Alway and Trumbull[6] "On the Sampling of Prairie Soils" they have found "that the difference found between individual samples taken close together are as great as those found between the soil of long cultivated fields and that of adjacent virgin prairies, that the difference becomes less when a composite of a number of individual samples is used. By using a composite of five samples the extremes would have become .304 per cent and .276 per cent, the difference becoming half or less of what they were found to be when the individual samples were composited. By combining from 10 to 15 individual samples as composites for analyses the extremes would have been for nitrogen .281 and .297 per

6. 25th Annual Report. Nebr. Agr. Exp. Station.

cent, the difference being half as great as with the composite of five. By increasing the number of individual samples used for the composites to 20 the difference between the different composites would have become less than the experimental error of analysis".

It is evident from the work with composites from five borings that a much larger number of borings is desirable in the study of changes in the nitrogen content in the soil.

In the case of the Caledonia, Preston, Spring Valley Areas the five virgin fields were sampled to a depth of six inches. From each field, three composites, each from ten borings, thirty yards apart, were taken and the nitrogen in these determined. Five long cultivated fields in each of these four areas were similarly sampled, but the soil from the thirty borings ten yards apart, was made into a single composite. In the case of the cultivated fields an effort was made to secure those which had longest been under cultivation and which had received the least manuring, so as to secure those in which the loss of nitrogen would be most marked. The importance of the history of these fields in such a connection is so great that the history of each so far as it was ascertained is given below.

Field I. Caledonia Area. This field has been in pasture the last three years. Oats and corn in rotation had been grown previously. So far as is known no manure was ever applied.

Field II. Caledonia Area. Corn has been grown on this field for the last three years while in the year previous to this oats has been harvested. No manure had been applied.

Field III. Caledonia Area. This field is in poor condition, weeds are thriving in all parts of the field. Corn has been planted for the last two or three years.

No leguminous crops have been grown and no manure has been applied.

Field IV. Caledonia Area. Weeds are thick in this field, being very similar to Field III. Corn was planted in 1913 and 1915. So far as could be ascertained no legumes have been grown. There was a good stand of corn, notwithstanding the poor tilth of the soil. The field has never been treated with manure.

Field V. Caledonia Area. Corn has been planted here the last four years. General rotation practiced previously. No legumes have been grown so far as is known. No manure has been applied.

Field I. Preston Area. This field has been under cultivation over forty years. Barley has beenharvested the last two years. Some alsike clover seeded about six years ago, when a light dressing of manure was applied.

Field II. Preston Area. This field has been in pasture the past three years. Barley, flax, corn and oats have been grown. Alsike clover is growing to some extent in this field. The land has never received any manure.

Field III. Preston Area. Corn has been under cultivation here during the past two seasons. Legumes have not been grown and no manure has been applied. The soil is light and in poor tilth.

Field IV. Preston Area. Corn has been planted continuously for the last ten years. Timothy has been grown but no legumes. The land has never received any barnyard manure. There are patches of alsike clover growing wild.

Field V. Preston Area. Corn and oats have been grown in rotation for the past ten years without the addition of manure, and previously the field has been in pasture. No clover seeded but some is growing wild.

Field I. Spring Valley Area. Timothy has been cut from this field for several seasons. It has been in corn the last few years. No legumes have been grown and no manure has ever been applied.

Field II. Spring Valley Area. This field has been cropped continuously for the last forty years to corn, oats and timothy. No leguminous crops have been grown and manure has never been applied.

Field III. Spring Valley Area. This field has been in pasture the past two years. There is a heavy stand of clover on it and the soil is heavy and rich in organic matter. Some hay, barley and oats have been grown. No cultivated crops have been grown the past ten years and it has never received barnyard manure.

Field IV. Spring Valley Area. Corn has been planted here in 1913 and 1914. Some clover may have been seeded some years ago but information regarding same could not be obtained. So far as is known no manure has been applied.

Field V. Spring Valley Area. This field has been under continuous cultivation for over forty years. No legumes have been grown the last ten years and no manure has been applied.

Field I. Luverne Area. This field has been planted to corn for several years. Oats has been raised to some extent. No legumes have been grown and no manure has been applied.

Field II. Luverne Area. This piece has been in corn the last two years, and in tame grass pasture for some time previous to this. No manure has ever been applied to this land.

Field III. Luverne Area. Corn and oats have been grown in rotation for the past seven years. Previous to this some timothy and clover was grown. This piece received a light dressing of manure about seven years ago.

Field IV. Luverne Area. Oats has been harvested from this piece the last two years. Some clover was seeded about five years ago, also a light dressing of manure was applied.

Field V. Luverne Area. Corn and oats have been grown in rotation for some time. No manure has been applied and no leguminous crops have been grown.

Table XVIII. shows the changes in the nitrogen content of the twenty cultivated fields compared with those of adjacent virgin fields. Considering only the averages of the five fields from the same area we find there has been a marked gain in nitrogen at Caledonia, a very slight loss at Preston, a distinct gain at Spring Valley and a distinct loss at Luverne. In the fields from the Caledonia Area there would appear to have been a gain in every case. In the fields from the Preston Area, three fields appear to show a loss, while two show a gain. In the fields from the Spring Valley Area, with one exception, there has apparently been a gain while in the fields from Luverne there appears to have been a loss in every

TABLE XVIII. NITROGEN IN INDIVIDUAL AND COMPOSITE SAMPLES FROM THE SURFACE SIX-INCHES.

Character of Field	Sample	Field I.	Field II.	Field III.	Field IV.	Field V.	AV.
		P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.
				CALEDONIA AREA			
Virgin	Comp. of 10 1.	.100	.117	.186	.203	.133	
Virgin	" " " 2.	.126	.146	.111	.187	.129	
Virgin	" " " 3.	.154	.179	.124	.183	.119	
	Comp. of 30 Av.	.127	.147	.140	.191	.127	.146
Cult'd.	Comp of 30	.153	.173	.223	.225	.223	.199
				PRESTON AREA			
Virgin	Comp of 10 1.	.177	.141	.147	.098	.108	
Virgin	" " " 2.	.134	.144	.157	.090	.125	
Virgin	" " " 3.	.160	.150	.182	.107	.071	
	Comp. of 30 Av.	.157	.145	.162	.098	.101	.133
Cult'd.	Comp. of 30	.120	.122	.098	.135	.144	.124
				SPRING VALLEY AREA			
Virgin	Comp. of 10 1.	.196	.133	.338	.195	.261	
Virgin	" " " 2.	.193	.163	.302	.190	.200	
Virgin	" " " 3.	.201	.163	.339	.207	.284	
	Comp. of 30 Av.	.197	.153	.326	.197	.248	.224
Cult'd.	" " "	.252	.265	.480	.202	.141	.268
				LUVERNE AREA			
Virgin	Comp. of 10 1.	.308	.323	.350	.354	.313	
Virgin	" " " 2.	.310	.323	.363	.310	.300	
Virgin	" " " 3.	.327	.311	.360	.325	.342	
	Comp. of 30 Av.	.315	.319	.358	.330	.318	.320
Cult'd.	" " "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

case.

It is evident that the data do not permit us to readily decide whether a loss or a gain in nitrogen is taking place in the eastern areas even where the soil has been unmanured and kept under cultivation from 25 to 40 years.

Then if all the fields be arranged in the order of their nitrogen content, as shown in Table XIX. a great variety of conclusions can be drawn according to the data upon which comparisons are based. A consideration of the data from the Caledonia area will serve to illustrate this. If virgin field IV. be ignored only gains are found to result from cultivation. Similarly if cultivated fields I. and II. are ignored only gains are shown. The data from the Preston Area is more difficult of comparison but if cultivated fields V., IV. and II. are compared with virgin fields V., and IV. gains results. On the other hand cultivated field V., IV., II., and III.

TABLE XIX. NITROGEN IN SURFACE SIX INCHES OF VIRGIN AND LONG CULTIVATED FIELDS.

CULTIVATED FIELDS				VIRGIN FIELDS		APPARENT CHANGE IN NITROGEN	
Field No.	Years under cultivation	Barnyard Manure applied	Per cent Nitrogen	Nitrogen Per cent	Field No.	Loss P.ct.	Gain P.ct.
			CALEDONIA AREA				
IV.	40	none	.225	.191	IV.		.034
V.	40	none	.223	.147	II.		.076
III.	40	none	.223	.140	III.		.083
II.	30	none	.173	.127	I.		.046
I.	30	none	.153	.127	V.		.026
			PRESTON AREA				
V.	30	none	.144	.162	III.	.018	
IV.	40	none	.135	.157	I.	.022	
II.	25	none	.122	.145	II.	.023	
I.	40	Lt.Dress. 7 yrs.ago	.120	.101	V.		.019
III.	30	none	.098	.098	IV.		
			SPRING VALLEY AREA				
III.	25	none	.480	.326	III.		.154
II.	40	none	.265	.248	V.		.017
I.	40	none	.252	.197	IV.		.055
IV.	40	none	.202	.197	I.		.005
V.	35	none	.141	.153	II.	.012	
			LUVERNE AREA				
III.	30	Lt.Dress. 6 yrs.ago	.353	.358	III.	.005	
I.	30	none	.299	.330	IV.	.031	
IV.	30	Lt.Dress. 7 yrs.ago	.264	.319	II.	.055	
V.	40	none	.250	.318	V.	.068	
II.	30	none	.249	.315	I.	.066	

compared with virgin Fields III., I., IV., and V. show losses.

With the soils from the Spring Valley Area if cultivated Field V. is compared with virgin Fields III., V., IV., I., and II. we find that there has been a marked decrease but if cultivated Fields IV. and V. and virgin Fields III. are ignored there are shown gains caused by cultivation.

Studying the data from the Luverne Area it will be seen that when cultivated Field III. is compared with virgin Fields IV., II., V. and I. no loss is shown, but in the case of the other four cultivated fields distinct losses are shown.

TOTAL PHOSPHORIC ACID.

Table XX. shows the distribution of phosphoric acid in the first, second and third feet of the area composites. It will be seen that the amounts present in the different areas are nearly uniform. In the first foot of the western loess the phosphoric acid is a trifle higher than in the eastern, the second and third feet remaining about the same. No marked regularity is observed in the second foot of the areas while the amount in the third foot is about uniform with the exception of the soils on the Kansan glaciation at Spring Valley in which it runs a little lower.

Table XXI. shows the phosphoric acid in the surface foot of soil of the different fields in each area.

TABLE XX. TOTAL PHOSPHORIS ACID IN FIRST, SECOND AND THIRD FEET OF THE AREA COMPOSITES.

AREA	First Foot Per cent	Second Foot Per cent	Third Foot Per cent
CALEDONIA	.18	.14	.17
PRESTON	.17	.16	.17
SPRING VALLEY	.20	.11	.13
ALBERT LEA	.21	.11	.15
WELLS	.25	.12	.15
FAIRMONT	.17	.12	.16
JACKSON	.15	.16	.18
WORTHINGTON	.15	.12	.17
ADRIAN	.17	.14	.15
LUVERNE	.19	.14	.18

TABLE XXI. PHOSPHORIC ACID CONTENT OF THE SURFACE FOOT OF SOIL OF THE DIFFERENT FIELDS IN EACH AREA.

AREA	Field I. P.ct.	Field II. P.ct.	Field III. P.ct.	Field IV. P.ct.	Field V. P.ct.	AV. P.ct.
CALEDONIA	.17	.19	.20	.17	.17	.18
PRESTON	.19	.24	.17	.16	.13	.17
SPRING VALLEY	.21	.22	.19	.19	.22	.20
ALBERT LEA	.20	.22	.20	.21		.21
WELLS	.25	.24	.27	.28	.23	.25
FAIRMONT	.22	.18	.16	.14	.17	.17
JACKSON	.14	.14	.16	.14	.16	.15
WORTHINGTON	.17	.17	.15	.13	.14	.15
ADRIAN	.17	.19	.19	.18	.15	.17
LUVERNE	.19	.19	.20	.20	.19	.19

TOTAL POTASH.

In the distribution of potash throughout the ten areas there are more marked regularities than in either that of the nitrogen or that of the phosphoric acid. The fields on the loess areas, both the eastern and the western, contain a high percentage compared with those on the Late Wisconsin. The potash in the eastern loess averages 2.33 per cent in the first foot, and that in the western 2.16 per cent. The second and third foot show about the same content.

The average percentage of potash in the first foot of the fields on the Kansan is 1.85, on the Late Wisconsin 1.81 - both containing about the same amount. The amount in the third foot on the Late Wisconsin, however, runs higher than that on the Kansan, being 1.80 percent against 1.57 percent. This loss is probably due to longer and deeper weathering and

and leaching of the older formation. Hopkins[7] in his study of the fertility in the soils of different glaciations in Illinois has found that there is a decided difference in the amount of potash, as well as phosphoric acid, between the early and late glaciations. In the soils examined in this investigation there is found no striking difference. The amounts of phosphoric acid are also very nearly uniform in all areas across this section of the state.

On the drift of Undetermined Age, an earlier glaciation, where the potash would be expected to be low, we found the amount to be nearly equal to that on the loess areas, being over 2.00 per cent. The same is true of the soils from the Worthington Area which contains over 2.00 per cent. Why the soils from the Worthington and Adrian Areas should correspond so closely to the soils on the loess covered

7. Bulletin 123 Illinois Agricultural Experiment Station (1908).

areas in potash content we are unable to explain from the data at hand. An explanation which seems reasonable is that the loess from the west may be commingled with the drift in these two areas which would explain the occurrence of the high potash content. Table XXII. shows the distribution in the first, second and third feet of the area composites.

TABLE XXII. TOTAL POTASH IN FIRST, SECOND AND THIRD FEET OF THE AREA COMPOSITES.

AREA	First Foot Per cent	Second Foot Per cent	Third Foot Per cent
Caledonia	2.31	2.23	2.24
Preston	2.35	2.27	2.34
Average for Eastern Loess	2.33	2.25	2.29
Spring Valley	1.85	1.77	1.57
Albert Lea	1.83	1.94	1.90
Wells	1.60	1.72	1.72
Fairmont	1.78	1.66	1.61
Jackson	1.79	1.69	1.69
Worthington	2.06	2.03	2.09
Average for Late Wisconsin	1.81	1.81	1.80
Adrian	2.07	2.03	1.90
Luverne	2.16	2.46	2.27

CARBONATES.

In Table XXIII. is reported the content of carbon dioxide in the samples from the individual fields. It is very probable that the carbonates present in the fields from Caledonia, Preston and Spring Valley, where the amount varies from .02 to .10 per cent, while not very rich in organic matter may be due to the liberation of carbon dioxide by oxidation.

The amount of carbonates becomes more marked when the Late Wisconsin drift is reached at Albert Lea and continues through the areas of Wells, Fairmont, Jackson and Worthington. The very high percentages in the first and second feet of some of the fields at Wells and Jackson may be explained by the fact that these areas are situated on very low places where the soil is of a heavy clay type and perculation is much impeded. There the carbonates have

TABLE XXIII. CARBON DIOXIDE IN INDIVIDUAL FIELDS.

Depth Foot	Field I. P.ct.	Field II. P.ct.	Field III. P.ct.	Field IV. P.ct.	Field V. P.ct.	Average. P.ct.
			CALEDONIA AREA			
1	.00	.06	.07	.05	.05	.05
2	.00	.10	.00	.00	.00	.02
3	.00	.02	.00	.00	.00	.00
			PRESTON AREA			
1	.00	.06	.03	.06	.00	.03
2	.00	.03	.00	.05	.00	.02
3	.00	.07	.00	.08	.00	.03
			SPRING VALLEY AREA			
1	.08	.04	.05	.04	.03	.05
2	.07	.04	.00	.03	.00	.03
3	.03	.00	.00	.00	.00	.00
			ALBERT LEA AREA			
1	.06	.01	.03	.06		.04
2	.06	.13	.06	.03		.07
3	.08	1.83	.04	.02		.49
			WELLS AREA			
1	.00	.40	6.10	3.53	.86	2.17
2	.00	3.04	5.14	5.33	1.32	2.97
3	.00	5.66	4.44	5.70	2.21	3.59

Depth Foot	Field I. P.ct.	Field II. P.ct.	Field III. P.ct.	Field IV. P.ct.	Field V. P.ct.	Average. P.ct.
			FAIRMONT AREA			
1	.04	3.30	.06	.04	.03	.69
2	.04	5.32	.59	.12	.03	1.22
3	.00	7.38	6.93	2.40	2.15	3.77
			JACKSON AREA			
1	2.37	.25	.09	1.40	.03	.83
2	4.55	.80	.43	2.62	.49	1.78
3	7.25	3.42	3.36	7.58	5.67	5.45
			WORTHINGTON AREA			
1	.11	.10	.65	.03	.08	.19
2	.17	.11	.70	.08	.20	.25
3	4.29	1.89	2.40	3.92	5.99	3.70
			ADRIAN AREA			
1	.00	.04	.02	.02	.05	.03
2	.05	.12	.08	.07	1.41	.35
3	3.99	1.49	.05	.80	4.34	2.17
			LUVERNE AREA			
1	.17	.03	.05	.04	.03	.06
2	1.56	.97	.04	.02	.33	.58
3	2.82	4.12	.03	1.26	3.65	2.37

been more or less held; their loss by leaching having been prevented. The samples from the areas at Albert Lea, Fairmont and Worthington were collected from moraines where the soil is usually lighter and conditions are more favorable for leaching, hence the lower carbonate content in the first and second feet. There is one exception to this, however, that being Field II., from Fairmont which shows an exceedingly large amount in the first and second feet, an explanation for which has as yet not been found.

On the drift of Undetermined Age at Adrian the carbonate content is very similar to that on the Late Wisconsin. The third foot in most cases is well supplied with carbonates.

The fields on the western loess area, with one exception, are very calcareous in the third foot. With this exception the western loess is sharply distinguished from the eastern in this respect. The explanation of this difference is to be found in the fact that the rainfall is considerably less and the evaporation much greater. Further, the loess itself may have originated from material where the lime content was higher.

Table XXIV. shows the amounts of carbonates, calculated as calcium carbonate, in the individual fields. For each field the amounts are shown in the fine material and in the pebbles with the total for each foot of the field.

The proportion of carbonates, with only two exceptions, Field II., Albert Lea, second foot, and Field I., Fairmont, third foot, is greater in the fine material. The difference is especially noticeable in the fields from the flat areas of Wells and Jackson, while on the moraines the percentages are higher as more calcareous pebbles were present.

TABLE XXIV. CALCIUM CARBONATE IN FINE MATERIAL AND IN PEBBLES IN INDIVIDUAL FIELDS.

Depth Foot	FIELD I. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	FIELD II. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	FIELD III. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.
				ALBERT LEA AREA					
1	.14	.00	.14	.02	.00	.02	.14	.00	.14
2	.14	.00	.14	.30	.35	.65	.07	.00	.07
3	.07	.00	.07	4.15	.85	5.00	.02	.00	.02
				WELLS AREA					
1	.00	.00	.00	.51	.00	.51	13.85	.00	13.85
2	.00	.00	.00	6.90	.00	6.90	11.67	1.75	13.42
3	.00	.00	.00	12.85	.22	13.07	10.08	.38	10.46
				FAIRMONT AREA					
1	.09	.00	.09	7.49	.43	7.92	.13	.00	.13
2	.09	.00	.09	12.08	.32	12.40	1.34	.07	1.41
3	.00	.03	.03	16.75	.77	17.52	15.73	1.06	16.79
				JACKSON AREA					
1	5.38	.00	5.38	.57	.00	.57	.20	.00	.20
2	10.33	.18	10.51	1.82	.00	1.82	1.00	.00	1.00
3	16.46	.00	16.46	7.74	.50	8.24	7.63	.48	8.11

FIELD IV.			FIELD V.		
In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	In fine Mat'l. P.ct.	In p. P.ct.	Total P.ct.
.14	.00	.14			
.07	.00	.07			
.02	.00	.02			
8.01	.00	8.01	1.95	.00	1.95
12.10	.00	12.10	3.00	.00	3.00
12.94	.27	13.21	5.02	.00	5.02
.09	.00	.09	.07	.00	.07
.26	.00	.26	.07	.00	.07
5.25	.67	5.92	4.88	.33	5.21
3.18	1.01	4.19	.07	.00	.07
5.95	.00	5.95	1.11	.55	1.66
17.21	.00	17.21	12.87	.39	14.26

TABLE XXIV. CALCIUM CARBONATE IN FINE MATERIAL AND IN PEBBLES IN INDIVIDUAL FIELDS.
(Continued)

Depth Foot	FIELD I. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	FIELD II. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	FIELD III. In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.
				WORTHINGTON AREA					
1	.25	.06	.31	.23	.00	.23	1.48	.00	1.48
2	.39	.00	.39	.24	.00	.24	1.59	.11	1.70
3	9.60	.47	10.07	4.29	.70	4.99	5.45	.22	5.67
				ADRIAN AREA					
1	.00	.00	.00	.09	.00	.09	.04	.00	.04
2	.11	.00	.11	.27	.00	.27	.17	.63	.80
3	9.08	.30	9.38	3.38	.44	3.82	.11	.04	.15
				LUVERNE AREA					
1	.14	.24	.38	.07	.00	.07	.12	.00	.12
2	3.54	.00	3.54	2.20	.00	2.20	.72	.00	.72
3	8.20	1.14	9.34	9.79	.00	9.79	.11	.00	.11

FIELD IV.			FIELD V.		
In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.	In fine Mat'l. P.ct.	In P. P.ct.	Total P.ct.
.07	.00	.07	1.70	.00	1.70
.18	.04	.22	.45	.00	.45
8.90	.57	9.47	13.62	.48	14.10
.04	.00	.04	.07	.00	.07
3.20	.05	3.25	.75	.66	1.41
9.85	.21	10.06	8.29	2.71	11.00
.09	.00	.09	.07	.00	.07
.09	.00	.09	1.41	.00	1.41
3.07	.00	3.07	11.00	.00	11.00

SUMMARY.

1. There are two, and possibly three, distinct areas of glacial drift in the southern counties of Minnesota, the Kansan, the Late Wisconsin and a drift of Undetermined Age. East of the exposed Kansan drift there is an area of loess soil while another lies to the west of the drift of Undetermined Age.

2. The proportion of pebbles in the drift has been found to be greatest in the soils on the Kansan, while those on the Late Wisconsin come next; those on the drift of Undetermined Age containing the lowest. Calcareous pebbles were not found in the soils on the Kansan but considerable quantities were found in the Late Wisconsin soils as well as in those on the drift of Undetermined Age.

The pebbles in the till consisted of Granites, Syenites, Limestones, Basalts, Shales, Quartz, Sandstones, Felsites and Cherts. Usually all of these kinds were found in each of the drifts with the exception of the Kansan where no calcareous pebbles were present.

3. Using a sensitive grade of litmus paper all virgin soils sampled at Caledonia, Preston, Spring Valley and Luverne were found to be acid. The litmus and Hopkins methods for acidity determinations have been found unsatisfactory in the study of the acidity of these soils.

4. The texture of the soils, as shown by the moisture equivalents, varies rather widely on the soils from the drift areas. Samples from different fields in the same area do not in all cases show a close similarity of texture. The texture of the eastern and western loess, however, appears to be very uniform. The western loess in the first and second feet

shows a higher moisture equivalent.

5. The nitrogen content in the virgin forests on the eastern loess is much lower than that in the western prairie loess. The nitrogen in the soils on the Kansan drift is somewhat higher than on the eastern loess. The soils on the Late Wisconsin and Undetermined Age drifts show varying amounts but as a rule, have a high content, especially the soils from the flat areas. In studying the effects of cultivation on the nitrogen content there has been found a gain in the soils from the Caledonia area; both gains and losses in the fields from Preston and Spring Valley; and only losses in the fields at Luverne. This really surprising result remains to be satisfactorily explained.

6. Carbon dioxide was found to be present in considerable quantities in the soils from the drifts of the Late Wisconsin and Undetermined Age, as well as those on the western loess. The small amounts present in

the fields from the areas of Caledonia, Preston, and Spring Valley are probably due to the oxidation of the organic matter.

7. The distribution of phosphoric acid is quite uniform in all areas.

8. The eastern loess contains a higher percentage of potash than any of the other soils, and the western loess just a little less, while the soils on the Kansan and Late Wisconsin drifts contain about the same with the exception of the Worthington area where it is somewhat higher similar to that on the drift of Undetermined Age.