SOIL INVESTIGATIONS

OHIO
Agricultural Experiment Station

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BULLETIN 261

OHIO AGRICULTURAL EXPERIMENT STATION

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BULLETIN

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SOIL INVESTIGATIONS

COMPOSITION OF CALCAREOUS AND NON-CALCAREOUS SOILS (WITH SPECIAL REFERENCE TO PHOSPHORUS SUPPLY)

J. W AMES AND E W GAITHER

The study of soil phosphorus is included as a part of the soil investigations being conducted at this Station. For the purpose of obtaining information concerning differences in composition of calcareous and non-calcareous soils of different types, a chemical examination of a number of soils from sandstone, limestone and shale formations has been made. The work was undertaken with the object in view of establishing a basis for investigation pertaining to the deficiency, availability and combination of the phosphorus supply in soils having widely differing characteristics. Considerable data have been secured showing the relation between the calcium carbonate content and soil reaction, which is considered of importance in measuring the availability of the phosphorus supply.

TOTAL ANALYSES

As pointed out by Merrill,* for a long period the fertility of soils was thought to be dependent largely upon their chemical composition. A vast amount of data was obtained by determining the portion of the several soil constituents soluble in strong acids. This has proven in the light of later knowledge to be of questionable value. By this method there is left undetermined a large proportion of the elements, aside from silica, concerning which it may be highly important to have complete information.

The determination of the total amounts of the elements present, not only for the surface soils, but for the various sub-strata as well, is of importance in connection with agricultural geology.

*Rocks, Rock Weathering and Soils.

In the chemical work on soils carried on at this Station the practice has been followed of determining the total amounts of the elements present, and the proportion of these soluble in fifth normal nitric acid, including iron and aluminum. For some soils the relative proportion of these two elements, compared with the calcium carbonate and phosphorus content, will have a bearing on the phosphorus availability.

The methods of analysis used are given in detail in addenda, page 503.

LIMESTONE AND SANDSTONE SOILS

The State is divided into two principal geological sections or divisions, designated as glaciated and unglaciated. The former lies over the northern and western sections of the State, while the section free from, or only slightly modified by glacial action extends over the eastern and southern portions; the division between these two is represented on the map shown on page 452. The soils studied lie mostly in the glaciated area; Jefferson, Washington, and Meigs counties being the only counties in the unglaciated section from which samples were obtained. The soil forming material over different parts of the area affected by glacial action was of different character. Soils east of a line extending north and south through the center of the State are largely derived from sandstones and shales, and those west of this line from limestone. The chief distinction between these two classes of soil which would be expected from their origin is in their content of calcium carbonate. In many instances the amount of calcium carbonate found in the surface soils gives only a slight indication of their being derived from limestone. The extent to which the decomposition and removal of soil forming materials have proceeded is indicated by chemical analyses of the different soil strata. The agencies through which these changes take place may exert a more marked influence upon the soil composition than does the material from which the soil was formed.

The terms "limestone soil" and "calcareous soil" are frequently used with reference to the presence of calcium carbonate. A limestone soil is not necessarily a calcareous soil, for many of the soils formed from limestone have had the calcium carbonate, at one time present, removed from the depth of soil which furnishes the medium for plant growth. In the case of many of the soils from limestone areas in the western part of the State there is a marked difference between the surface six inches of soil and the depth from six inches to three feet, as regards the amount of calcium and magnesium carbonates present.

Table I points out the differences found between soils from the eastern and western parts of the State. This table is a summary of results for calcium carbonate; total and fifth normal nitric acid-soluble calcium, magnesium and phosphorus. The soils from the western section, overlying limestone, are divided into two groups, calcareous and non-calcareous. The more extended area, represented by samples from the western part of the State, compared with that from the eastern portion, probably does not admit of more than an approximate comparison being made. Nevertheless, the larger amounts of calcium carbonate found in soils from the western portion, and the proportions of total and fifth normal nitric acid-soluble calcium, even in cases where no carbonates were found, are of interest.

TABLE I. Soils from eastern and western sections of the State compared. Results expressed as pounds per 2,000,000 pounds of soil.

	Depth	* $CaCO_3$	Calcium		Magnesium		Phosphorus	
			Total	N-5 HNO_3 soluble	Total	N-5 HNO_3 soluble	Total	N-5 HNO_3 soluble
Eastern..............	0-6 in.	0	6,850	1,652	8,856	286	986	23.1
"	6-36 in.	0	6,814	1,576	11,324	532	645	31.0
Western, No $CaCO_3$...	0-6 in.	0	10,183	2,484	8,890	509	913	60.0
" " " ...	6-36 in.	0	9,300	2,482	13,614	870	702	19.8
Western, Containing $CaCO_3$....	0-6 in.	6,025	16,221	7,680	9,830	1,284	1,310	144.0
Western, Containing $CaCO_3$.....	6-36 in.	42,800	25,188	16,590	16,182	5,401	904	166.0

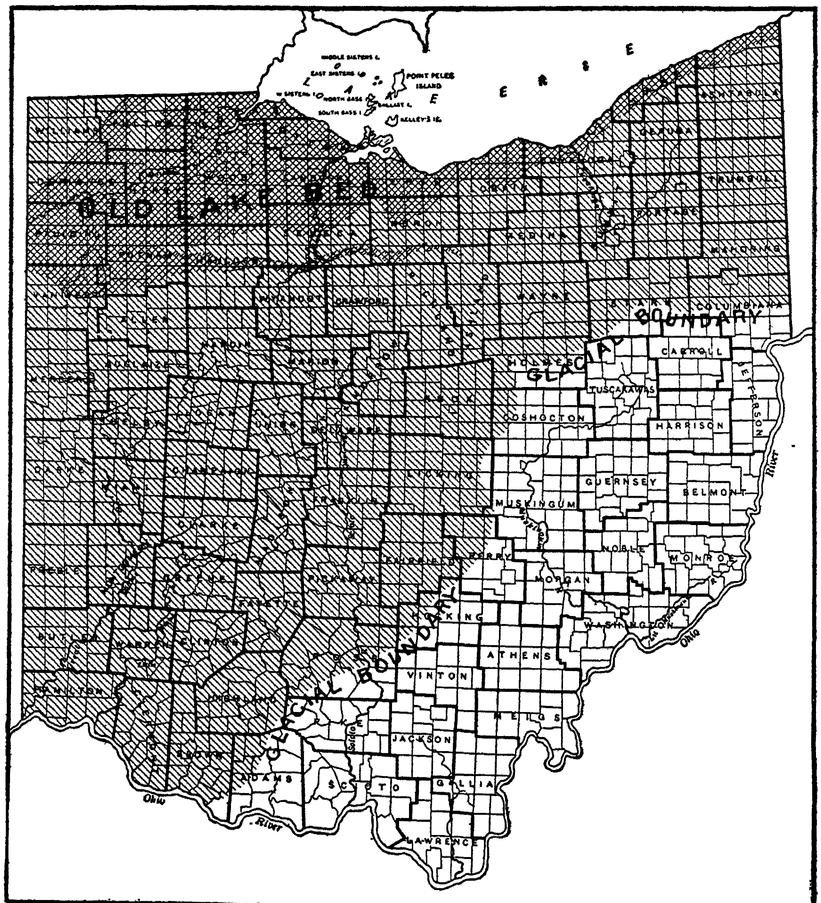
*Calcium carbonate.

The amounts of calcium, both total and fifth normal nitric acid-soluble, found in these instances, indicate that a portion of the calcium which at some time in the past existed as calcium carbonate, now exists in other combinations than the basic carbonate of calcium, by reason of chemical changes taking place between the calcium carbonate and the organic and inorganic constituents. It is probable that, where a considerable amount of organic material existed in the soil, acidity was developed, which was neutralized by the carbonates of calcium and magnesium, forming organic combinations with these elements. Since these organic compounds are not readily soluble in carbonated water, they remain in the soil after the excess of natural carbonates is decomposed and leached out. Calcareous soils generally support a luxuriant natural growth of vegetation, which returned to the soil furnishes abundant organic material to bring about this condition, thus giving rise to the accumulation of calcium in the surface strata, while the subsoil may contain less of this element.

Bacteria acting on this supply of calcium in organic combination may form calcium carbonates, which will tend to maintain a neutral reaction in soils even though the amount of calcium carbonate can not be measured by a chemical analysis.

Experiments, which are indicative of the change from organic calcium salts to calcium carbonate, are reported by the Rothamsted Experiment Station.*

Table II, on page 453 and following, gives the fertility constituents and reaction of soils grouped according to the counties from which the soils analyzed were secured. The location and description of the soils studied are shown in Table III.



Map of Ohio showing glaciated area.

*C. T. Gimingham, Jour. Agr. Science, Vol. IV, part 2, pp. 145.

TABLE II. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	† CaCO3 in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
4651	0-6	Ashtabula	Gravelly loam	8,444	112	9,290	1,210	1,620	88	25,144	2,314	31,200	0	Acid
4648	0-6	"	"	10,742	192	5,472	1,280	1,008	6	34,492	3,360	31,400	0	"
4649	6-36	"	"	17,370	612	4,512	1,392	622	2	51,388	1,380	......	0	"
4650	0-6	"	"	9,188	184	8,256	974	1,132	4	31,912	2,844	30,400	0	Sl. acid
4652	0-6	"	Gravel	7,854	82	9,216	896	1,326	24	26,240	2,480	35,800	0	Acid
4654	0-6	"	"	8,510	102	6,432	788	1,930	170	26,564	3,626	41,800	0	"
4658	0-6	"	Sandy loam	6,980	70	11,232	164	1,150	50	22,632	3,314	38,600	0	"
4659	6-36	"	"	8,686	90	13,728	158	556	30	25,144	1,040	.. ..	0	"
4660	0-6	"	"	12,204	120	17,760	890	1,116	232	22,952	2,254	27,000	100	Sl. acid
4661	0-6	"	"	10,588	52	10,752	262	2,200	120	22,696	3,070	38 600	0	Acid
4662	0-6	"	"	8,268	292	7,008	3,916	1,034	48	25,726	4,090	42,400	0	"
4644	0-6	"	Volusia loam	11,812	272	6,096	2,582	988	6	39,458	4,280	40,400	0	"
4645	6-36	"	"	17,478	840	5,088	2,214	596	4	49,386	1,340	......	0	"
4646	0-6	"	"	9,690	236	5,380	2,454	746	6	31,590	3,900	34,200	0	"
4647	0-6	"	"	9,800	122	3,744	560	964	12	29,916	2,814	27,600	0	"
4655	0-6	"	Clay	7,394	358	5,100	1,634	1,008	88	34,428	6,380	70,800	0	"
4656	6-36	"	"	15,182	970	8,100	5,346	834	190	45,772	1,350	.....	400	Alkaline
4657	0-6	"	"	9,078	556	6,240	2,734	1,318	8	39,328	5,050	48,000	0	Acid
4733	0-6	Allen	Silt loam	8,338	798	17,922	6,156	1,408	28	37,588	5,080	49,800	0	Sl. acid
4730	0-6	"	Clay loam	10,854	1,356	14,914	5,166	1,336	22	39,132	4,420	38,600	2,200	Alkaline
4731	6-36	"	"	26,030	7,874	46,652	33,508	964	98	48,100	1,694	......	92,200	"
4732	0-6	"	"	9,132	742	11,906	3,632	950	24	43,072	5,674	35,800	0	Sl. acid
10746	0-6	Auglaize	Silt loam	11,310	496	9,644	3,040	854	14	37,396	3,074	......	0	Sl. acid
10744	0-6	"	Blk. clay loam	17,172	2,188	21,254	9,900	1,374	168	36,624	6,650	......	.	....
10745	0-6	"	"	19,076	1,784	20,566	11,050	2,330	302	44,100	7,324	......	.	....
5286	0-6	Brown	Silt loam	11,400	392	9,828	1,752	1,206	14	26,370	2,930	36,000	.	....
5287	6-36	"	"	14,624	450	7,984	672	690	6	29,208	924	.....	0	Acid
5288	0-6	"	"	10,498	526	12,896	1,350	880	14	25,016	2,474	37,000	0	"
5289	6-36	"	"	10,464	474	10,066	1,398	582	8	24,372	.....	....	.	....
5294	0-6	"	"	6 234	280	3,958	1,650	1,234	8	25,792	2 790	36 200	0	Acid

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	CaCO3 † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
10751	0-6	Butler	Sandy loam	55,584	33,732	131,902	108,532	1,392	176	29,660	1,894	19,000	403,000	Str. alk'line
4565	0-6	"	Silt loam	8,120	662	9,698	2,714	1,158	14	37,008	2,714	48,200	0	Sl. acid
4566	6-36	"	"	36,528	20,058	81,520	70,024	1,760	458	39,584	1,230	......	.	....
4567	0-6	"	"	7,874	778	10,802	3,044	734	14	34,172	2,530	27,600	0	Sl. acid
4568	6-36	"	"	32,660	10,478	38,968	19,400	1,486	138	35,588	1,704	......	.	....
10750	0-6	"	Clay loam	7,328	1,052	10,924	4,056	1,694	132	35,848	2,674	......	2,400	Sl. alkaline
4744	0-6	Clarke	Silt loam	6,432	474	8,256	2,498	930	20	37,008	2,170	26,200	600	Alkaline
4745	6-36	"	"	11,460	936	7,248	1,888	822	12	39,328	1,044	......	0	Sl. acid
4746	0-6	"	"	6,258	552	7,776	2,278	910	26	37,458	2,644	28,600	300	Alkaline
4747	0-6	"	"	9,800	352	8,660	1,752	818	18	38,426	2,304	19,400	150	Sl. alkaline
4748	6-36	"	"	19,360	3,448	15,842	8,872	1,042	28	45,712	1,380	.....	25,100	Alkaline
4749	0-6	"	"	8,612	1,526	14,116	4,866	1,360	28	37,394	3,034	22,600	3,100	Sl. alkaline
4750	6-36	"	"	29,202	13,088	35,108	23,618	1,114	22	38,170	1,624	.....	91,400	"
4751	0-6	"	"	6,588	752	11,968	3,004	790	16	36,106	2,514	19,600	2,300	Alkaline
4741	0-6	"	Bl'k, clay loam	13,300	3,828	26,400	21,200	2,188	108	26,240	13,250	129,600	2,300	Alkaline
4742	6-36	"	"	17,150	5,120	20,928	12,400	646	264	36,362	1,940	.....	16,600	"
4743	0-6	"	"	17,346	9,626	49,344	40,800	2,586	320	30,174	16,644	131,200	69,200	"
4665	0-6	Cuyahoga	Stony loam	6,748	252	5,010	1,202	580	8	31,720	2,520	26,800	0	Acid
4666	6-36	"	"	8,288	576	4,718	1,272	542	2	42,134	1,084	......	0	"
4667	0-6	"	"	5,864	192	5,690	448	900	8	29,980	2,460	23,800	100	Alkaline
4670	0-6	"	Gravelly loam	8,048	150	6,810	742	2,624	10	25,790	3,410	36,400	0	Acid
4668	0 6	"	Sandy loam	7,326	180	6,372	684	978	4	29,626	2,250	24,000	0	"
4669	6-36	"	"	9,328	530	6,032	742	602	6	35,588	780	......	0	"
4663	0-6	"	Clay loam	11,178	206	6,712	1,650	764	2	32,816	2,850	32,200	0	"
4664	6-36	"	"	11,822	918	6,908	2,652	642	8	48,096	1,344	......	0	"
4671	0-6	"	"	11,330	312	5,058	2,228	1,116	6	39,974	3,344	30,000	0	Sl. acid
4672	6-36	"	"	10,554	246	4,718	918	650	2	30,134	1,340	......	0	Acid
11381	0-6	"	Clay	8,356	578	5,100	2,162	880	12	41 320	3,600	40,000	0	Acid

*Soluble N-5 nitric acid †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	CaCO3 † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
5284	0-6	Clermont	Silt loam	11,892	316	11,056	2,300	1,356	14	30,880	186	28,000	0	Sl. acid
5285	6-36	"	"	15,694	762	9,152	1,488	640	6	33,784	944	.....	0	"
5293	0-6	"	"	6,562	494	5,626	2,840	1,540	4	34,172	3,580	35,800	0	Acid
10756	0-6	"	"	6,104	232	6,788	1,420	856	2	28,758	2,380	......	0	"
4712	0-6	Defiance	Clay loam	10,644	1,322	12,310	4,752	770	28	39,522	3,154	39,200	2,450	Alkaline
4713	6-36	"	"	24,358	8,312	43,786	39,392	634	124	54,608	1,300	......	94,400	"
4714	0-6	"	"	11,604	3,456	19,168	12,854	962	48	36,942	4,244	24,600	26,000	"
4715	0-6	"	Clay	16,418	1,396	8,418	2,842	1,206	12	58,734	4,290	40,400	0	Sl. Acid
10769	0-6	Darke	Silt loam	11,944	1,816	17,016	8,962	2,136	108	35,782	.....	......	.	....
10770	0-6	"	"	12,512	1,740	18,984	8,300	1,192	110	37,588	....	......	.	"
10771	0-6	"	"	12,514	1,488	17,410	6,450	1,434	118	36,492	4,670	......	600	Alkaline
10772	0-6	"	"	12,316	1,772	18,492	9,800	1,586	170	37,072	.....	......	500	"
10766	0-6	"	Clay loam	14,328	2,790	20,264	10,532	1,514	22	37,654	.....	......	.	....
10767	0-6	"	"	10,062	584	10,328	2,800	828	24	44,228	2,560	......	0	Sl. acid
10768	0-6	"	"	8,926	506	9,442	2,000	796	18	42,232	2,794	......	.	....
4734	0-6	Franklin	"	6,342	378	8,172	2,016	686	6	35,328	2,150	20,200	0	Sl. acid
4735	6-36	"	"	11,538	836	6,468	1,782	692	4	44,324	1,400	.....	0	"
4736	0-6	"	"	6,080	468	8,074	3,030	786	10	33,510	2,874	25,600	0	"
5085	1-14	"	"	5,578	548	9,730	3,254	656	16	32,848	2,250	21,800	650	Alkaline
5088	14-24	"	"	8,826	1,316	8,074	3,774	422	26	36,490	1,264	......	0	Sl. alkaline
4737	0-6	"	Bl'k, clay loam	15,092	1,792	18,292	11,804	1,580	106	35,910	6,290	63,000	0	Neutral
4738	6-36	"	"	11,866	1,910	14,252	8,798	1,050	158	38,842	2,274	......	400	Sl. alkaline
4739	0-6	"	"	13,618	2,408	19,802	14,658	1,792	106	34,910	8,460	69,800	1,280	"
4740	0-6	"	"	6,432	288	8,736	3,880	1,750	200	30,304	2,840	25,400	200	Neutral
5087	1-14	"	Black clay	10,662	2,864	26,998	20,286	1,960	484	25,370	6,934	65,200	11,500	Alkaline
5086	14-24	"	"	44,844	35,960	102,066	96,004	1,034	416	25,982	.....	......	359,500	"

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
14169	....	Fulton	Black sand	.....	.....	28,360	15,860	2,420	240	25,240	12,780	148 460	.	....
5081	0-6	Greene	Silt loam	8,510	758	9,730	2,982	746	58	37,846	1,530	9,400	0	Acid
5082	6-36	"	"	11,420	1,378	9,682	3,302	704	2	40,038	920	......	0	Sl. alkaline
5083	0-6	"	"	7,722	1,268	12,552	5,218	1,134	276	35,782	3,634	26,800	3,600	Alkaline
5279	0-6	Hamilton	Silt loam	12,166	426	15,724	3,712	1,184	52	32,880	2,340	25,000	0	Acid
5280	6-36	"	"	22,502	612	14,986	2,720	1,130	26	39,132	1,164	.....	0	"
10752	0-6	"	"	7,000	440	6,000	2,930	1,222	8	29,916	2,794	......	0	Sl. acid
10758	0-6	"	"	9,866	.....	4,802	1,550	642	34	33,012	2,794	.....	.	....
10759	0-6	"	Clay loam	20,738	.....	23,608	19,936	3,062	2,810	61,444	.....	.....	.	....
5281	0-6	"	"	40,250	2,110	56,266	19,298	6,116	2,558	55,832	3,844	30,000	4,300	Alkaline
5282	6-12	"	"	28,108	4,286	47,914	35,846	6,228	3,242	64,216	.....	......	.	"
5283	0-6	"	Silt loam	19,250	822	35,010	10,290	5,610	2,418	41,388	5,164	44,200	0	Acid
5531	0-6	Hancock	Clay loam	6,562	540	9,500	3,430	1,068	10	36,420	3,554	......	.	....
5532	6-36	"	"	6,868	532	8,600	2,720	794	4	38,160	2,374	. ...	.	....
14163	....	Hardin	Blk. clay loam	......	.....	20,880	14,720	2,020	340	40,480	8,020	63,600	0	....
5401-1	0-6	Jefferson	Silt loam	8,772	278	6,590	3,520	1,236	22	37,072	1,348	.....	1,700	Alkaline
5401-2	6-36	"	"	10,894	574	6,000	3,830	1,116	24	43,906	726	......	600	Neutral
4709	0-6	Lucas	Sand	5,238	188	12,890	1,026	554	114	26,400	1,430	18,200	0	Sl. acid
4710	6-36	"	"	7,568	142	12,844	682	252	24	29,110	510	...	0	Sl. acid
4711	0-6	"	"	5,238	170	14,302	1,084	502	50	27,528	1,700	29,400	0	"
4701	0-6	"	Sandy loam	8,558	810	21,100	8,160	1,056	344	34,910	5,424	67,000	500	Alkaline
4702	6-36	"	"	10,308	1,022	17,454	5,082	762	344	35,456	1,290	... ..	400	Sl. alkaline
4703	0-6	"	"	8,334	714	18,640	7,334	986	234	34,590	4,884	52,600	400	Sl. acid
4704	0-6	"	"	7,504	526	19,460	5,200	934	274	28,658	3,660	40,800	0	Sl. acid
4705	6-36	"	"	7 152	740	17,902	2,302	752	288	31,394	974	......	100	Neutral

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
4699	0-6	Lucas	Clay	10,078	678	9,306	2,023	1,088	82	40,650	2,446	24,200	0	Acid
4700	6-36	"	"	18,528	1,990	9,332	2,452	804	26	53,444	1,220	.....	0	"
4696	0-6	"	Clay	12,698	872	19,412	6,982	1,312	106	43,164	5,094	46,200	0	Sl. acid
4697	6-36	"	"	16,860	1,494	14,180	7,052	788	126	47,872	1,754	......	3,500	Alkaline
4698	0-6	"	"	16,812	4,286	21,028	15,118	996	154	43,934	4,460	37,600	25,600	Neutral
4706	0-6	"	"	10,488	1,634	20,526	7,072	1,562	404	37,006	6,544	67,800	0	Sl. acid
4707	6-36	"	"	12,106	1,838	15,210	4,342	1,044	384	40,326	1,740	......	400	Sl. alkaline
4708	0-6	"	"	8,214	1,138	17,362	5,066	1,264	88	34,362	5,640	57,600	50	"
10743	0-6	Miami	Silt loam	13,476	724	10,136	3,850	1,748	88	43,200	3,990	.....	0	Sl. acid
10763	0-6	"	"	7,876	314	11,016	3,830	1,234	18	36,364	4,050	......	0	Sl. acid
10734	0-6	Montgomery	"	12,470	520	9,400	1,990	720	206	37,394	2,414	......	1,000	Sl. alkaline
10736	0-6	"	"	12,534	654	11,414	3,162	806	30	35,720	. ...	......	...	....
10735	0-6	"	Clay loam	19,798	976	18,598	11,120	2,444	106	41,200	.....	......	...	....
10732	0-6	"	Silt loam	8,948	494	11,218	2,850	576	62	36,492	1,850	.....	550	Sl. alkaline
10733	0-6	"	Clay loam	15,970	532	18,892	1,990	1,906	20	43,452	5,160	.	...	....
4752	0-6	"	"	6,388	454	8,026	2,600	794	8	39,196	2,074	18,200	...	.. .
4753	6-36	"	"	12,600	1,062	8,854	3,208	936	10	43,584	1,080	.....	...	....
4754	0-6	"	Blk. clay loam	12,994	2,592	19,752	12,766	1,486	38	35,782	6,154	61,800	4,400	Alkaline
4755	0-6	"	"	17,500	9,952	36,584	28,776	1,302	22	34,556	5,960	56,800	74,000	Str. alk'line
10728	0-6	"	Clay loam	6,036	416	9,100	2,674	670	18	33,520	2,120	3,400	...	....
4639	0-6	Mahoning	"	10,662	336	5,472	1,606	1,168	26	33,204	4,120	48,000	0	Acid
4640	0-6	"	"	12,032	236	5,280	1,536	908	10	31,720	3,590	37,600	0	"
4641	0-6	"	"	10,662	406	6,528	2,834	1,118	8	31,204	4,060	37,800	0	"
4642	0-6	"	"	10,060	286	5,184	1,662	822	6	31,204	3,390	50,000	0	"
4643	0-6	"	"	11,586	346	5,136	1,626	1,076	8	31,140	3,890	39,200	0	"
9702	0-6	Meigs	Silt loam	6,016	292	4,000	1,926	722	8	29,260	2,694	......	...	....
9703	0-6	"	Silt loam	5,644	304	3,200	1,810	690	12	30,760	2,974	......	...	...
9704	0-6	"	"	5,512	274	3,600	2,280	848	8	30,820	2,930	31,800	. .	....

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Continued. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
10738	0-6	Preble	Clay loam	44,472	28,700	84,600	56,800	1,694	210	35,202	3,320	......	239,000	Str. alk'line
10737	0-6	"	Silt loam	15,116	766	10,530	2,500	580	14	36,880	1,820	......	0	Sl. alkaline
10739	0-6	"	"	8,992	690	10,332	3,960	964	48	36,558	2,874	......	650	Alkaline
10740	0-6	"	Clay loam	14,592	4,288	19,386	8,150	1,808	236	37,912	5,480	......	550	Sl. alkaline
4722	0-6	Putnam	Sandy loam	6,268	584	16,960	5,818	1,122	38	36,618	4,194	34,400	200	Alkaline
4723	6-36	"	"	10,444	894	16,286	6,346	768	46	35,200	1,434	.....	300	"
4724	0-6	"	"	5,512	420	14,402	4,716	1,228	18	36,810	4,510	35,800	600	Sl. alkaline
4727	0-6	"	"	7,718	366	8,426	5,318	906	236	35,324	3,804	31,000	0	Neutral
4728	6-36	"	"	12,300	418	6,134	3,758	578	78	37,136	1,524	......	0	Sl. alkaline
4716	0-6	"	Bl'k, clay loam	14,066	1,334	16,720	8,448	1,948	276	48,160	3,960	41,800	350	Sl. alkaline
4717	6-36	"	"	10,500	1,614	13,882	7,290	1,694	294	48,672	2,490	.....	500	Neutral
4718	0-6	"	"	11,100	1,388	14,466	8,506	2,346	150	49,512	7,464	64,800	100	Acid
4719	0-6	"	Clay loam	10,564	1,020	7,334	2,058	1,086	16	48,386	3,404	32,200	0	"
4720	6-36	"	"	14,600	1,342	6,258	4,846	654	14	55,022	1,534	.....	0	"
4721	0-6	"	"	13,542	1,090	12,844	5,418	1,396	26	45,418	4,714	28,800	600	Sl. acid
4725	0-6	"	Sandy clay	6,692	730	13,682	5,632	1,432	40	37,038	3,850	36,000	400	Sl. alkaline
4726	6-36	"	"	5,456	860	14,152	4,774	924	32	38,906	1,874	......	0	Neutral
14168	....	Sandusky	Sand	.... .	......	17,420	40	940	140	32,900	1,400	......	...	....
10755	0-6	Warren	Sandy loam	24,720	15,838	80,774	71,694	2,638	1,934	35,720	.....	......	...	Str. alk'line
10753	0-6	"	Silt loam	7,198	456	6,788	2,440	1,180	32	31,786	.....	... ..	...	....
10754	0-6	"	"	6,498	328	6,688	2,450	1,064	24	31,076	.....	......	...	....
10757	0-6	"	"	5,862	252	5,508	1,374	704	8	27,854	2,100	......	...	....
10760	0-6	"	"	7,700	312	6,098	1,866	1,042	24	37,910	2,100	......	0	Acid
10761	0-6	"	"	10,104	774	12,784	6,060	1,508	34	38,428	4,730	......	400	Neutral
10762	0-6	"	"	7,154	432	8,952	4,766	1,888	172	38,558	2,530	.....	0	Neutral
10764	0-6	"	Clay loam	17,348	2,898	22,918	15,300	2,668	500	49,000	2,060	......	24,250	Sl. alkaline

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE II.—Concluded. Fertility constituents and reaction. Soils grouped by counties. Results expressed in pounds per 2,000,000 pounds of soil.

Lab. No.	Depth inches	County	Classification	Magnesium		Calcium		Phosphorus		Potassium	Nitrogen	Humus	$CaCO_3$ † in soil	Reaction to litmus paper
				Total	Soluble*	Total	Soluble*	Total	Soluble*					
4690	0-6	Wayne	Gravelly loam	7,624	156	7,200	812	1,140	72	30,368	2,360	22,600	0	Acid
4691	6-36	"	"	10,216	340	6,276	458	782	8	31,590	914	......	0	"
4688	0-6	"	Sandy loam	5,490	160	8,952	884	554	6	24,178	2,434	30,000	0	"
4689	6-36	"	"	6,628	246	9,778	636	270	2	26,112	490	......	0	"
4673	0-6	"	Silt loam	7,546	206	5,398	966	806	30	34,138	2,010	24,000	0	Sl. acid
4674	0-6	"	"	6,998	390	6,810	1,698	1,086	48	33,784	3,074	43,400	0	"
4675	0-6	"	"	7,468	260	6,380	1,178	812	4	33,780	2,450	30,000	0	"
4676	6-36	"	"	10,530	610	5,884	1,238	686	2	35,878	960	....	0	Neutral
4677	0-6	"	"	6,254	178	5,106	600	782	6	32,236	2,454	32,400	0	Acid
4679	0-6	"	"	6,922	242	5,018	990	1,008	8	34,204	2,660	32,400	0	"
4680	0-6	"	Clay loam	7,862	258	5,350	1,154	692	4	32,816	2,274	24,800	0	Sl. acid
4681	0-6	"	"	7,450	224	6,812	1,414	786	2	30,882	2,744	23,600	0	Acid
4682	6-36	"	"	10,588	558	6,812	1,344	442	2	36,748	1,100	......	0	"
4683	0-6	"	"	6,934	...	8,562	2,406	886	4	29,658	3,284	32,200	0	"
4684	0-6	"	"	7,766	434	7,396	2,074	1,020	8	32,172	3,284	31,400	0	"
4685	0-6	"	Clay	13,584	1,080	8,660	5,766	1,928	46	41,134	6,860	68,800	0	"
4686	6-36	"	"	10,544	378	6,032	2,122	1,176	244	36,620	1,854	......	0	"
4687	0-6	"	"	6,660	242	5,108	1,414	848	4	28,884	2,644	30,600	0	Sl. acid
14101	0-6	Washington	Clay	.....	...	10,140	7,760	1,140	260	49,240	2,120	19,160	.	......

*Soluble N-5 nitric acid. †Calcium carbonate.

TABLE III: Giving location and description of soils studied.

Lab. No.	County	Township	Depth inches	Classification	Description
4644	Ashtabula	Saybrook	0-6	Silt loam	2½ mi. northeast of Austinburg. Timothy meadow with only a fair stand of grass and considerable sorrel. Mapped by the Bureau of Soils, U. S. D. A. as Volusia loam.
4645	Ashtabula	Saybrook	6-36	Silt loam	
4646	Ashtabula	Saybrook	0 6	Silt loam	Virgin timber soil ¼ mi. west of 4644 and 4645.
4647	Ashtabula	Conneaut	0-6	Silt loam	5 mi. southeast of Conneaut, 2 mi. west of South Ridge Road. Timothy meadow, grass poor, topography quite rolling. Mapped by Bureau of Soils, U. S. D. A. as Volusia loam.
4648	Ashtabula	Saybrook	0-6	Gravelly loam	5 mi. north of Austinburg. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4649	Ashtabula	Saybrook	6-36	Gravelly loam	
4650	Ashtabula	Saybrook	0-6	Gravelly loam	Maple grove 30 rods north of 4648 and 4649.
4651	Ashtabula	Kingsville	0-6	Gravelly loam	2 mi. southwest of Amboy and 5 mi. west by southwest from Conneaut. Timothy meadow, grass poor. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4652	Ashtabula	Saybrook	0-6	Gravel	5½ mi. north of Austinburg, 10 rods from Nickel Plate railroad. Timothy meadow, grass poor. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravel.
4654	Ashtabula	Conneaut	0-6	Gravel	3½ mi. southwest of Conneaut. Field was in wheat 1908. Timothy was sown but failed for 1909 crop. Sorrel in almost absolute possession. Large gravel extremely more abundant than in same type (4652) from different source. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravel.
4655	Ashtabula	Saybrook	0-6	Clay	2 mi. north of Saybrook Corners. In timothy. Fair grass. Considerably darker in color than described by Bureau of Soils. Mapped by Bureau of Soils, U. S. D. A., as Dunkirk clay.
4656	Ashtabula	Saybrook	6-36	Clay	
4657	Ashtabula	Saybrook	0-6	Clay	Virgin timber soil. 2½ inches to yellow clay. About ½ mi. east of 4655 and 4656.
4658	Ashtabula	Saybrook	0-6	Sandy loam	2 mi. southeast of Ashtabula city, ¼ mi. north of Nickel Plate tracks. Corn 1908, uncultivated 1909. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4659	Ashtabula	Saybrook	6-36	Sandy loam	
4660	Ashtabula	Conneaut	0-6	Sandy loam	Virgin 2 mi. west of Conneaut, 10 rods north of Lake Shore railroad on left of road. Native timber, spruce or cedar. Mapped by Bureau of soils, U. S. D. A. as Dunkirk sandy loam.
4661	Ashtabula	Conneaut	0-6	Sandy loam	2½ mi. west of Conneaut. Timothy very poor, sorrel abundant, 45 rods north of 4660. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4662	Ashtabula	Plymouth	0-6	Sandy loam	Waste land or pasture. In plot on right of north and south road at end of viaduct in Ashtabula city and about 20 rods south of Nickel Plate tracks. Mapped by Bureau of Soils, U. S. D. A. as meadow.
4730	Allen	....	0 6	Clay loam	Virgin from blue grass pasture, farm of Adam Bame. Has not been plowed for over 10 years. Bed rock limestone about 6 feet beneath surface. Subsoil brownish yellow, large amounts of rotten limestone perceptible.
4731	Allen	....	6-36	Clay loam	
4732	Allen	....	0-6	Clay loam	30 rods east of 4730. Farm of Adam Bame. Timothy meadow.

TABLE III. Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
4733	Allen	....	0-6	Silt loam................	Cornfield adjoining Bluffton Stone Co.'s quarry on the east. Limestone gravel at about 20-24 inches. Farmed in corn for a number of years.
10744	Auglaize	Washington	0-6	Black clay loam	Upland, timber, 3 inches to color line. Limestone 15-25 feet.
10745	Auglaize	Washington	0-6	Black clay loam	Upland pocket black clay loam, 8 inches to color line. Limestone 15-25 feet.
10746	Auglaize	Washington	0-6	Silt loam	Upland grey silt loam, 8 inches to color line. Limestone 15-25 feet.
5286	Brown	....	0-6	Silt loam	Virgin sample from Mr. Tracy's farm known as "Hill Top Farm." From woodlot southeast of house.
5287	Brown	....	6-36	Silt loam	
5288	Brown	....	0-6	Silt loam	From Mr. Tracy's farm, from field adjoining and southeast of barn. Corn 1909, yield 40 bu. Poor clover in 1908. Soil probably representative of that community.
5289	Brown	....	6-36	Silt loam	
5294	Brown	....	0-6	Silt loam................	From Mr. Tracys' farm, from field adjoining and southeast of barn. Good clover 1909.
10750	Butler	Madison	0-6	Clay loam	Second bottom blue clay loam, 6 inches to color line, limestone pebbles exposed.
10751	Butler	Madison	0-6	Sandy loam..............	First bottom fine sandy loam, 16 inches to color line, limestone pebbles scattered in soil.
4565	Butler	....	0-6	Silt loam	From test plots on farm of J. C. Overpeck, Hamilton, O., R. F. D. No. 7.
4566	Butler	....	6-36	Silt loam	
4567	Butler	....	0-6	Silt loam	From test plots on farm of J. J. Kennel, Trenton, O., R. F. D. No. 1.
4568	Butler	....	6-36	Silt loam	
4741	Clarke	....	0-6	Black clay loam	8½ mi. southeast of Springfield, farm of E. J. Kitchen. Soil is mainly of alluvial or swamp origin, and is underlaid at about 15 in. by tenacious drab-colored clay. Locally known as "Gumbo." This field has been in corn for 17 years in succession, and gave promise of 50-60 bu. per acre in 1909. Water was encountered at about 3 ft. below the surface.
4742	Clarke	....	6-36	Black clay loam	
4743	Clarke	....	0-6	Black clay loam.........	Fence row.
4744	Clarke	....	0-6	Silt loam	From farm of E. J. Kitchen. Brown silt loam underlaid by a reddish yellow, gravelly loam.
4745	Clarke	....	6-36	Silt loam	
4746	Clarke	....	0-6	Silt loam................	Fence row.
4747	Clarke	....	0-6	Silt loam	Upland silt loam, underlaid by a subsoil containing fine gravel and corresponding closely with sample 4745.
4748	Clarke	....	6-36	Silt loam	
4749	Clarke	....	0-6	Silt loam	5 mi. north of Springfield. From farm of R. L. Holman. Alfalfa meadow 3 years old and showing fine stand. Soil is a brown friable loam underlaid by a yellowish gravel subsoil containing an abundance of limestone pebbles at a depth of 20 inches.
4750	Clarke	....	6-36	Silt loam	
4751	Clarke	....	0-6	Silt loam................	4751 is from pasture cleared from forest about 1860, and has not been plowed for at least 40 years.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
4663	Cuyahoga	Bedford	0-6	Clay loam	2½ mi. southwest of Bedford. Timothy fair. Mapped by Bureau of Soils, U. S. D. A., as Miami clay loam.
4664	Cuyahoga	Bedford	6-36	Clay loam	
11381	Cuyahoga	....	0-6	Clay	From Sec. B, 5-yr. rotation of the Strongsville Test Farm.
4665	Cuyahoga	Bedford	0-6	Stony loam	4 mi. southwest of Bedford. Corn 1908. Stalks small, indicating poor crop. Uncultivated 1909. Mapped by Bureau of Soils, U. S. D. A., as Miami stony loam.
4666	Cuyahoga	Bedford	6-36	Stony loam	
4667	Cuyahoga	Bedford	0-6	Stony loam	150 ft. south of 4665 and 4666 in corner of woodlot. In timothy but evidently quite recently broken, grass fair. Mapped by Bureau of Soils, U. S. D. A. as Miami stony loam.
4668	Cuyahoga	Independence	0-6	Sandy loam	1 mi. east of Alexander, cornfield. Corn good. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk sandy loam.
4669	Cuyahoga	Independence	6-36	Sandy loam	
4670	Cuyahoga	Independence	0-6	Gravelly loam	½ mi. north of Alexander; cornfield. Not fertilized. Corn fine. Subsoil too gravelly to bore. Mapped by Bureau of Soils, U. S. D. A. as Dunkirk gravelly loam.
4671	Cuyahoga	Independence	0-6	Clay loam	1½ mi. north of Alexander. Bottom land. Timothy fair. Wild morning glory abundant. (Soil somewhat sticky.) 6-28 in. in stiff clay. 28-36 in. sandy. Mapped by Bureau of Soils, U. S. D. A. as Wabash loam.
4672	Cuyahoga	Independence	6-36	Clay loam	
5284	Clermont	....	0-6	Silt loam	2 mi. east of Batavia. Farm of Mr. Reed. From 8-acre field east of house. Typical farm land of that section of the county.
5285	Clermont	....	6-36	Silt loam	
5293	Clermont	....	0-6	Silt loam	From alfalfa field north of house. Alfalfa poor, probably needs lime and drainage.
10756	Clermont	....	0-6	Silt loam	Upland grey silt loam, 10 in. to color line, limestone rock at 25 ft.
4712	Defiance	Noble	0-6	Clay loam	2 mi. west of Defiance. Farm of E. G. Hudson. A dark colored clay soil to a depth of about 7 in. Subsoil to a depth of 20-24 in. consists of a compact yellow clay underlaid by a greyish blue clay. This type is prevalent for miles along the river.
4713	Defiance	Noble	6-36	Clay loam	
4714	Defiance	Noble	0-6	Clay loam	Fence row, road side.
4715	Defiance	Highland	0-6	Clay	5 mi. southeast of Defiance on Ottawa Pike. Soil is very stiff tenacious clay, dark yellow color, slightly more granular than 4712. The color line here lies nearer the surface than in 4712, and the yellow subsoil stratum is only about 16-18 in. deep. It is difficult to drain this soil, because the tenacious clay subsoil cements over the tile joints; open ditches become filled up in from 12 to 18 months.
10766	Darke	Greenville	0-6	Clay loam	First bottom clay loam. 8 in. to color line.
10768	Darke	Greenville	0-6	Clay loam	Wooded upland, grey clay loam. 2 in. to color line.
10769	Darke	Twin	0-6	Silt loam	Upland brown silt loam. 8 in. to color line.
10767	Darke	Greenville	0-6	Clay loam	Upland grey clay loam.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10770	Darke	Buren	0-6	Silt loam	Upland timber, brown silt loam. 3 in. to color line. U. S. elevation 1,040 ft.
10771	Darke	Buren	0-6	Silt loam	Upland brown silt loam. 8 in. to color line. U. S. elevation 1,040 ft.
10772	Darke	Twin	0-6	Silt loam	Upland brown silt loam. Wooded pasture. 3 in. to color line.
4734	Franklin	....	0-6	Clay loam	6 mi. east of Columbus. South of Broadstreet Pike and ½ mi. west of Columbus, Sandusky and Hocking railroad. Light brown loam underlaid by stiff mottled clay containing some gravel and course sand. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4735	Franklin	....	6-36	Clay loam	
4736	Franklin	....	0-6	Clay loam	Open woodland.
4737	Franklin	....	0-6	Black clay loam	¼ mi. north of National Pike and 1 mi. west of Columbus, Sandusky and Hocking railroad. Black clay loam 12-16 in. deep, underlaid by a stiff yellow clay. Mapped by Bureau of Soils, U. S. D. A. as Miami black clay loam.
4738	Franklin	....	6-36	Black clay loam	
4739	Franklin	....	0-6	Black clay loam	Fence row.
4740	Franklin	....	0-6	Clay loam	River terrace 1 mi. north of Storage Dam on west side of Scioto river, and opposite Wyandot Club House. Soil 10-15 in. deep and full of rock fragments. Bed limestone rock at 10-15 in. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
5085	Franklin	....	1-14	Clay loam	Probably 80 ft. to limestone.
5088	Franklin	....	14-24	Clay loam	Subsoil of 5085.
5087	Franklin	....	1-14	Black clay	Black swale.
5086	Franklin	....	14-24	Black clay	Black swale. 5085, 5086, 5087 and 5088 are from farm of P. J. McCoy, Station A, Route 2, Columbus, Ohio. 1½ mi. from Storage Dam and west of Scioto river.
14169	Fulton	....		Sand	
5081	Greene	....	0-6	Silt loam	Soldiers' and Sailors' Orphans' Home, Xenia, Ohio. Clover field.
5082	Greene	....	6-36	Silt loam	Subsoil of 5081.
5083	Greene	....	0-6	Silt loam	Woodlot, uncultivated.
5084	Greene	....	0-6	Silt loam	From plot planted in alfalfa.
5279	Hamilton	....	0-6	Silt loam	1 mi. east of Madisonville on Richard's farm. From top of hill, south field. Seeded to alfalfa 1908, not very good.
5280	Hamilton	....	6-36	Silt loam	
5281	Hamilton	....	0-6	Clay loam	1 mi. east of Madisonville. From hillside of south field on Richard's farm. Alfalfa for 20 years, fine crop. Limestone outcrop and stones all over field. Could not go down deeper than 12 inches.
5282	Hamilton	....	6-12	Clay loam	
5283	Hamilton	....	0-6	Silt loam	1 mi. east of Madisonville on Richard's farm. From pasture field south of house. Could not get subsoil on account of limestone rock.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10752	Hamilton	Anderson	0-6	Silt loam.................	Upland grey silt loam. 9 in. to color line.
10758	Hamilton	Anderson	0-6	Silt loam..................	Upland silt loam.
10759	Hamilton	Anderson	0-6	Clay loam	Upland clay hillside, limestone rock on surface.
5531	Hancock	....	0-6	Clay loam }	Composite samples from Findlay Test Farm.
5532	Hancock	....	6-36	Clay loam }	
14163	Hardin	Marion	......	Black clay loam	From farm near McGuffey, Ohio. Prairie soil.
5401-1	Jefferson	....	0-6	Silt loam }	Mt. Pleasant, Ohio. Farm of Geo. E. Scott.
5401-2	Jefferson	....	6-36	Silt loam }	
4696	Lucas	Waynesfield	0-6	Clay }	1 mi. northwest of Maumee on Holland road, 40 rods northwest of flat-roofed brick house on left of road. Clover sod. Black, somewhat sticky clay loam. Subsoil very tenacious, yellowish clay. Mapped by Bureau of Soils, U. S. D. A. as Miami black clay loam and recorrelated as Clyde clay.
4697	Lucas	Waynesfield	6-36	Clay }	
4698	Lucas	Waynesfield	0-6	Clay...........	From fence row. Blue grass prevailing.
4699	Lucas	Adams	0-6	Clay }	3½ mi. north of Maumee. Clover sod. Subsoil mottled brown and grey clay. Corresponds closely with the Bureau's description of Dunkirk clay loam, but the type appears to be quite variable, as sandy soil was found in the same field, and on practically the same level. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4700	Lucas	Adams	6-36	Clay }	
4701	Lucas	Adams	0-6	Sandy loam }	3 mi. north of Maumee, ¼ mi. west of 4699 and 4700 in same area, but quite different in character. Samples were taken from field of alfalfa 2 years old, fine stand. Soil to a depth of 7 to 9 in., black, medium grained, sandy loam, underlaid by yellowish grey sandy subsoil. This type in area mapped as Miami clay loam and recorded by Bureau of Soils, U. S. D. A. as Dunkirk clay, is sufficiently extensive to be classed as a sandy loam.
4702	Lucas	Adams	6-36	Sandy loam }	
4703	Lucas	Adams	0-6	Sandy loam..............	Open woodland.
4704	Lucas	Adams	0-6	Sandy loam }	5 mi. north of Maumee and ½ mi. south of L. S. & M. S. R. R. Black sandy loam to a depth of 7-10 in. and closely resembles 4701, but seems to be a little more sandy, darker colored and coarser. Subsoil to a depth of 30 in. is a drab or grey colored sand. Below 30 in. it is a yellow sand. Mapped by Bureau of Soils, U. S. D. A. as Miami sandy loam.
4705	Lucas	Adams	6-36	Sandy loam }	
4706	Lucas	Adams	0-6	Black clay }	¾ mi. north of 4704, in the same area, and mapped as Miami sandy loam by the Bureau of Soils, U. S. D. A. In reality the soil as found at this point is a black clay containing apparently but a small percentage of sand. The type is quite extensive. The black clay extends to a depth of 7-9 in. underlaid by a mottled, stiff, sticky clay.
4707	Lucas	Adams	6-36	Clay }	
4708	Lucas	Adams	0-6	Black clay................	Open woodland.
4709	Lucas	Adams	0-6	Sand }	5 mi. north of Maumee, 1 mi. east of 4706, ½ mi. north of L. S. & M. S. R. R. Mapped by Bureau of Soils, U. S. D. A. as Miami sand.
4710	Lucas	Adams	6-36	Sand }	
4711	Lucas	Adams	0-6	Sand.....................	Fence row (rd. Sd.)

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10743	Miami	Washington	0-6	Silt loam................	Second bottom brown silt loam. 8 in. to color line, limestone gravel outcrops and runs about 2 ft. from surface.
10763	Miami	Washington	0-6	Silt loam.....	Upland brown silt loam. 6 in. to color line, gravel and limestone pebbles at 15 in.
10732	Montgomery	Jackson	0-6	Silt loam...	Upland grey silt loam. 5 in. to color line.
10733	Montgomery	Jackson	0-6	Clay loam............	Upland black pocket. 10 in. to color line.
10734	Montgomery	Jackson	0-6	Silt loam.....	Upland clay loam. Limestone pebbles at 2 ft. 7 in. to color line.
10735	Montgomery	Jackson	0-6	Clay loam	Upland clay loam. Dark pocket, virgin soil. 9 in. to color line.
10736	Montgomery	Jackson	0-6	Silt loam...........	Upland timber. 3 in. to color line.
4754	Montgomery	....	0-6	Black clay loam	6 mi. southwest of Dayton and ½ mi. to the right of the Germantown Pike.
4755	Montgomery	....	0-6	Black clay loam	Virgin, from fence row.
10728	Montgomery	....	0-7	Clay loam	From tobacco plots of S. W. Substation, Germantown, Ohio.
4752	Montgomery	....	0-6	Clay loam }	Alfalfa field on left of Germantown pike, 5 mi. southwest of Dayton, field adjoining limestone quarry. The soil and subsoil show very little differentiation, except that the latter is somewhat more compact.
4753	Montgomery	....	6-36	Clay loam }	
9702	Meigs	....	0-7	Silt loam.................	From S. E. Substation, Carpenter, Ohio. Sec. B, Plot 16.
9703	Meigs	....	0-7	Silt loam.........	East border of Sec. B.
9704	Meigs	....	0-7	Silt loam.................	North border of Sec. A.
4639	Mahoning	....	0-6	Clay loam.................	From Boardman field. Composite of Plots 1-4-7-10, Sec. A. Grew potatoes 1908, fertilizer corn 1909.
4640	Mahoning	....	0-6	Clay loam.................	Boardman field. Composite of Plots 1-4-7-10, Sec. B, wheat 1908, variety soybeans 1909.
4641	Mahoning	....	0-6	Clay loam...............	Boardman field. Composite of Plots 1-4-7-10, Sec. E, proposed alfalfa test 1909. wheat 1908. East end quite wet.
4642	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. C, wheat 1908, variety corn 1909.
4643	Mahoning	....	0-6	Clay loam	Boardman field. Composite of Plots 1-4-7-10, Sec. D, orchard grass. Sod turned under and medium green soybeans planted in 1909.
10740	Preble	Jackson	0-6	Clay loam	Upland black pocket, black clay loam. Sandy at 36 in.; 9 in. to color line.
10739	Preble	Jackson	0-6	Silt loam...........	Gently rolling upland, grey silt loam. 15 in. to color line.

TABLE III: Giving location and description of soils studied.—Continued

Lab. No.	County	Township	Depth inches	Classification	Description
10738	Preble	Lanier	0-6	Clay loam	Level clay loam. 18 in. to color line.
10737	Preble	Lanier	0-6	Silt loam...........	Upland grey silt loam, gently rolling. 12 in. to color line.
4716	Putnam	Blanchard	0-6	Black clay loam	4 mi. southeast of Ottawa. Farm of Wm. Blodget. Black clay loam, underlaid by a dark colored clay subsoil. Clover fine stand.
4717	Putham	Blanchard	6-36	Black clay loam	
4718	Putnam	Blanchard	0-6	Black clay loam.....	Open woodland, 40 rods west of 4716.
4719	Putnam	Blanchard	0-6	Clay loam	Farm of J. A. Maidlow. Said to be rather unproductive, is quite hard and cracks in dry weather. Subsoil is tough, mottled clay.
4720	Putnam	Blanchard	6-36	Clay loam	
4721	Putnam	Blanchard	0-6	Clay loam	Fence row.
4722	Putnam	Blanchard	0-6	Sandy loam	Putnam County Infirmary Farm. Alfalfa patch just north of orchard. Soil is a decided sandy loam, containing limestone pebbles or particles of crushed limestone, which may have been applied to the soil at one time. This feature is especially perceptible at the east end of field. Subsoil appears to be mainly a mixture of clay, sand and fine gravel.
4723	Putnam	Blanchard	6-36	Sandy loam	
4724	Putnam	Blanchard	0-6	Sandy loam.............	School yard adjoining 4722 and 4723.
4725	Putnam	Van Buren	0-6	Sandy clay	Farm of C. Gusar, along south line of Van Buren Tp. and 1½ mi. from east county line. Red clay soil with perceptible sand content. The subsoil closely resembles the surface to a depth of 20-36 in. Below 36 in. is a thin stratum of yellowish clay underlaid by a stratum of creek sand. Soil appears to be quite fertile. Corn good stand.
4726	Putnam	Van Buren	6-36	Sandy clay	
4727	Putnam	Pauline	0-6	Sandy loam	Surface is a sandy loam underlaid by a sandy subsoil, not much different in character from surface except being lighter in color, due doubtless to a larger amount of organic matter in surface. Wheat stubble indicated fine crop.
4728	Putnam	Pauline	6-36	Sandy loam	
10753	Warren	Deerfield	0-6	Silt loam.................	Upland grey to brown silt loam. 6 in. to color line. Limestone outcrops 1 mi. northwest on same level.
10754	Warren	Deerfield	0-6	Silt loam.................	Upland grey silt loam. Wooded pasture. 3 in. to color line. Limestone outcrops ½ mi. northwest on same level.
10755	Warren	Hamilton	0-6	Sandy loam...............	Little Miami river bottom, fine sandy loam. 21 in. to color line. Limestone pebbles on river bottom.
10757	Warren	Deerfield	0-6	Silt loam	Upland grey silt loam. 6 in to color line. Limestone outcrops 1 mi. northwest on same level.
10760	Warren	Union	0-6	Silt loam.....	Upland reddish grey silt loam. 3 in. to color line. Limestone rock at 20-25 ft.
10761	Warren	Turtle Creek	0-6	Silt loam.................	Upland black loam. 13 in. to color line. Infirmary Farm.
10762	Warren	Union	0-6	Silt loam.................	Second bottom grey silt loam. 8 in. to color line. Limestone outcrops in surrounding hills.

TABLE III: Giving location and description of soils studied.—Concluded

Lab. No.	County	Township	Depth inches	Classification	Description
10764	Warren	Turtle Creek	0-6	Clay loam	Upland grey clay loam, hillside; 5 in. to color line. Limestone scattered on surface.
4673	Wayne	....	0-6	Silt loam	2½ mi. north of Wooster, Bruce field. Timothy very poor, weeds in possession, sorrel, hood leaf and plantain predominating. Heavily farmed for years with very little fertilization. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4674	Wayne	....	0-6	Silt loam	From fence row of Bruce field.
4675	Wayne	....	0-6	Silt loam }	¼ mi. north of Madisonburg. Oats good. Not much differentiation in color between soil and subsoil to 36 in. depth. Below 36 in. begin to strike gravelly stratum. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4676	Wayne	....	6-36	Silt loam }	
4677	Wayne	....	0-6	Silt loam	1½ mi. north of Madisonburg. Oats fair. Soil evidently in poorer tilth than 4675. Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4679	Wayne	....	0-6	Silt loam	5 mi. northeast of Wooster. Timothy very good. (Grady farm.) Mapped by Bureau of Soils, U. S. D. A. as Volusia silt loam.
4680	Wayne	....	0-6	Clay loam	3 mi. north of Madisonburg. Corn 1909. Sod plowed down. Crop fertilized in row. Samples were taken directly from between the rows. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4681	Wayne	....	0-6	Clay loam }	2 mi. south of Creston. Wheat fair to good. No clover. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4682	Wayne	....	6-36	Clay loam }	
4683	Wayne	....	0-6	Clay loam	Virgin timber joining field from which 4681 and 4682 were taken.
4684	Wayne	....	0-6	Clay loam	4 mi. north of Smithville. Timothy good. Subsoil mottled yellow and grey. Mapped by Bureau of Soils, U. S. D. A. as Miami clay loam.
4685	Wayne	....	0-6	Clay }	1 mi. southwest of Sterling. Timothy very good. Soil very black and sticky. Is typical of the darker colored local areas of the Waverly clay type, as described by the Bureau of Soils. Mapped by Bureau of Soils, U. S. D. A. as Waverly clay.
4686	Wayne	....	6-36	Clay }	
4687	Wayne	....	0-6	Clay	Permanent pasture. Not as black as 4685 and according to Bureau of Soils, more typical of larger areas of type. Subsoil at 18 in. more yellow than 4686. Mapped by Bureau of Soils, U. S. D. A. as Waverly clay.
4688	Wayne	....	0-6	Sandy loam }	2½ mi. southwest of Sterling. Timothy fair. Mapped by Bureau of Soils, U. S. D. A. as Miami sandy loam.
4689	Wayne	....	6-36	Sandy loam }	
4690	Wayne	....	0-6	Gravelly loam }	3 mi. southeast of Sterling. Timothy fair. Below 30 in. gravel and sand much more abundant than in upper stratum of subsoil. Mapped by Bureau of Soils, U. S. D. A. as Miami gravelly loam.
4691	Wayne	....	6-36	Gravelly loam }	

COMPOSITION OF DIFFERENT SOIL TYPES

In classifying the soils sampled, the terms applied by the Bureau of Soils, U. S. Dept. of Agriculture, have been used when the soils were secured from areas surveyed and mapped by that Bureau. Where samples were taken from sections not mapped the soils were classified according to color and texture.

The distinguishing characteristics of different soil types are chiefly those aside from their chemical composition. Differentiations are generally based on texture, color, geological origin, physical or mechanical properties, depth of surface soil, presence of greater or less quantities of organic matter, topography and drainage conditions. The mineral particles which are present in different degrees of fineness as sand, silt and clay determine the soil texture. The mineral content of a sandy soil may not vary greatly from that of a clay soil. Soil particles of different grades of fineness are the result of disintegration of rocks through mechanical, chemical, and biological agencies and may be feldspar, quartz, limestone, mica or other minerals, so that often fine particles classed as clays include a considerable amount of quartz, while the sands may be made up largely of other minerals than quartz. Except in the case of soils largely of organic formation—peats—the bulk of the material which composes a sand, silt or clay is silica or quartz.

Chemically pure or true clay is a compound of silica and alumina containing no potassium or other constituents which contribute towards plant growth. The term clay, used in describing soils, refers to the soil texture and denotes soil particles of a diameter of less than .0002 of an inch.

The physical distinction made between sands, silts and clays, does not necessarily indicate that there is more true clay in soils made up of finer particles than in those of coarser texture.

The composition of the mechanical separations of soils which, in the order of their size are sand, silt and clay, shows that as the degree of fineness increases so does the proportion of soluble constituents. It would be expected therefore that clay soils would differ chemically from silts, and silts from sandy soils.

No marked variation has been found in the total amounts of the elements present in the several grades of soil: the clays and clay loams generally contain less silicon, and somewhat larger amounts of iron, aluminum, potassium and phosphorus than the soils of coarser texture.

TABLE IV. Giving average composition of the several classes of soil. Divided into calcareous and non-calcareous. Surface soil 0-6 inches.

	Silicon	Iron	Aluminum	Calcium	Magnesium	Phosphorus	Potassium	Nitrogen	Humus
Calcareous Sands and Sandy Loam Soils.									
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Total....................	33.1700	2.0550	4.6790	1.9372	.8056	.0652	1.659	.1926	1.90
N-5 HNO_3 Soluble.....	.0301	.0369	.1263	1.3279	.3286	.0201	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	.0900	1.8000	2.6900	68.5600	40.7800	30.8300	.....	.....	....
Non-calcareous Sands and Sandy Loam Soils.									
Total..................	36.4900	1.7680	4.3590	.5685	.3539	.0548	1.296	.1371	1.63
N-5 HNO_3 Soluble.....	.0178	.0296	.1198	.0826	.0102	.0041	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	.0490	1.7000	2.7500	14.6000	2.8800	7.4800	.....	.....	....
Calcareous Silts and Silt Loam Soils.									
Total..................	34.9100	2.1440	4.8850	.8076	.5938	.0553	1.846	.1378	1.19
N-5 HNO_3 Soluble.....	.0306	.0352	.1181	.3686	.1288	.0045	.....	.....	....
Percent of total, soluble in N-5 HNO_3.......	.0870	1.6300	2.4100	44.4300	21.6900	8.1300	.....	.....	....
Non-calcareous Silts and Silt Loam Soils.									
Total..................	35.9700	2.1370	4.9840	.4075	.4368	.0514	1.678	.1445	1.63
N-5 HNO_3 Soluble.....	.0170	.0194	.1114	.1099	.0197	.0009	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	.04600	.8900	2.2200	26.9600	4.5100	1.7500	.....	.....	....
Calcareous Clays and Clay Loam Soils excluding Black Clay Loams.									
Total..................	33 2400	2.6230	5.2500	.7500	.5662	.0709	1.945	.1822	1.48
N-5 HNO_3 Soluble.....	.0402	.0576	.1349	.3673	.0952	.0067	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	.1200	2.1900	2.5600	48.9700	16.8100	9.4500	.....	.....	....
Non-calcareous Clays and Clay Loam Soils									
Total..................	33.9400	2.5540	5.7460	.3868	.4949	.0516	1.851	.1908	1.91
N-5 HNO_3 Soluble.....	.0170	.0405	.1414	.1085	.0254	.0011	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	.0500	1.5800	2.4600	28.0600	5.1300	2.1100	.....	.....	....
Black Clay Loam Soils (Calcareous or of Limestone origin).*									
Total..................	29.6600	2.9580	5.4660	1.1795	.6688	.0850	1.835	.3725	3.43
N-5 HNO_3 Soluble.....	.0608	.0941	.1927	.7749	.1681	.0082	.....	.....	....
Percent of total, soluble in N-5 HNO_3........	..2050	3.1800	3.5300	65.7000	25.2400	9.5600	.....	.....	....

*Only two of the black clay loams sampled contained no calcium carbonate; the subsoils of these two contained calcium carbonate.

Soils classed as being of the same texture often differ widely with respect to their agricultural value, as a result of the presence or absence of calcium carbonate. When the soils are considered with reference to the presence or non-presence of calcium carbonate, greater variations are noticed in the chemical composition of soils of the same class than when a comparison is made between soils classified according to differences in texture.

Table IV, page 469, gives the average composition of the several classes of soils, divided into calcareous and non-calcareous. The calcareous soils all contain less total silicon and larger amounts of total phosphorus and potassium than the non-calcareous soils of the same class; their content of total calcium and magnesium is also greater, as would be expected.

It will be noticed that there is an increase in the solubility of iron, calcium and magnesium in the calcareous soils. There is a decidedly increased amount of soluble phosphorus in the calcareous soils as compared with soils containing no calcium carbonate.

The composition of the black clay loams differs considerably from that of the other classes of soil. These black clay loams were all of limestone origin and contain less total silicon and more nitrogen and phosphorus than the other classes of soil analyzed. Table V, page 477, gives the percents of total and N- 5 nitric acid soluble constituents found in the several classes of soil studied.

SOIL AND SUB-SOIL

The term soil is here used with reference to the layer of soil extending from the surface to a depth of six inches, and the term subsoil is applied to the depth from 6 inches down to 3 feet. Information concerning the underlying soil to the depth of three feet is considered sufficient so far as any effect on the surface soil is concerned. The depths of soil sampled are purely arbitrary since the change from surface soil to subsoil as indicated by color and texture is not always observed at a depth of 6 inches, but varies considerably; when the samples were taken, differences were frequently noted. The first 6 to 7 inches of soil in most cases is the depth which is affected by cultivation, and except where the original soil has been covered with a deposit less rich in organic matter this depth of soil always contains more organic matter than the subsoil.

Phosphorus and nitrogen, the two elements—phosphorus especially—which are most often deficient in Ohio soils, are present to the greatest extent in the surface 6 or 7 inches. Except in a few instances, where the lower soil stratum is found to be liberally supplied with calcium carbonate, phosphorus is always most abundant in the surface six or seven inches, where it accumulates from plant remains and from leachings by rain and dew on vegetation. A considerable portion of the phosphorus stored in plants, and subsequently returned to the soil, is taken up by the plant roots from soil strata deeper than six or seven inches. Another factor which may contribute to this increased accumulation of phosphorus in the surface soil is the absorbing power of organic matter. As the soil solution carrying phosphorus is continually moving through the soil mass, it may have phosphorus fixed or absorbed from it by organic matter, which is generally present in the largest amount in the upper layer of soil. An indication of the power of organic matter to absorb phosphorus from solution is given by work now in progress on the absorption of phosphorus by soils. The results show that peat soils have this power greatly in excess of what would be expected from their small content of mineral material; and when the organic matter is partially destroyed by oxidation with hydrogen peroxide, the amount of phosphorus absorbed by a peat soil in contact with a solution containing phosphorus is decreased.

Total silicon is present in largest amounts in the surface soil, while the silicon from silicates most readily attacked and taken into solution by the weak acid used—fifth normal nitric acid—increases in the subsoil; greater quantities of total iron, aluminum and potassium are present in the lower strata.

The chief distinction between soils and subsoils is their difference in texture. By the action of various agencies, including cultivation, weathering and bacterial activities, the soil grains are gradually disintegrated and the finer particles carried from the surface to lower depths by the rain water percolating down through the soil, leaving a larger portion of the silicon as quartz in the surface or top soil.

CALCIUM AND MAGNESIUM

An interesting relationship is shown between calcium and magnesium in the two depths of soil analyzed. Comparing the content of these two elements in all soils, regardless of the absence or presence of calcium carbonate, it will be noticed that a greater proportion have more total calcium than magnesium in the surface soil, while in the subsoil the magnesium exceeds the calcium in the greater number of instances. Comparing only the soils containing no calcium carbonate, either in the surface or subsoil, a greater number of the soils have more magnesium than calcium in each depth.

An average of the amounts of these two elements present, however, shows that soils containing no calcium carbonate have a greater percent of calcium in the surface soil than in the subsoil and a greater percent of magnesium in the subsoil.

In soils and subsoils containing calcium carbonate the calcium and magnesium are both found in larger amounts in the subsoil than in the surface. The presence of a larger amount of total calcium in surface soils which contain no carbonates may be explained by the existence of insoluble organic salts of calcium in the surface; this has previously been referred to.

Of forty-two surface soils containing calcium carbonate, the magnesium exceeds the calcium in only five soils. Of the hundred and twenty-six samples of surface soils examined, seventy-three contained more calcium than magnesium and in forty-two of these there were carbonates of calcium or magnesium present. In fifty-four soils containing more magnesium than calcium there were carbonates found in only six samples. Of the forty subsoils examined, sixteen contained more calcium than magnesium and in ten of these carbonates were found. Twenty-four of the subsoils contained more magnesium than calcium and of these only three showed the presence of carbonates. It may be stated that when the magnesium is in excess of the calcium, as a rule, no carbonates are found.

The more readily soluble calcium and magnesium in the two depths follow the same general order as the total calcium and magnesium. In all the soils represented by the samples studied, there is a much larger proportion of calcium than of magnesium soluble in N-5 nitric acid. The difference in calcium and magnesium content is pointed out by the summarized results in Table I, page 451. The reason for the greater amount of magnesium in subsoil than in surface soil is not evident.* Calcium and magnesium carbonates are soluble in water containing carbonic acid gas. The solubility of chemically precipitated magnesium carbonate in carbonated water is greater than that of calcium carbonate; when these compounds as found in the soil are acted upon by carbonated water, their solubility may be different.

Authorities state that carbonate of lime has a greater solubility than magnesium carbonate as the latter ordinarily exists in nature. According to Hilgard, dolomitic rocks are much more easily decomposed by weathering than the non-magnesian limestones. In some of the soils analyzed it is doubtful whether calcium or magnesium

*Work recently reported by Lyon and Bizzel has shown that calcium is much more abundant than magnesium in soil drainage water and that their ratio is influenced by cropping. Jour. Ind. and Eng. Chem., Vol. III, No. 10.

ever existed as carbonates. The comparative solubility of these two elements combined as silicates is then involved. The relative solubility of calcium and magnesium in soil water is indicated by the amounts contained in spring and well waters; considerable quantities are found in most water supplies even in sections devoid of limestone. Analysis of well water from the Wooster Station farm, the soil of which has no natural carbonates of calcium or magnesium, shows the presence of .067 grams of CaO and .021 grams MgO per liter.

Hopkins[1] states that an average of 90 analyses of Illinois well water, drawn chiefly from glacial sands, gravel or till, shows 330 pounds of calcium and 130 pounds of magnesium in 3 million pounds of water. (About average annual drainage per acre for Illinois).

Data given by Clarke[2] show that in well and spring water and in the water of the rivers of the world, the calcium content is generally in excess of the magnesium.

The crop requirements for these two elements, as indicated by the composition of farm crops, show that calcium is removed in excess of magnesium.

SOIL ACIDITY

Calcium carbonate performs such an important part in the maintenance of soil fertility that, by the action of numerous agencies, the supply is rapidly decreased. The formation of carbonic and other acids, as a natural result of changes taking place in organic matter due to organisms, contributes largely to this loss of lime carbonate from soils. The composition of drainage waters shows that this important soil constituent is removed more abundantly by the percolating soil water than any of the other mineral elements which make up the soil.

Determinations of calcium carbonate residual from applications made to the Wooster soil, which does not contain natural carbonates and is acid in its reaction to litmus paper, give an indication of the rate with which calcium carbonate disappears from cultivated soil.

On a portion of this soil devoted to a fertility experiment, which includes the growing of cereals and sweet clover in a 5-year rotation, ground limestone was applied at the rate of six tons per acre in 1907. This quantity of limestone carried calcium and magnesium carbonates equivalent to 12,000 pounds of calcium carbonate per acre. In 1912 the soil to a depth of eight inches contained only 2,085 pounds; a loss of 9,900 pounds in a period of five years. This means that 82 percent of the calcium carbonate applied has been leached from the soil, or changed by some processes taking place in the soil into forms, other than basic lime compounds,

[1]Univ. of Ill. Agr. Expt. Sta. Soil report No. 4.
[2]The Data of Geochemistry Bul. No. 330 series E. U. S. Geol. Survey.

capable of preventing soil acidity. No calcium carbonate was found in depth of soil below eight inches, to a depth of two feet. A part of the calcium carbonate, carried down by the soil water in solution as calcium bi-carbonate, would react chemically with the minerals present in the lower strata, and the remainder would be carried away into the drainage.

To another part of the farm, used for a 5-year rotation of corn, oats, wheat, clover and timothy, a smaller quantity of lime was applied, and the loss has been distributed over a longer period. The lime treatment here has been as follows: in 1904 caustic lime, which would rapidly change to calcium carbonate in contact with the soil, was applied at the rate of 1,000 pounds per acre; in 1909, the soil was treated with ground limestone at the rate of 2,000 pounds per acre. These amounts of caustic lime and limestone are equivalent to 3, 780 pounds of calcium carbonate. An analysis of this soil, in 1912, showed the presence of only 300 pounds per acre 6 inches of soil, a loss of 92 percent of the quantity originally added. The second depth of soil, 6 to 12 inches, contained only 100 pounds of calcium carbonate per acre.

A deficiency of lime carbonate is indicated by the character of the vegetation and the red color imparted to blue litmus paper.

The fact that leguminous plants which thrive best on calcareous soils can only be grown successfully on acid soils after lime is artificially supplied is sufficient evidence of the necessity of maintaining soils in a neutral or slightly alkaline condition. The degree of acidity, measured by the amount of lime required to change the reaction from acid to neutral, varies considerably for different soils. Sandy soils as a rule have a lower lime requirement than clay soils.

The nature of the acidity, or the cause, is not the same for all soils. Organic matter, in some cases where the drainage is not adequate, is an important factor in the production of acidity. In peat soils or in soils where the organic matter is excessive the presence of organic acids is apparent from the solvent action of the water which drains from the peat on the iron deposits in the sand or gravel through which the water passes. This condition was observed in Lorain county along a sandy ridge three miles east of Amherst, on the farm of H. W. Schmitkons. Here the topography is such that a sandy ridge separates a peat formation on one side from an area on the other which lies so that it receives the drainage from the soil rich in organic matter; the water seeping through the sand formation dissolves iron, which when gradually oxidized gives a characteristic red color to the soil surface on which it is deposited. In soils which contain scanty supplies of organic materials the acid condition may be due to silicic acid or acid salts of inorganic origin. Cultivated soils develop an increasing acid condition which is indicated by the gradual failure of clover on soils which at one time produced fair yields of this crop and have continued to produce good yields of cereals. This is particularly noticeable on non-calcareous soils where various fertilizing materials, including acid phosphate and ammonium sulphate, were used. The selective absorptive capacity of plants, where different forms of the essential nutrients are supplied, no doubt contributes to an increasing or decreasing degree of acidity.

Nitrogen is assimilated from ammonium sulphate, leaving sulphuric acid in the soil. Where nitrate of soda is applied as a carrier of nitrogen, the crops use the nitrogen furnished, leaving sodium in the soil. The sodium is gradually changed to sodium carbonate, which tends to decrease the acidity. The two carriers of phosphorus, acid phosphate and bone meal, each differ in their effect; acid phosphate adds acid salts to the soil, while where bone meal is used phosphorus, with some calcium, is assimilated by the growing crops, and a portion of the calcium remaining may, under certain conditions, be gradually converted into calcium carbonate.

The growth of clover on the plots of the unlimed Wooster soil treated with acid phosphate and ammonium sulphate, compared with plots where nitrate of soda is used as a carrier of nitrogen, and bone meal as a carrier of phosphorus, serves to illustrate the effect of the relation between the growing crops and the fertilizer used, on the degree of acidity. On the unlimed soil where nitrate of soda furnishes the nitrogen and phosphorus is supplied in bone meal, some clover grows, while on the unlimed soil where acid phosphate and ammonium sulphate are used clover is a complete failure.

The calcium carbonate residual from an application of 3,800 pounds of calcium carbonate to unfertilized soil, and to soil treated with acid phosphate and ammonium sulphate, gives further confirmation of the effect these fertilizing materials have in decreasing the basicity of the soil. Part of the lime was added to the land in 1904 and the rest in 1909. When the soil was examined in 1912, 600 pounds of calcium carbonate per acre were present in the unfertilized soil; 300 pounds in the soil from the acid phosphate plots, and none in the soil where ammonium sulphate was applied as the nitrogen carrier.

The difference between limestone soils and sandstone soils previously referred to shows the deficiency in lime carbonate of the soils from the eastern section of the State.

From the detailed results given in Table II, page 453 and following, will be seen the calcium carbonate expressed in pounds per two million pounds of soil and the reaction to litmus paper.

Comparative tests made in this laboratory on soils have demonstrated that the litmus paper test, if properly made, is a satisfactory qualitative test for the presence or absence of natural lime carbonate. Of the surface soils examined for calcium carbonate and acidity, only five of those which contained calcium carbonate reddened blue litmus paper. Of these five soils two, containing only 100 pounds of calcium carbonate per acre, were virgin timbered soils; one overlaid alkaline subsoil containing calcium carbonate; one, with 400 pounds calcium carbonate per acre, was a virgin timbered soil overlying subsoil containing calcium carbonate; and one, which showed the presence of 600 pounds per acre, was a virgin soil from fence row probably contaminated with dust from limestone road. All of the surface soils that reacted alkaline to red litmus paper contained calcium carbonate.

Treatment with dilute acid is of course a sure indication of carbonates in soils when present in sufficient quantity and not in too finely divided a condition to produce a noticeable effervesence.

Soils from sandstone and shales will, from the nature of their origin, have a greater tendency to be acid than will those from limestone. The detailed results given in Table II point out this fact. Considering the surface soils from Ashtabula, Cuyahoga, Mahoning and Wayne counties, which are not in the limestone area, carbonates were found in amounts equal to 100 parts per 2,000,000 pounds of soil in only two instances, and all the soils with the exception of one were acid in their reaction to litmus paper. With one exception, none of the subsoils from these counties contained calcium carbonate. This one soil, located in Ashtabula county, 2 miles north of Saybrook Corner, Saybrook township, showed the presence of 400 pounds per 2,000,000 pounds of soil in the depth from six inches to three feet.

Dr. Geo. N. Coffey, in charge of the soil survey work of this Station, reports the presence of carbonates, as determined by effervesence with acid, at a depth of three to four feet in a number of places along roadside cuts, in Wayne, Medina and Cuyahoga counties.

Calcium carbonate was found in considerable amounts in many of the surface soils from the western part of the State, as will be seen from an inspection of the data in Table II. In practically all instances, where the surface soil contained calcium carbonate, the source of the supply was evidenced by the increased amount of calcium carbonate in the corresponding subsoil.

TABLE V. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Alum-inum Percent	Calcium Percent	Magne-sium Percent	Potas-sium Percent	Phos-phorus Percent	Nitrogen Percent	Humus Percent	Man-ganese Percent
4652	0-6	Gravel...........	Total	33.3500	2.6228	4.9570	.4608	.3927	1.3120	.0663	.1240	1.79	.0480
			Soluble	.0069	.0140	.1447	.0448	.0041	......	.0012	.....	...	.....
4654	0-6	Gravel.............	Total	33.6500	2.4076	5.1070	.3216	.4255	1.3282	.0965	.1813	2.09	.1079
			Soluble	.0104	.0294	.2064	.0394	.0051	......	.0085	.....	....	.....
4709	0-6	Sand	Total	39.3500	1.1953	3.9200	.6445	.2619	1.3200	.0277	.0715	.91	.0094
			Soluble	.0225	.0160	.1174	.0513	.0094	......	.0057	.....	....	.....
4710	6-36	Sand	Total	39.7200	1.2797	3.9500	.6422	.3784	1.4555	.0126	.0255	....	.0049
			Soluble	.0305	.0104	.1176	.0341	.0071	......	.0012	.....	....	.....
4711	0-6	Sand	Total	39.0700	1.1672	3.6800	.7151	.2619	1.3764	.0251	.0850	1.47	.0115
			Soluble	.0211	.0111	.1174	.0542	.0085	......	.0025	.....	....	.....
4665	0-6	Stony loam.........	Total	36.0400	2.2197	4.9800	.2505	.3374	1.5860	.0390	.1260	1.34	.0546
			Soluble	.0054	.0218	.0832	.0601	.0126	......	.0004	.....	....	.....
4666	6-36	Stony loam.........	Total	33.7300	3.8257	6.3600	.2359	.4144	2.1067	.0271	.0542	....	.0155
			Soluble	.0218	.0323	.0916	.0636	.0288	......	.0001	.....	....	.....
4667	0-6	Stony loam.........	Total	36.9400	2.2483	4.6500	.2845	.2932	1.4990	.0450	.1230	1.19	.0694
			Soluble	.0044	.0253	.0874	.0224	.0096	......	.0004	.....	....	.....
4690	0-6	Gravelly loam......	Total	36.8400	2.1626	4.3700	.3600	.3812	1.5184	.0570	.1180	1.13	.1104
			Soluble	.0093	.0861	.1323	.0406	.0078	......	.0036	.....	....	.....
4691	6-36	Gravelly loam......	Total	35.2500	3.8828	5.1650	.3138	.5108	1.5795	.0391	.0457	....	.0526
			Soluble	.0164	.0584	.1044	.0229	.0170	......	.0004	.....	....	.....
4670	0-6	Gravelly loam......	Total	36.5000	2.1199	4.2500	.3405	.4024	1.2895	.1312	.1705	1.82	.0573
			Soluble	.0117	.0812	.2317	.0371	.0075	......	.0005	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Alum-inum Percent	Calcium Percent	Magne-sium Percent	Potas-sium Percent	Phos-phorus Percent	Nitrogen Percent	Humus Percent	Man-ganese Percent
4648	0-6	Gravelly loam......	Total	33.6100	2.7313	5.8970	.2736	.5371	1.7246	.0504	.1680	1.57	0779
			Soluble	.0068	.0106	.1178	.0640	.0096	.....	.0003	.....	....	.....
4649	6-36	Gravelly loam......	Total	31.0100	4.5188	7.9340	.2256	.8685	2.5694	.0311	.0690	....	.0295
			Soluble	.0308	.0403	.1526	.0696	.0306	.. ...	.0001	.....	....	.....
4650	0-6	Gravelly loam......	Total	32.5700	3.0316	5.6530	.4128	.4594	1.5956	.0566	.1422	1.52	.1005
			Soluble	.0035	.0137	.1069	.0487	.0092	......	.0002	.....	....	.....
4651	0-6	Gravelly loam.	Total	34.9800	3.0935	4.6510	.4565	.4222	1.2572	.0810	.1157	1.56	.0529
			Soluble	.0115	.0199	.1471	.0605	.0056	......	.0044	.....	....	.....
4722	0-6	Sandy loam	Total	34.4900	2.1698	5.0500	.8480	.3134	1.7809	.0561	.2097	1.72	.0793
			Soluble	.0263	.0080	.0977	.2909	.0292	......	.0019	.....	. ..	.....
4723	6-36	Sandy loam	Total	32.8700	3.5544	6 1300	.8143	.5222	1.7600	.0384	.0717	....	.0686
			Soluble	.0831	.0558	.1545	.3173	.0447	......	.0023	.....	....	.....
4724	0-6	Sandy loam.......	Total	35.3700	1.6274	4.3500	.7201	.2756	1.8405	.0614	.2255	1.79	.1049
			Soluble	.0162	.0107	.1044	.2358	0210	......	.0009	.....	....	.....
4701	0 6	Sandy loam.......	Total	34.2700	1.3922	4.9100	1 0550	.4279	1.7455	.0528	.2712	3 35	.0151
			Soluble	.0317	.0279	.2041	.4080	.0405	.....	.0172	.....	....	.....
4702	6-36	Sandy loam.......	Total	35.9900	1 8847	5.5100	.8727	.5154	1.7728	.0381	.0645	....	.0204
			Soluble	.0519	.0426	.1553	.2541	.0511	......	.0172	.....	....	.....
4703	0-6	Sandy loam.......	Total	35.3300	1.3640	4 6900	.9320	.4167	1.7295	.0493	.2442	2 63	.0108
			Soluble	.0237	.0551	.1755	.3667	.0357	......	.0117	.....	....	.....
4704	0-6	Sandy loam.......	Total	37.1200	1.2164	4.0800	.9730	.3752	1.4329	.0467	.1830	2.04	.0093
			Soluble	.0166	.0335	.1063	.2600	.0263	.0051	.0137	.....	...	.....
4705	6-36	Sandy loam.......	Total	37.4800	1.5891	4.4600	.8951	.3576	1.5697	.0376	.0487	....	.0145
			Soluble	.0366	.0251	.0822	.1151	.0370	.0020	.0144	.....	....	.....
4688	0-6	Sandy loam........	Total	38.7400	1 3061	3.7550	.4476	.2745	1.2089	.0277	.1217	1.50	.0102
			Soluble	.0042	.0783	.0921	.0442	.0080	.....	.0003	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. S rface and subsoils.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4689	6-36	Sandy loam......	Total	39.6200	1.5488	3.8820	.4889	.3314	1.3056	.0135	.0245	....	.0105
			Soluble	.0075	.3106	.0569	.0318	.0123	.....	.0001	.....	....	.....
4658	0-6	Sandy loam......	Total	34.2600	2.1924	4.3330	.5616	.3490	1.1316	.0575	.1657	1.93	.0188
			Soluble	.0346	.0171	.1954	.0082	.0035	.....	.0025	.....	....	.....
4659	6 36	Sandy loam......	Total	35.9500	2.3807	4.5340	6864	.4343	1.2572	.0278	.0520	..	.0210
			Soluble	.0298	.0255	.1244	.0079	.0045	......	.0015	.....	....	.....
4660	0-6	Sandy loam......	Total	32 4200	3.6719	4.7470	.8880	.6102	1.1476	.0558	.1127	1.35	.0750
			Soluble	.0183	.0437	.1475	.0445	.0060	......	.0116	.....	....	.....
4661	0-6	Sandy loam......	Total	31.7300	2.9187	5 2820	.5376	5294	1.1348	.1100	.1535	1.93	.0313
			Soluble	.0205	.0252	.1455	.0131	.0026	......	.0060	.....	..	.....
4662	0-6	Sandy loam......	Total	34 6400	2.1789	5 1760	3504	.4134	1.2863	.0517	.2045	2.12	.0272
			Soluble	.0169	.0227	.0834	.1958	.0146	......	.0024	.....	....	.....
4668	0-6	Sandy loa■......	Total	37.0500	1.9700	4.6500	.3186	.3663	1.4813	.0489	.1125	1.20	.0679
			Soluble	.0058	.0328	.1012	.0342	.0090	......	.0002	.....	....	.....
4669	6-36	Sandy loam......	Total	35.7300	2.9550	5.4800	.3016	.4664	1.7794	.0301	.0390	....	.0309
			Soluble	.0173	.0223	.0998	.6371	.0265	......	.0003	.....	....	.....
10751	0-6	Sandy loam......	Total	26.4200	1.9937	4.1360	6.5951	2.7792	1.4830	.0696	.0947	.95	.....
			Soluble	.0646	.0375	.0732	5.4266	1.6866	......	.0088	.....	....	.....
10755	0-6	Sandy loam......	Total	30 8500	2.1863	4.5532	4.0387	1.2360	1.7860	.1319	.....	....	.....
			Soluble	.0423	.0946	.1177	3.5847	.7919	......	.0967	.....	....	.....
4727	0-6	Sandy loam....	Total	36.3100	2.0391	5.0000	.4213	.3859	1.7617	.0453	.1902	1.55	.0132
			Soluble	0180	.0181	.0903	.2659	.0183	......	.0118	.....	....	.....
4728	6-36	Sandy loam..... .	Total	37.0300	4.1700	5.5100	.3067	.6150	1.8568	.0289	.0762	....	.0118
			Soluble	.0239	.0208	.0814	.1879	.0209	......	.0039	.....	....	.....
5279	0-6	Silt loam	Total	36.1800	2.0271	4.6826	.7862	.6083	1.6440	.0592	.1170	1.25	.1454
			Soluble	.0260	.0386	.1262	.1586	.0213	.0064	.0026	.....	....	.....
5280	6-36	Silt loam..... ..	Total	33.7300	3.4545	6.0246	.7493	1.1251	1.9566	.0565	.0582	....	.0554
			Soluble	.0437	.0951	.1682	.1360	.0306	.0074	.0013	....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5288	0-6	Silt loam..........	Total	38.0000	1.5607	4.3778	.6448	.5249	1.2508	.0440	.1237	1.85	.... .
			Soluble	.0117	.0177	.0661	.0675	.0262	.0090	.0007	.....	....	.....
5289	6-36	Silt loam.........	Total	35.3600	2.7294	6.2026	.5033	.5232	1.2186	.0291	.....	....	.....
			Soluble	.0242	.0322	.1208	.0699	.0237	.0102	.0004	.....	....	.....
5294	0-6	Silt loam..... ..	Total	37.0500	2.1588	4.7219	.1979	.3117	1.2896	.0617	.1395	1.81	.....
			Soluble	.0134	.0182	.0909	.0825	.0140	.0075	.0004	.....	....	.....
5307	0-6	Silt loam.........	Total	36.9700	2.1238	5 0700	.1827	.3007	1.6924	.0334	.0917	1.19	.....
			Soluble	.0117	......	......	.0409	.0104	.0060	.0003	.. ..	....	.....
10762	0-6	Silt loam..........	Total	36.3700	2.2412	4.3134	.4476	.3577	1.9279	.0944	.1265	....	.....
			Soluble	.0356	.0361	.1776	.2383	.0216	......	.0086	.....	....	.....
4565	0-6	Silt loam..... ...	Total	35.7700	2.2890	5 2525	.4849	.4060	1.8504	.0579	.1357	2 41	.....
			Soluble	.0204	.0112	.1026	.1357	.0331	......	.0007	.....	....	.....
4566	6-36	Silt loam.........	Total	27.4800	3 6989	6.9579	4.0760	1.8264	1.9792	.0880	.0615	....	.....
			Soluble	.0829	.0815	.2100	3 5012	1.0029	......	.0229	.....	...	.....
4567	0-6	Silt loam....... .	Total	36.1600	2.0075	5 4901	.5401	.3937	1.7086	.0367	.1265	1.38	.....
			Soluble	.0235	.0375	.0875	.1522	.0389	......	.0007	.....	....	.....
4568	6-36	Silt loam.........	Total	27.5200	4.4344	7.9343	1.9484	1.6330	1.7794	.0743	.0852	....	.....
			Soluble	.0700	.0532	.1856	.9700	.5239	......	.0069	.....	....	.....
4733	0-6	Silt loam.........	Total	32.5600	2.6121	5.7224	.8961	.4169	1 8794	.0704	.2540	2 49	.0645
			Soluble	.0338	.0064	.1731	.3078	.0399	.....	.0014	. ...	....	.....
5286	0-6	Silt loam.........	Total	36.7700	2.2482	4.9462	.4914	5700	1.3185	.0603	.1465	1.80	.....
			Soluble	.0226	.0462	.1410	.0876	.0196	.0135	.0007	.....	....	.....
5287	6-36	Silt loam..........	Total	35.2700	2.9013	6.0428	.3992	.7312	1.4604	.0345	.0462	....	.....
			Soluble	.0240	.0261	.1138	.0336	.0225	.0082	.0003	.....	....	.....
4744	0-6	Silt loam.........	Total	36.7300	2.0808	4.2340	.4128	.3216	1.8504	.0465	.1085	1.31	.....
			Soluble	.0182	.0140	.0957	.1249	.0237	......	.0010	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoils

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4745	6-36	Silt loam........	Total	32.8500	2.6920	6.1908	.3624	.5730	1.9664	.0411	.0522	....	.....
			Soluble	0309	.0244	.1534	.0944	.0468	......	.0006	.....	....	.....
4746	0-6	Silt loam........	Total	36.9400	1 8257	4.1435	.3888	.3129	1.8729	.0455	.1322	1.43	.....
			Soluble	.0170	.0230	.0864	.1139	.0276	......	.0013	.....	....	.....
4747	0-6	Silt loam........	Total	36.0300	2.2016	5.3200	.4330	.4900	1.9213	.0409	.1152	.97	.....
			Soluble	.0160	.0101	.0841	.0876	.0176	.....	.0009	.....	....	.....
4748	6-36	Silt loam........	Total	29 9900	4.4571	8.0700	.7921	.9680	2.2856	.0521	.0690	....	.....
			Soluble	.0529	.0459	.1772	.4436	.1724	......	.0014	.....	....	.....
4749	0-6	Silt loam........	Total	33.7500	3.2354	5.7800	.7058	.4306	1.8697	.0680	.1517	1.13	.....
			Soluble	.0351	.0165	.1099	.2433	.0763	......	.0014	.....	....	.....
4750	6-36	Silt loam...... .	Total	27.3200	4.8933	7.6900	1.7554	1 4601	1.9085	.0557	.0812	....	.....
			Soluble	.0613	.0210	.1674	1.1809	.6544	......	.0011	.....	...	.....
4751	0-6	Silt loam.........	Total	36.8200	2.0004	3.9105	.5984	.3294	1.8053	.0395	.1257	.98	.....
			Soluble	.0164	.0426	.0642	.1502	.0376	......	.0008	.....	....	.....
5081	0-6	Silt loam.........	Total	36.1100	2.3483	4.9641	.4865	.4255	1.8923	.0373	.0765	.47	.0439
			Soluble	.0387	.0391	.1222	.1491	.0379	......	.0029	.....	....	.....
5082	6-36	Silt loam.........	Total	33.4000	3.5688	6.0779	.4841	.5710	2.0019	.0352	.0460	..	.0513
			Soluble	.0594	.0470	.1333	.1651	.0689	......	.0001	....	....	.....
5083	0-6	Silt loam.........	Total	36.2400	1.6416	4.1260	.6276	.3861	1.7891	.0567	.1817	1.34	.0570
			Soluble	.0274	.0694	.0867	.2609	.0634	.....	.0138	.....	...	.....
5284	0-6	Silt loam.........	Total	35.8600	2.2688	5.4100	.5528	.5946	1.5440	.0678	.1482	1.40	.....
			Soluble	.0193	.0101	.1166	.1150	.0158	.0093	.0007	.....	....	.....
5285	6-36	Silt loam.........	Total	34.1700	3.3894	6.4491	.4576	.7847	1.6892	.0320	.0472	....	.....
			Soluble	.0418	.0350	.1448	.0744	.0381	.0097	.0003	.....	...	.....
5293	0-6	Silt loam..........	Total	35 0100	2.3444	5.5189	.2813	.3281	1.7086	.0770	.1790	1.79	.....
			Soluble	.0221	.0308	.1106	.1420	.0247	.0094	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
10769	0-6	Silt loam.....	Total	32.3400	2.2688	5.3767	.8508	.5972	1.7891	.1068	.....	....	.....
			Soluble	.0531	.0375	.1795	.4481	.0908	......	.0054	.....	....	.....
10770	0-6	Silt loam.........	Total	30.1800	2.5369	5.5212	.9492	.6256	1.8794	.0596	.....	....	.....
			Soluble	.0451	.0845	.2258	.4150	.0870	......	.0055	.....	....	.....
10771	0-6	Silt loam........	Total	32.0600	2.4750	5.7164	.8705	.6257	1.8246	.0717	.....	....	.....
			Soluble	.0542	.0412	.1754	.3225	.0744	......	.0059	.....	....	.....
10772	0-6	Silt loam.........	Total	31.4000	2.3305	5.5434	.9246	.6158	1.8536	.0793	.....	....	.....
			Soluble	.0528	.0846	.2120	.4900	.0886	......	.0085	.....	....	.....
10732	0-6	Silt loam	Total	37.0900	1.6638	4 5509	.5609	.4474	1.8246	.0288	.0925	....	.....
			Soluble	.0244	.0328	.0421	.1426	.0247	......	.0031	.....	....	.....
4679	0-6	Silt loam.........	Total	36.5200	1.9841	4.6460	.2509	.3461	1.7102	.0504	.1330	1 62	.1321
			Soluble	.0075	.0132	.1069	.0495	.0121	......	.0004	.....	....	.....
4675	0-6	Silt loam........	Total	36.2600	1.8415	4.7150	.3190	.3734	1.6890	.0406	.1225	1.50	.1359
			Soluble	.0082	.0099	.0910	.0589	.0130	......	.0002	.....	....	. ...
4676	6-36	Silt loam	Total	34.7700	3.4472	5.4890	.2942	.5265	1.7939	.0343	.0480	....	.0548
			Soluble	.0178	.0195	.0854	.0619	.0305	......	.0001	.....	....	.....
4677	0-6	Silt loam.........	Total	36.6700	1.8700	4.7150	.2553	.3127	1.6118	.0391	.1227	1.62	.1291
			Soluble	.0061	.0099	.0883	.0300	.0089	......	.0003	.....	....	.....
4673	0-6	Silt loam.........	Total	37.0300	1.9128	4.6560	.2699	.3773	1.7069	.0403	.1005	1 20	.0949
			Soluble	.0082	.0058	.1008	.0483	.0103	......	.0015	.....	....	.....
4674	0-6	Silt loam.........	Total	36.2200	1.8272	4.4340	.3405	.3499	1.6892	.0543	.1537	2.17	.1158
			Soluble	.0089	.0226	.0921	.0849	.0195	......	.0024	.....	....	.....
4644	0-6	Silt loam	Total	31.9000	3.0030	6.1150	.3048	.5906	1.8729	.0494	.2140	2.02	.0798
			Soluble	.0088	.0124	.1817	.1291	.0136	.....	.0003	.....	....	.....
4645	6-36	Silt loam..........	Total	30.8500	4.3329	7.4300	.2544	.8739	2.4693	.0298	.0670	....	.0327
			Soluble	.0411	.0510	.1529	.1107	.0420	......	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Alum-inum Percent	Calcium Percent	Magne-sium Percent	Potas-sium Percent	Phos-phorus Percent	Nitrogen Percent	Humus Percent	Man-ganese Percent
10756	0-6	Silt loam..... ...	Total Soluble	38.2300 .0246	1 5537 .0050	3.9960 .0997	.3394 .0710	.3052 .0116	1.4379	.0428 .0001	.1190	....	....
10734	0-6	Silt loam.........	Total Soluble	36.1900 .0603	1.7876 .0428	5.4456 .2136	.4700 .0995	.6235 .0260	1.8697	.0360 .0103	.1207	....	....
10736	0-6	Silt loam.........	Total Soluble	36 0300 .0102	1.5744 .0398	4.5934 .0840	.5707 .1581	.6267 .0327	1.7860	.0403 .0015	....	....	....
10737	0-6	Silt loam.........	Total Soluble	36.2000 .0267	2.2138 .0272	5.1753 .0791	.5265 .1250	.7558 .0383	1.8440	.0290 .0067	.0910	....	....
10739	0-6	Silt loam.........	Total Soluble	36.3300 .0238	1.8357 .0364	4.7507 .0875	.5166 .1980	.4496 .0345	1.8279	.0482 .0024	.1437	....	....
10743	0-6	Silt loam.........	Total Soluble	33.6300 .0302	2 5438 .0238	5.4170 .1234	.5068 .1925	.6738 .0362	2 1600	.0874 .0044	.1995	....	....
10763	0-6	Silt loam.........	Total Soluble	35.4200 0194	1.8700	4.5551	.5508 .1915	.3938 .0157	1 8182	.0617 .0009	.2025	....	....
10746	0-6	Silt loam..........	Total Soluble	35.1900 .0192	2.1107 .0182	5.2905 .1080	.4822 .1520	5655 .0248	1.8698	.0427 .0007	.1537	....	....
10753	0-6	Silt loam..........	Total Soluble	37.2600 .0235	1.3610 .0333	4 1804 .1145	.3394 .1220	.3599 .0228	1.5893	.0590 .0016	....	....	....
10754	0-6	Silt loam..........	Total Soluble	37.1600 .0227	1.3750 .0367	4.1539 .1194	.3344 .1225	.3249 .0164	1.5538	.0532 .0012	. .. .	....	....
10757	0-6	Silt loam.........	Total Soluble	38.0600 .0148	1.5399 0521	4.0848 .0999	.2754 .0687	.2931 .0126	1 3927	.0352 .0004	.1050	....	....
10760	0-6	Silt loam..........	Total Solnble	36.8400 .0251	1 9662 .0168	4.4132 .0759	.3049 .0933	.3850 .0156	1.8955	.0521 .0012	.1050	....	....
10761	0-6	Silt loam..........	Total Soluble	33.0600 .0338	2.4613 .0227	5.1039 .1476	.6392 .3030	.5052 .0387	1.9214	.0754 .0017	.2365	....	....
4646	0-6	Silt loam..........	Total Soluble	34.2600 .0048	2.3032 .0350	5.4040 .1382	.2640 .1227	.4845 .0118	1.5795	.0373 .0003	.1950	1.71	.0273 .....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5401-1	0-6	Silt loam.........	Total Soluble	32.3100 .0226	2.9975 .0207	7.1484 .1197	.3295 .1760	.4386 .0139	1.8536	.0618 .0011	.0674	....	....
5401-2	6-36	Silt loam..........	Total Soluble	30.6900 .0438	3.8431 .0493	8.8023 .1442	.3000 .1915	.5447 .0287	2.1953	.0558 .0012	.0363	....	....
5283	0-6	Silt loam.........	Total Soluble	32.2900 .0648	2.4338 .2244	5.3298 .2603	1.7505 .5145	.9625 .0411	2.0694 .0107	.2805 .1209	.2582	2.21	.0980 .....
4647	0-6	Silt loam..... ...	Total Soluble	35.4100 .0031	2.4453 .0165	5.1500 .1233	.1872 .0280	.4900 .0061	1.4958	.0482 .0006	.1407	1.38	.0257 .....
10738	0-6	Clay loam.......	Total Soluble	27.4300 .0377	2 7402 .0244	5.4567 .1436	4.2300 2.8400	2.2236 1.4350	1.7601	.0847 .0105	.1660	....	....
10740	0-6	Clay loam........	Total Soluble	30.5300 .0721	2.7552 .0428	6.3650 .2542	.9693 .4075	.7296 .2144	1.8956	.0904 .0118	.2740	....	....
4680	0-6	Clay loam....	Total Soluble	36.3400 .0093	2.2198 .0027	4.9480 .0989	.2675 .0577	.3931 .0129	1.6408	.0346 .0002	.1137	1.24	.1118 .....
4671	0-6	Clay loam........	Total Soluble	32.8900 .0140	3 2110 .0251	6.4200 .1464	.2529 .1114	.5665 .0156	1.9987	.0558 .0003	.1672	1.50	.0521 .....
4672	6-36	Clay loam.........	Total Soluble	34.3400 .0122	3.1756 .0223	6.2400 .1163	.2359 .0459	.5277 .0123	1.9567	.0325 .0001	.0670	....	.0410 .....
4712	0-6	Clay loam.........	Total Soluble	33.9600 .0411	2.2697 .0512	5.4730 .1331	.6155 .2376	.5322 .0661	1.9761	.0385 .0014	.1577	1.96	.0921 . ...
4713	6-36	Clay loam.........	Total Soluble	27.8000 .1445	4.0256 .1902	7.7800 .2450	2.1893 1.9696	1 2174 .4156	2.7304	.0317 .0062	.0650	....	.0493 .....
4714	0-6	Clay loam.........	Total Soluble	33.2600 .0505	2.2126 .1007	3.3250 .1209	.9584 .6427	.5802 .1728	1.8471	.0481 .0024	.2122	1.23	.0660 .....
10735	0-6	Clay loam.........	Total Soluble	28.2900 .0524	3.1488 .0874	6.5293 .2318	.9299 .5560	.9899 .0488	2.0600	.1222 .0053	....	....	....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
10764	0-6	Clay loam........	Total	29.8600	4.3175	7.0973	1.1456	.8674	2.4500	.1334	.1030	....	.....
			Soluble	.0726	.0924	.1971	.7650	.1449	......	.0250	.....	....	.....
10733	0-6	Clay loam.........	Total	30.8000	2.7844	6.3960	.9446	.7985	2.1726	.0953	.2580	....	.....
			Soluble	.0143	.0213	.0852	.0995	.0266	......	.0010	.....	....	.....
4752	0-6	Clay loam........	Total	36.1400	2.4840	4.9852	.9299	.3194	1.9598	.0397	.1037	.91	.0779
			Soluble	.0242	.0173	.1021	.4013	.0227	......	.0004	....	....	.....
4753	6-36	Clay loam........	Total	32.4200	3.8684	6.4648	.4427	.6300	2.1792	.0468	.0540	....	.0525
			Soluble	.0505	.0475	.1470	.1604	.0531	......	.0005	....	....	.....
4639	0-6	Clay loam........	Total	34.6400	2.4167	5.5012	.2736	.5331	1.6602	.0584	.2060	2.40	.....
			Soluble	.0091	.0180	.1637	.0803	.0168	.0198	.0013	.....	....	.....
4640	0-6	Clay loam........	Total	35.4100	2.1593	5.3991	.2640	.6016	1.5860	.0454	.1795	1.88	.....
			Soluble	.0089	.0101	.1515	.0768	.0118	.0108	.0005	.....	....	.....
4641	0-6	Clay loam........	Total	34.4400	2.3452	5.6810	.3264	.5331	1.5602	.0559	.2030	1.74	.....
			Soluble	.0107	.0165	.1429	.1417	.0203	.0115	.0004	.....	....	.....
4642	0-6	Clay loam.......	Total	35.6900	2.1021	5.3347	.2592	.5030	1.5602	.0411	.1695	2.50	....
			Soluble	.0088	.0291	.1397	.0831	.0143	.0129	.0003	.....	....	.....
4643	0-6	Clay loam........	Total	34.9800	2.3166	5.5389	.2568	.5793	1.5570	.0538	.1945	1.96	.....
			Soluble	.0081	.0137	.1533	.0813	.0173	.0105	.0004	.....	....	.....
4663	0-6	Clay loam.........	Total	34.7300	2.4910	5.2700	.3356	.5589	1.6408	.0382	.1425	1.61	.0557
			Soluble	.0089	.0166	.0903	.0825	.0103	......	.0001	.....	....	.....
4664	6-36	Clay loam........	Total	31.1600	4.0970	7.2400	.3454	.5911	2.4048	.0321	.0672	....	.0250
			Soluble	.0406	.0542	.1411	.1326	.0459	......	.0004	.....	...	.....
4681	0-6	Clay loam.........	Total	36.7100	2.0556	4.6880	.3406	.3725	1.5441	.0393	.1372	1.18	.1220
			Soluble	.0089	.0181	.1032	.0707	.0112	......	.0001	.....	....	.....
4682	6-36	Clay loam.........	Total	34.6900	3.1834	5.8070	.3406	.5294	1.8374	.0221	.0550	....	.0586
			Soluble	.0204	.0163	.1087	.0672	.0279	......	.0001	.....	....	.....
4683	0-6	Clay loam.........	Total	36.3900	1.9342	4.4020	.4281	.3467	1.4829	.0443	.1642	1.61	.1058
			Soluble	.0101	.0205	.1218	.1203	.....	......	.0002	.....	....	.....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
5085	0-6	Clay loam........	Total Soluble	36.7900 .0138	1.7016 .0376	4.2300 .0690	.4865 .1627	.2789 .0274	1.6424	.0328 .0008	.1125 ...	1.09	.0506 .....
5088	6-36	Clay loam.......	Total Soluble	32.8700 .0354	3.7187 .0330	5.9500 .0896	.4037 .1887	.4413 .0658	1.8245	.0211 .0013	.0632	....	.0208 ....
4736	0-6	Clay loam.......	Total Soluble	36.5500 .0138	2.0320 .0317	4.5600 .0779	.4037 .1515	.3040 .0234	1.6755	.0393 .0005	.1437	1.28	.0746 ....
4734	0-6	Clay loam.......	Total Soluble	36.8600 .0108	2.0321 .0110	4.6100 .0783	.4086 .1008	.3171 .0189	1.7664	.0343 .0003	.1075	1.01	.0731 .....
4735	6-36	Clay loam........	Total Soluble	32.8500 .0284	4.1558 .0317	6.8600 .1163	.3234 .0890	.5769 .0418	2.2162	.0346 .0002	.0700	... .	.0421 .....
4730	0-6	Clay loam........	Total Soluble	33.4200 .0263	2.4265 .0335	5.3352 .1136	.7457 .2583	.5427 .0678	1.9566	.0668 .0011	.2210	1.93	.0987 .....
4731	6-36	Clay loam........	Total Soluble	29.4800 .0817	3.7114 .1189	6.6929 .1216	2.3326 1.6754	1.3015 .3937	2.4050	.0482 .0049	.0847	....	.0465 .....
4732	0-6	Clay loam........	Total Soluble	33.9600 .0213	2.4265 .0361	5.6269 .1172	.5953 .1816	.4566 .0371	2.1536	.0475 .0012	.2837	1.79	.0487 ....
4719	0-6	Clay loam........	Total Soluble	31.7100 .0211	3.3761 .0503	6.6400 .1142	.3667 .1029	.5282 .0510	2.4193	.0543 .0008	.1702	1.61	.0606 .....
4720	6-36	Clay loam........	Total Soluble	30.0200 .0613	4.0541 .0726	7.8000 .1267	.3129 .2423	.7300 .0671	2.7511	.0327 .0007	.0767	....	.0447 .....
4721	0-6	Clay loam........	Total Soluble	31.6400 .0284	3.0556 .0836	5.9800 .1093	.6422 .2709	.6771 .0545	2.2709	.0698 .0013	.2357	1.44	.0914 .....
10766	0-6	Clay loam........	Total Soluble	30.4500 .0522	3.8775 .0392	5.5879 .1843	1.0132 .5266	.7164 .1395	1.8827	.0757 .0011	....	... .	....
10767	0-6	Clay loam........	Total Soluble	35.0400 .0251	2.3099 .0238	5.3942 .0825	.5164 .1400	.5031 .0292	2.2114	.0414 .0012	.1280	....	 .....
10768	0-6	Clay loam........	Total Soluble	35.2500 .0190	1.9731 .0350	5.0883 .1022	.4721 .1000	.4463 .0253	2.1116	.0398 .0009	.1397	....	....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4684	0-6	Clay loam	Total Soluble	35.1400 .0117	2.2412 .0657	5.2980 .1285	.3698 .1037	.3883 .0217	1.6086	.0510 .0004	.1642	1.57	.0422 .....
4740	0-6	Clay loam	Total Soluble	36.4300 .0157	2.2462 .0188	4.4000 .0836	.4368 .1940	.3216 .0144	1.5152	0875 .0100	.1420	1.27	....
5281	0-6	Clay loam	Total Soluble	28 2600 .1583	3.8500 .2949	7.1060 .3755	2.8133 .9649	2.0125 .1055	2.7916 .0116	.3058 .1279	.1922	1.50	.1136 .....
5282	6-36	Clay loam	Total Soluble	25.9800 .2835	3.9470 .6044	8.3260 .4576	2 3957 1.7923	1.4054 .2143	3.2108 .0084	.3114 .1621	....	....	.0999 .....
10750	0-6	Clay loam.........	Total Soluble	35.2200 .0552	2.6607 .0465	4 8398 .1514	5462 .2028	.3664 .0526	1.7924	.0847 .0066	.1337	....	....
5087	0-6	Black clay.......	Total Soluble	29.1600 .0857	2.4891 .0423	5.9800 .2963	1.3499 1.0143	.5331 .1432	1 2685	.0980 .0242	.3467	3.26	.0223 .....
5086	6-36	Black clay	Total Soluble	26.2400 .1278	3.1712 .0278	4.5400 .1340	5.1033 4.8002	2.4222 1.7980	1.2991	.0517 .0208	....	....	.0232 .....
4725	0-6	Sandy clay.......	Total Soluble	32.1300 .0371	1.1592 .0549	5 3300 .1049	.6841 .2816	.3346 .0365	1.8519	.0716 .0020	.1925	1.80	.0891 .....
4726	6-36	Sandy clay......	Total Soluble	33.8000 .0446	1.0547 .0604	5.6700 .1024	.7076 .2387	.2728 .0430	1.9453	.0462 .0016	.0937	....	.0676 .....
4741	0-6	Black clay loam ..	Total Soluble	25.9000 .0608	4.0006 .1641	5.0188	1.3200 1,0600	.6650 .1914	1.3120	.1094 .0054	.6625	6.48	. ...
4742	6-36	Black clay loam	Total Soluble	31.4600 .0767	2.4769 .0599	6.2265 .1961	1 0464 .6200	.8575 .2560	1.8181	.0323 .0132	.0970	....	....
4743	0-6	Black clay loam ..	Total Soluble	24.9900 .0835	2.9468 .2618	2.2490 .2076	2.4672 2.0400	.8673 .4813	1.5087	.1293 .0160	.8322	6.56	....

TABLE V.—Continued. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO_3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4737	0-6	Black clay loam ..	Total	29.7100	3.2205	5.4700	9146	.7546	1.7955	.0790	.3145	3.15	.0336
			Soluble	0507	.0811	.1813	.5902	.0896	......	.0053	.....	....	.....
4738	6-36	Black clay loam..	Total	31.3600	3 9798	6.0900	.7126	.5933	1.9421	.0525	.1137	...	.1221
			Soluble	.0700	.0601	.1618	.4399	.0955	......	.0079	.....	....	. ...
4739	0-6	Black clay loam ..	Total	28.8200	3.2205	5.6800	.9901	.6809	1.7455	.0896	.4230	3.49	.0189
			Soluble	.0582	.0999	.2138	.7329	.1204	......	.0053	.....	....	.....
10744	0-6	Black clay loam ..	Total	29.7900	2.4888	6 2848	1.0627	.8586	1.8312	.0687	.3325	....	.....
			Soluble	.0571	.0835	2239	.4950	.1094	.....	.0084	.....	....	.....
10745	0-6	Black clay loam ..	Total	28 1900	2 9838	7.1307	1.0283	.9538	2.2050	.1165	.3662	....	.....
			Soluble	0771	.0910	.2748	.5525	.0892	......	.0151	.....	....	.....
4754	0-6	Black clay loam ..	Total	30 2100	3.0121	5.6534	.9876	.6497	1.7891	.0743	.3077	3.09	.0823
			Soluble	.0763	.0307	.2445	.6383	.1296	......	.0019	.....	....	.....
4755	0-6	Black clay loam ..	Total	29.8200	2.8907	5 2080	1.8292	.8750	1.7278	.0651	.2980	2 84	.0692
			Soluble	.0592	.0652	.0872	1.4388	.4976	......	.0011	....	....	.....
4716	0-6	Black clay loam ..	Total	30.4200	2 9769	6.5600	.8360	.7033	2 4080	.0974	.1980	2.09	.0297
			Soluble	.0592	.1231	.2439	.4224	.0667	.0104	.0138	.....	....	.....
4717	6-36	Black clay loam ..	Total	31.1800	2.3767	6.8100	.6941	.5250	2.4336	.0847	.1245	....	.0585
			Soluble	.0881	.1346	.2450	.3645	.0807	.0124	.0147	.....	....	.....
4718	0-6	Black clay loam ..	Total	27.9100	3 6279	6.8400	.7233	.5550	2.4756	.1173	.3732	3.24	.0560
			Soluble	.0474	.1340	.2330	.4253	.0694	.0207	.0075	.....	...	.....
14163	0-6	Black clay loam ..	Total	....	......	......	1.0440	.....	2.0240	.1010	.4010	4.27	.....
			Soluble	....	.. ...	......	.7360	.....	.0110	.0170	. ..	....	.....
4715	0-6	Clay	Total	30.3500	3.5474	7.1600	.4209	8209	2.9367	.0603	.2145	2.02	.0757
			Soluble	.0385	0649	.1924	.1421	.0698	......	.0006	.....	....	.....
4699	0-6	Clay	Total	36.0400	2.1165	5.3900	.4653	.5039	2.0325	.0544	.1223	1.21	.0616
			Soluble	.0220	.0559	.1076	.1014	.0339	......	.0041	.....	....	.....

TABLE V.—Concluded. Total and N-5 nitric acid soluble constituents. Surface and subsoil.

Lab. No.	Depth inches	Classification	Total and N-5 HNO3 Soluble	Silicon Percent	Iron Percent	Aluminum Percent	Calcium Percent	Magnesium Percent	Potassium Percent	Phosphorus Percent	Nitrogen Percent	Humus Percent	Manganese Percent
4700	6-36	Clay	Total	30.8700	2.9904	7.6400	.4666	.9264	2.6722	.0402	.0610	....	.0380
			Soluble	.0794	.1091	.2503	.1226	.0995	......	.0013	.....	....	.....
4657	0-6	Clay	Total	29.8700	4.4654	6.9420	.3120	.4539	1.9664	0659	.2525	2.40	.1258
			Soluble	.0150	.0215	.1735	.1367	.0278	.....	.0004	.....	....	.....
4685	0-6	Clay	Total	25.4200	4.1112	9.2010	.4330	.6792	2.0567	.0964	.3430	3.44	.0615
			Soluble	.0359	.1840	.2275	.2883	.0540	......	.0023	.....	....	.....
4686	6-36	Clay	Total	33.7500	2.7480	6.6120	.3016	.5272	1.8310	.0588	.0927	....	.0163
			Soluble	.0270	.4905	.1522	.1061	.0189	......	.0122	.....	...	.....
4687	0-6	Clay	Total	36.7300	2.0484	4.7620	.2554	.3330	1 4442	0424	.1322	1.53	.0502
			Soluble	.0084	.0889	.1098	.0707	.0121	.....	.0002	....	....	... .
4696	0-6	Clay	Total	32.2300	3.2910	5.6000	.9706	.6349	2.1582	.0656	.2547	2.31	.0535
			Soluble	.0516	.0650	.1553	.3491	.0436	......	.0053	.....	..	.....
4697	6-36	Clay	Total	32.1700	3.2910	6.8400	.7090	.8430	2.3936	.0394	.0877	....	.0417
			Soluble	.0824	.0748	.1156	.3526	.0747	.....	.0063	.....	....	.....
4698	0 6	Clay	Total	31 3600	2.7563	6.2200	1.0514	.8406	2.1967	.0498	.2230	1.88	.0351
			Soluble	.0606	.0657	.1071	.7559	.2143	......	.0077	....	....	... .
4706	0-6	Clay	Total	31.4100	2.1025	5.4500	1 0263	.5244	1 8503	0781	.3272	3.39	.0129
			Soluble	.0639	.0489	.1999	.3536	.0817	.....	.0202	.....	....	.....
4707	6-36	Clay	Total	33.4800	2.9884	5 9300	.7605	.6053	2.0163	.0522	.0870	....	.0580
			Soluble	.0909	.0636	.1569	.2171	.0919	.....	.0192	.....	....	.....
4708	0-6	Clay	Total	33.6500	1.9266	5.1400	.8681	.4107	1.7181	.0632	2820	2.88	.0354
			Soluble	.0335	.0419	.1431	.2533	.0569	......	.0044	.....	...	.....
4655	0-6	Clay	Total	31.0900	1.1567	7.0060	.2556	.3697	1.7214	.0504	,3190	3.54	.0063
			Soluble	.0127	.0263	.3349	.0817	.0179	......	.0044	.....	....	.....
4656	6-36	Clay	Total	31.1100	4.1157	7.5790	.4056	.7591	2.2886	.0417	.0675	....	.0183
			Soluble	.0892	.0849	.2417	.2673	.0485	......	.0095	.....	....	.....

METHOD USED FOR DETERMINING CARBONATES

While the analytical methods employed in the work are outlined in the addenda, special attention is directed to the method used in determining carbonates, for the reason that the results obtained by the method in general use give inaccurate and misleading results concerning the calcium carbonate content of soils. Determinations made by the Official method,[1] boiling soils at 100° C. with dilute acid, showed no correlation between the calcium carbonate found and the soil's reaction with litmus paper or the Veitch qualitative test.

For many of the acid surface soils examined, the Official method indicated the presence of 3,000 pounds of calcium carbonate per 2,000,000 pounds of soil; a much larger quantity than was found in other soils which gave an alkaline reaction with red litmus paper. These differences between calcium carbonate found and the soil reaction were especially marked in the case of soils containing fairly large amounts of organic matter. These facts led to the adoption of the method devised by F. S. Marr while connected with the Rothamsted Experiment Station.[2]

The essential feature of the method is treating the soil with very dilute acid at 50° C., and under reduced pressure. This procedure eliminates the error due to the decomposing organic matter and liberation of carbon dioxide other than that from inorganic carbonates. Table VI, page 491, gives a comparison of the carbon dioxide obtained by the two methods and the soil reaction for a large number of the soils included in this work.[3]

PHOSPHORUS

Only fourteen, of the hundred and twenty-six surface soils examined, contained more than 0.10 percent of phosphorus. The highest percent of phosphorus, 0.30 percent, was found in soil from an alfalfa field located near Madisonville, Hamilton county. Other soils from this vicinity, which have been examined with respect to their phosphorus supply, show a larger amount than the average for soils throughout the State. The agency causing the increased accumulation of phosphorus in some soils from this particular area has probably been a continuation of the geological formation, carrying tri-calcium phosphate, found in Tennessee and which extends north through part of Kentucky. Evidence of this is given by the analysis, made in this laboratory, of soil from the farm of the Kentucky Experiment Station; 0.45 percent of phosphorus was found in the surface six inches and 0.52 percent in the depth from six to eighteen inches.

[1]Bul. 107, Bureau of Chemistry, U. S. Department of Agriculture.
[2]Jour. Agr. Science, Vol III, part 2.
[3]For a more detailed presentation of results obtained in this laboratory in connection with this work, see article in the Jour. of Ind. and Engineering Chemistry, Vol. 5, No. 2, 1912, "A Comparison of Some Qualitative and Quantitative Methods for Carbonates in Soil," by E. W. Gaither.

TABLE VI.—Part 1. Surface soils 0-6 inches that redden blue litmus paper

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Percent Humus	Condition	Class
4688	Acid	Acid	0	0.0242	1.50	C.	Sandy loam
5081	"	"	0	0.0308	0.47	C.	Silt loam
4687	Sl. Alk.	Sl. Acid	0	0 0308	1 53	P.	Clay
4709	Acid	Sl. Acid	0	0 0341	0 91	C.	Sand
4677	"	Acid	0	0.0352	1.62	C.	Silt loam
4681	"	"	0	0.0440	1.18	C.	Clay loam
4680	"	Sl. Acid	0	0.0460	1.24	C.	Clay loam
4711	"	"	0	0 0462	1.47	V. F. R.	Sand
4734	Sl. Alk.	"	0	0.0462	1.01	C.	Clay Loam
4651	Acid	Acid	0	0 0484	1.56	M.	Gravelly loam
4652	"	"	0	0 0484	1.79	M.	Gravel
4668	"	"	0	0.0484	1.20	C.	Sandy loam
4673	Sl. Alk.	Sl. Acid	0	0.0484	1.20	C.	Silt loam
4719	Acid	Acid	0	0.0506	1.61	C.	Clay loam
4650	"	Sl. Acid	0	0.0506	1.52	V. M. G.	Gravelly loam
4727	Sl. Alk.	Neutral	0	0.0550	1.55	C.	Sandy loam
4655	Acid	Acid	0	0.0572	3.54	C.	Clay
4663	"	"	0	0.0572	1.61	C.	Clay loam
4690	"	"	0	0.0572	1.13	C.	Gravelly loam
4640	Sl. Alk.	"	0	0.0594	1.88	C.	Clay loam
4671	"	Sl. Acid	0	0.0594	1.50	C.	Clay loam
4684	Acid	Acid	0	0.0594	1.57	C.	Clay loam
4642	"	"	0	0.0616	2.50	C.	Clay loam
4643	"	"	0	0.0616	1.96	C.	Clay loam
4661	"	"	0	0.0616	1.93	C.	Sandy loam
4704	"	Sl. Acid	0	0.0660	2.04	C.	Sandy loam
4699	"	Acid	0	0.0680	1.21	C.	Clay

Sl.=slightly. St.=strongly. Alk.=alkaline. C.=cultivated. P.=pasture. V. F. R.=virgin fence row. M.=meadow. V. O. W.=virgin open woodland R.=road side. V. P. virgin pasture. P.=pasture. V. M. G.=virgin maplegrove.

TABLE VI. Part 1.—Continued. Surface soils 0-6 inches that redden blue litmus paper

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Percent Humus	Condition	Class
4660	Acid	Sl. Acid	0.0022	0.0682	1.35	V. O. W	Sandy loam
4639	"	Acid	0	0 0682	2.40	C.	Clay loam
4662	"	"	0	0.0682	2.12	M.	Sandy loam
4641	"	"	0	0.0682	1.74	C.	Clay loam
5279	"	"	0	0.0704	1.25	C.	Silt loam
4675	"	Sl. Acid	0	0.0704	1.50	C.	Silt loam
4696	"	"	0	0.0715	2.31	C.	Clay
4665	Sl. Alk.	Acid	0	0.0726	1.34	C.	Stony loam
4732	"	Sl. Acid	0	0.0748	1.79	M.	Clay loam
4647	Acid	Acid	0	0.0770	1.38	M.	Silt loam
4654	"	"	0	0.0770	2.09	C.	Gravel
4658	Alk.	"	0	0.0770	1.93	C.	Sandy loam
4679	Acid	"	0	0.0792	1.62	M.	Silt loam
4733	Sl. Alk.	Sl. Acid	0	0.0814	2 49	C.	Silt loam
4674	Acid	"	0	0.0814	2.17	V. F. R.	Silt loam
4715	"	"	0	0 0836	2.02	V. O. W.	Clay
4736	"	"	0	0.0902	1 28	V. O. W.	Clay loam
4670	"	Acid	0	0.0902	1 82	C.	Gravelly loam
4648	"	"	0	0 0946	1.57	C.	Gravelly loam
4703	"	Sl. Acid	0	0 0957	2.63	V. O. W.	Sandy loam
4644	"	Acid	0	0.0990	2.02	M.	Silt loam
4657	Sl. Alk.	"	0	0 1012	2.40	V. O. W.	Clay
4721	Acid	Sl. Acid	0.0132	0.1034	1.44	R. V. F. R.	Clay loam
4683	"	Acid	0	0.1078	1.61	V. O. W.	Clay loam
5283	"	"	0	0 1100	2.21	V. P.	Silt loam
4685	"	"	0	0.1100	3.44	C.	Clay
4646	"	"	0	0.1166	1.71	V. O. W.	Silt loam
4706	"	Sl. Acid	0	0.1188	3.39	V. O. W.	Clay
4718	"	Acid	0.0022	0 1320	3.24	V. O. W.	Black clay loam
4737	Alk.	Neutral	0	0.1518	3.15	C.	Black clay loam

Average 0.0714 percent CO_2 = 3244 pounds $CaCO_3$ per acre, 7 inches by official method.

TABLE VI.—Part 2. Surface soils 0-6 inches that turn red litmus paper blue.

Lab. No.	Veitch test	Litmus test	Percent CO_2 by Marr method	Percent CO_2 by official method	Difference	Percent humus	Condition	Class
4708	Acid	Sl. Alk.	0 0011	0.1122	0.1111	2.88	V. O. W.	Clay
4667	"	Alk.	0.0022	0 0726	0.0704	1.19	V. O. W.	Stony loam
4747	Sl. Alk.	V. Sl. Alk.	0.0033	0 0440	0.0407	0.97	C.	Silt loam
4722	Alk.	Alk.	0.0044	0.0902	0 0858	1.72	C.	Sandy loam
4740	"	Neutral	0.0044	0.0704	0.0660	1.27	River T.	Clay loam
4746	Sl. Alk.	Alk.	0.0066	0.0462	0.0396	1.43	V. F. R.	Silt loam
4725	"	Sl. Alk.	0.0088	0 0968	0 0880	1.80	C.	Sandy clay
4701	"	Alk.	0.0110	0.1034	0.0924	3.35	C.	Sandy loam
4724	Alk.	Sl. Alk.	0.0132	0.0770	0.0638	1.79	V. S. Y.	Sandy loam
4744	"	Alk.	0.0132	0.0660	0.0528	1.31	C.	Silt loam
5085	"	"	0.0143	0.0528	0.0385	1.09	C.	Clay loam
4739	"	Sl. Alk.	0.0281	0.1496	0.1215	3.49	V. F. R.	Black clay loam
4730	"	Alk.	0.0484	0.1232	0.0748	1.93	P.	Clay loam
4741	"	"	0 0506	0.2168	0.1662	6.48	Alluvial	Black clay loam
4751	"	"	0.0506	0.0814	0 0308	0.98	V.	Silt loam
4712	"	"	0.0539	0.1210	0.0671	1.96	C.	Clay loam
4749	"	Sl. Alk.	0.0682	0.1210	0.0528	1.13	C.	Silt loam
5083	"	Alk.	0.0792	0.1540	0.0748	1.34	V. O. W.	Silt loam
5281	"	"	0 0946	0.1782	0.0836	1 50	C.	Clay loam
5087	"	"	0.2530	0.3630	0.1100	3.26	Blk. Swale	Black clay
4698	Sl. Alk.	Neutral	0.5632	0.6809	0.1177	1.88	V. F. R.	Clay
4714	Alk.	Alk.	0.5720	0.6600	0 0880	1.23	V. F. R.	Clay loam
4743	"	"	1.5220	1.8830	0.3610	6.56	V. Alluv.	Black clay loam

Average difference, 0.0912 percent CO_2 = 4144 pounds $CaCO_3$ per acre, 7 inches by official method.

The total phosphorus content of practically all Ohio soils is less than that of any of the other constituents considered essential for crop production. The analyses of the soils reported here show that the average total phosphorus in the surface soil is approximately .06 percent, which, expressed as pounds per acre of soil to the depth of 6 inches, is about 1,200 pounds. The total phosphorus content has been found to be greater in the surface than in the subsoil, except in four instances, where the subsoil contained large quantities of calcium carbonate.

The smallest quantity of phosphorus found in the soils from different sections of Ohio was .025 percent, equal to 500 pounds per acre 6 inches of soil.

An invoice of the soil's phosphorus supply compared with that of potassium and nitrogen leaves no doubt of the importance of obtaining all the information possible concerning this element. There is an abundance of total potassium in all Ohio soils examined except those classed as peats. About 1.80 percent, approximately 36,000 pounds of potassium per acre, is the average amount found in the surface 6 inches.

The producing power of a soil, so far as the plant food supply is concerned, depends not alone upon the total amount present, but is influenced to a greater extent by the availability. No method has been devised which will properly measure what proportion of this great store of potassium may be in a condition capable of being assimilated by plants. Field tests have demonstrated that soils containing an abundance of potassium do have potassium liberated for the needs of crops by the right system of soil management, which includes the use of lime if needed, and the growing and returning to the soil, of leguminous crops. Nitrogen may be added to the soil by following the same practice. Aside from increasing the nitrogen content of the soil and supplying organic matter which liberates potassium, the growing of leguminous crops furnishes potassium assimilated from the lower soil strata. Leguminous plants are heavy potassium feeders and their deep root system enables them to draw upon supplies which are below the range of other farm crops.

But for the majority of soils, the phosphorus supply must be replenished by using fertilizers carrying phosphorus. The form of phosphorus to be used depends somewhat upon the character of the soil. Bone meal and basic slag phosphate will be better adapted than acid phosphate for soils with only a small amount of organic matter and containing no calcium carbonate, while on soils containing liberal quantities of calcium carbonate, acid phosphate will give better returns for the money invested than if used on acid soils. Raw rock phosphates give practically no return on the money invested if used on soil not liberally supplied with active organic matter.*

CALCIUM CARBONATE AND PHOSPHORUS RELATION

The results obtained point out the fact that soils containing calcium carbonate have a larger amount of phosphorus than soils containing no calcium carbonate. By referring to the summarized data given in Table I, page 451, it will be observed that the average phosphorus content of surface soils containing calcium carbonate is 1,310 pounds per acre, compared with 913 pounds and 986 pounds in the non-calcareous soils from the western and eastern sections.

In cases where the phosphorus content is from .3 to .1 per cent, four of the seven surface soils showing this range in phosphorus contain calcium carbonate, and three give an alkaline reaction to litmus paper. Four out of ten soils containing phosphorus varying from .1 to .07 percent have calcium carbonate present; three of these ten soils are alkaline, and three are neutral in their reaction to litmus paper. When the phosphorus content is from .07 to .06 percent, five out of nine soils contain carbonates and two are alkaline. Out of nineteen soils containing phosphorus varying from .06 to .05 percent, four contain carbonates and only two show an alkaline reaction. In soils having .05 to .04 percent phosphorus, seven of the nineteen soils analyzed contain calcium carbonate; four give an alkaline and two a neutral reaction. Where the phosphorus decreases from .04 to .025 percent, the smallest amount found, two out of the fifteen soils contain calcium carbonate and these two show an alkaline reaction.

Hilgard in his work on soils, calls attention to the fact that, in soils having high lime percentages, relatively low percentages of phosphorus are adequate for good crop production; while the same or even higher amounts of phosphorus, in soils without sufficient lime, may be less than is necessary for crop needs. It is assumed that calcium phosphates are more available than phosphates of iron and aluminum. There are no doubt other reasons, why soils supplied with basic calcium compounds have more of their phosphorus available, than that of the function performed by calcium carbonate in maintaining part of the soil phosphorus supply as calcium phosphates, rather than in the form of iron and aluminum phosphates. The soil bacteria render phosphorus and other mineral plant nutrients available, and their activities are increased by maintaining a neutral or alkaline reaction in the soil.

*These points are being investigated at this Station.

The phosphorus taken into solution when a soil is digested with fifth normal nitric acid is mostly phosphate of calcium. For this reason, nitric acid of this strength is used to measure the more easily assimilated soil phosphates.

Investigations reported by the Wisconsin Experiment Station* show that acid soils lack available phosphorus. It is stated for Wisconsin soils, that if the fifth normal nitric acid-soluble phosphorus falls below .015 percent phosphoric acid ($P_2 O_5$), equivalent to .0065 percent phosphorus, the soils respond to fertilizers carrying phosphorus.

The relations found to exist between the fifth normal nitric acid soluble phosphorus, calcium carbonate content and soil reaction of the soils studied, indicate that soils which contain calcium carbonate and give an alkaline reaction have more available phosphorus than non-calcareous acid soils.

The averaged results for phosphorus in the calcareous and non-calcareous soils of the several different classes are included in Table IV, page 469.

It will be noticed that soils naturally calcareous contain a much larger amount of phosphorus soluble in fifth normal nitric acid than is found in the non-calcareous soils. Sandy soils contain much more soluble phosphorus than do silts and clays. The amounts of phosphorus soluble in fifth normal nitric acid found in calcareous and non-calcareous sandy soils is much greater than for the corresponding divisions of silts and clays. The proportion of total phosphorus content of acid sandy soils, soluble in fifth normal nitric acid, is only slightly less than that found for the calcareous soils of the other two classes, silts and clays.

ORGANIC MATTER

The content of organic matter is an important factor in determining soil differences; this is especially true in regard to its effect on physical properties. Of no less importance is its relation to availability of mineral plant nutrients, due to the solvent action of carbon dioxide, liberated from the decomposition of vegetable matter incorporated with the soil. The mineral constituents are continually being subjected to the same action of air and water as gave rise to the formation of soil from rock: but the changes produced by these agencies take place at a more accelerated rate where larger amounts of active organic matter are present, because increased quantities of carbon dioxide are furnished. The necessity of maintaining a sufficient supply of organic matter by the use of manure, and incorporating with the soil leguminous and other crops,

*Whitson and Stoddart, Research Bulletin No. 2, 1909, Univ. of Wis.

is generally recognized. Some attribute little value to the vegetation returned to the soil, other than that it supplies organic matter. It must be remembered that plant remains carry considerable quantities of fertilizing materials, including nitrogen, and that these have a value comparable with that of the same plant nutrients in commercial fertilizers.

The color of soils gives some indication of the amount of organic matter present, but the influence of mineral materials present, and the nature and extent of the decomposition of incorporated organic material, are such that equal amounts will not produce the same color in different soils. A measure of the supply of carbonaceous material in the soils studied has been obtained by making the so called humus determination. The greater number of the soils examined contained less than 2 percent humus; in two of the black clay loams the amount found was 6 percent; the average for the black clay loams being 3.5 percent. Determinations of nitrogen and humus show that the nitrogen gives a measure of the humus content; in most instances the amount of humus is ten times the nitrogen found. The soil nitrogen is practically all contained in the organic matter and this supply of nitrogen, compared with the carbon of the organic matter, gives some indication of the character of the organic material present.

Soils containing old organic residues will have a less proportion of carbon to nitrogen than those in which fresh supplies of organic matter have been more recently incorporated. Drainage and supply or deficiency of calcium carbonate are important factors affecting the condition of the organic material in soils. The results for total humus and total carbon, obtained in this laboratory, show that for a large number of soils the organic matter extracted with a 4 percent ammonium hydrate solution approximates very closely the total carbon content. Considering the humus results as total carbon, and comparing the ratio of humus to nitrogen in the calcareous and non-calcareous soils, it is found that those naturally supplied with calcium carbonate have a less proportion of carbon to nitrogen than the soils which contain no calcium carbonate. As a general rule there is a greater proportion of carbon to nitrogen in the cultivated soils than in the uncultivated soils from fence rows and woodlands adjacent to the cultivated areas sampled. Averaged results for the different classes of soil examined show that the sands and sandy loams have more carbonaceous matter, in proportion to their nitrogen content, than the soils classed as silts and clays.

TABLE VII. Composition of soil from Wooster farm, sampled in 1896 and 1911. Results expressed as pounds per 2,000,000 pounds of soil.

Description	Depth inches	Phosphorus		Potassium		Nitrogen	Humus	Calcium		Magnesium	
		Total	Soluble	Total	Soluble			Total	Soluble	Total	Soluble
5-yr. rotation, sampled 1896.	0-6	742	6	34,104	162	2,114	22,200	4,740	1,072	6 596	158
5-yr. rotation, sampled 1896..........	6-12	652	4	35,910	130	1,350	......	4,400	1,080	8,630	224
5.yr. rotation, sampled 1911.	0-6	664	4	33,110	144	1,778	18,800	4,720	882	7,778	186
5-yr. rotation, sampled 1911.	6-12	598	2	36,100	138	1,266	......	4,400	1,094	9,592	250
Variety field, sampled 1911...........	0-6	1,030	60	33,202	236	2,430	22,800	5,200	1,726	7,064	424
Variety field, sampled 1911.....	6-12	860	14	35,360	146	1,510	......	4,410	1,280	8,550	350

VALUE OF SOIL ANALYSIS

When the changes induced by cropping and fertilizing are sufficiently pronounced to be detected by a chemical analysis the results obtained indicate the value of such an analysis. The composition of the soil from the farm at the Wooster Station shows that measurable changes have occurred during a period of 15 years. The analyses of samples taken in 1896 from the unfertilized and unlimed soils of the 5-year rotation fertility plots are compared with the analyses of the soils secured from the same plots in 1911. A comparison of these results with the composition of soils from another part of the farm, designated as the variety field, and which is used for a four-year rotation of corn, oats, wheat and clover, serves to contrast the difference in chemical composition of a non-productive soil and the same soil brought to a high state of fertility by treatment. The soil samples taken in 1896 are representative of the condition and composition of the soil at the time the Station's fertility investigations on these soils were begun. From an inspection of the results, which are expressed as pounds per 2,000,000 pounds of soil, in Table VII, page 498, it will be observed that the phosphorus, potassium, nitrogen and humus decreased an appreciable amount in 15 years, which is in accordance with the crop history. A different condition is noticed in the case of the magnesium, for both depths of soil contained more of this element at the time of sampling in 1911, than was found in the samples taken in 1896. The amounts of total phosphorus, nitrogen and humus are greater in the soil from the variety field than in the unlimed and unfertilized soil of the 5-year rotation plots; the soluble phosphorus and potassium are also greater. The variety field plots have been limed and liberally treated with manure and fertilizers carrying phosphorus, potassium and nitrogen. The large crops of clover grown on this part of the farm once in four years are responsible for the increased quantities of nitrogen and humus stored in this soil, as compared with the impoverished soil of the unlimed and unfertilized plots of the 5-year rotation sampled in 1911. The amount of organic matter carrying nitrogen in the variety field soil is only slightly greater than the amount present in the 5-year rotation soil when sampled in 1896.

The fertility of the unfertilized and unlimed soil has been decreasing. Without the aid of lime, no clover grows on this soil to maintain a supply of organic matter.

SUMMARY

The work herein reported shows differences in calcareous and non-calcareous soils which are representative of many of the soil types found in Ohio. Special attention has been directed to the phosphorus content.

Soils, containing no calcium carbonate, from counties in the western part of the State have larger amounts of total and fifth normal nitric acid-soluble calcium and magnesium than the soils from the eastern counties overlying sandstone and shales; this illustrates the gradual loss of calcium carbonate in soils which were originally of limestone formation.

The different grades of soil examined, sands, silts and clays, do not exhibit any marked differences in chemical composition. Clays and clay loams generally contain less total silicon and slightly increased percentages of iron, aluminum and potassium.

When these soils are considered with respect to their calcium carbonate content, considerable differences in the amounts of total and fifth normal nitric acid-soluble constituents are found. Calcareous soils contain less total silica and are more liberally supplied with phosphorus and potassium than the non-calcareous soils.

Black clay loams contain larger amounts of phosphorus and nitrogen than the other soils analyzed; these soils were of limestone origin and all except two contained calcium carbonate.

In sampling the soils studied, two depths were taken, the surface 6 inches and 6 to 36 inches called subsoil. One of the marked differences between the surface soil and the lower stratum is that the surface soil contains more phosphorus than the subsoil; this was found to be the case except in a very few instances where the subsoil contained considerable quantities of calcium carbonate. The nitrogen associated with the increased amounts of organic matter is present in greater quantity in surface soils.

Aside from their phosphorus content and amount of incorporated organic matter from plant remains, the chief distinction between the surface soil and the subsoil is their difference in texture. The surface soil contains more fine particles than the subsoil. This is shown by the relative proportion of the more abundantly distributed soil constituents found in the two depths; more total silicon is present in the upper layer of soil, while the lower stratum contains increased quantities of silicon soluble in fifth normal nitric acid, and more total iron, aluminum and potassium.

The calcium and magnesium content is of interest. In soils containing no calcium carbonate, more calcium is present in the surface than in the subsoil, while the subsoil contains more magnesium.

Both calcium and magnesium are present in larger amounts in the subsoil than in the surface 6 inches of soils containing calcium carbonate; the calcium being in excess of the magnesium, while for non-calcareous soils magnesium is always greater than the calcium in the subsoil. The greater number of non-calcareous soils contain more magnesium than calcium. All the soils examined have a much larger amount of calcium than of magnesium soluble in fifth normal nitric acid.

The relation between soil acidity and calcium carbonate, which has been investigated in regard to phosphorus availability as measured by chemical methods, shows that the litmus paper test, if properly made, is a satisfactory qualitative test for the presence or absence of natural calcium carbonate in soils. Of 126 surface soils examined for calcium carbonate and reaction, only five of those containing calcium carbonate reddened blue litmus paper. All the soils which gave an alkaline reaction with red litmus contained calcium carbonate.

The loss of calcium carbonate from cultivated soil is indicated by the amount residual from an application of 12,000 pounds per acre to an acid soil. This soil was limed in 1907 and an analysis in 1912 showed a loss of 9,900 pounds during the five years.

Many of the surface soils from the western section of the State contain considerable quantities of calcium carbonate and in practically all cases the corresponding subsoil contains an increased amount. All soils from the eastern section show a decided deficiency of calcium carbonate.

The total phosphorus content of the soils studied varies from .30 percent or 6,000 pounds per acre to .025 percent or 500 pounds of phosphorus per acre six inches of soil. Fourteen of the one hundred and twenty-six surface soils examined show the presence of more than .10 percent of total phosphorus.

The averaged results of the chemical examination of a large number of calcareous and non-calcareous soils show that those containing calcium carbonate have a larger supply of total phophorus than the non-calcareous soils. The average phosphorus content of calcareous surface soils is 1,310 pounds per acre, compared with 913 pounds and 986 pounds for the non-calcareous soils from the eastern and western sections of the State.

Soils classed as black clay loams contained the largest amount of total phosphorus followed by the calcareous clays and clay loams.

Considering the fifth normal nitric acid-soluble phosphorus to be a measure of phosphorus availability, the results obtained show that soils giving an alkaline reaction and containing natural supplies of calcium carbonate have a greater supply of available phosphorus than do acid soils.

The soils classed as sands and sandy loams have a larger proportion of their total phosphorus content soluble in fifth normal nitric acid than do the silts and clays, 30 percent of the total phosphorus in the calcareous sands and sandy loams being soluble. The amount of fifth normal nitric acid-soluble phosphorus in the non-calcareous sands and sandy loams is approximately the same as found for the calcareous silts and clays.

The fifth normal nitric acid-soluble phosphorus of the black clay loams which are calcareous is greater than that of any of the other classes of soils, with the exception of calcareous sands and sandy loams.

A deficiency of available phosphorus is indicated by the low solubility of phosphorus for the non-calcareous silts and silt loams, clays and clay loams which show an acid reaction.

ADDENDA

METHODS OF SOIL ANALYSES

Collecting sample: From 10 to 20 borings with a 1-inch soil auger are taken and thoroughly mixed. When samples are not taken below a depth of 2 feet, a more satisfactory sampling can be made with a soil sampling tube.

Preparation of sample: After the sample is thoroughly air dried it is pulverized in a porcelain pebble mill to pass a 0.5 mm. sieve. For total constituents a sub-sample of 50 grams is reground to pass fine bolting cloth (No. 15). All samples are carefully preserved in tight glass containers.

Moisture: Five grams of finely pulverized soil are weighed into an aluminum drying dish 2½ inches in diameter and 1 inch deep, provided with a tight cover. The soil is dried at a temperature of 110° C. for 5 hours, covered and allowed to cool in desiccator previous to weighing.

TOTAL CONSTITUENTS

Fusion for silicon and aluminum: Weigh .5 grams of soil into a platinum crucible containing 2.5 grams of a mixture of sodium and potassium carbonates, mixed in molecular proportion. After the soil is thoroughly mixed with the fusion mixture the crucible is covered and the contents melted at a moderate heat over a Bunsen burner; when fused the crucible is heated over blast until the soil is completely decomposed, this requires about 15 minutes. The melt is poured as quickly as possible into a dry platinum dish set in a beaker containing sufficient water to cover about one-sixth of the outside of the dish. As soon as the bead is sufficiently cool, as indicated by the sinking in of the top, it is transferred to a beaker containing 60 cc. of water in which the crucible containing the remainder of the fusion has previously been placed (the crucible can easily be cleaned in from 5 to 15 minutes and the whole sample is frequently disintegrated in this time). The crucible is washed out with a small quantity of hydrochloric acid, transferring the washings to a covered beaker containing the bulk of the fusion; when the sample is thoroughly disintegrated a small excess of hydrochloric acid is added from a burette, through the lip of the covered beaker. The beaker is placed on steam bath and after all effervescence has ceased the cover is removed and the solution evaporated to dryness; allowed to bake for one hour* when 3 cc. of hydrochloric acid and 10 cc. of water are added. The sample is well broken up with a stirring rod and again evaporated to dryness. The residue is taken up with

*Do not stir solution or break up gelatinous mass, but allow it to evaporate and bake until ready to add HCl.

dilute hydrochloric acid and heated on steam bath until all salts are dissolved; the separated silica is filtered out and washed a few times with dilute hydrochloric acid. After washing free from chlorides the silica is ignited in platinum crucible for at least 30 minutes and weighed.

Aluminum: Aluminum may be determined in the filtrate by either the potassium hydroxid or the sodium thio-sulphate method. For soils containing considerable calcium carbonate the latter method is preferable. When the aluminum content is very high, if the potassium hydroxid method is used, two precipitations are necessary, adding a small amount of phosphate solution before making the second precipitation. The double precipitation facilitates the removal of occluded potassium salts.

Potassium hydroxid method for aluminum: The filtrate from the silicon determination is concentrated to 100 cc., transferred to a 200 cc. flask containing 50 cc. of a 10 percent solution microcosmic salt or ammonium phosphate, and 20 cc. of a 50 percent potassium hydroxid solution. The contents of the flask are heated to 100° for 30 minutes with occasional shaking. After cooling to room temperature the solution is made up to 200 cc., thoroughly shaken and filtered. Of the clear filtered solution 100 cc. (equal to .25 grams of soil) are diluted to about 200 cc.; a few drops of methyl orange are added and the solution slightly acidified with nitric acid, then made slightly alkaline with ammonium hydroxid. After heating at a temperature of 65° until the precipitate settles, which requires about 30 minutes, the precipitate is filtered off and washed 15 times with a 5 percent solution of ammonium nitrate. After drying between blotting paper it is ignited over a blast for 20 minutes, cooled and weighed as $AlPO_4$.

Sodium thio-sulphate method for aluminum: The filtrate from the silicon determination is neutralized with ammonium hydroxid and slightly acidified with hydrochloric acid; 2 cc. concentrated hydrochloric acid and 10 cc. of a 10 percent solution of ammonium phosphate are added. The solution is evaporated to 300 cc.; then 10 grams of sodium thio-sulphate and 15 cc. of acetic acid (one part glacial acetic acid and two parts water) are added. After heating on hot plate for 15 minutes the precipitated aluminum phosphate and admixed sulphur are filtered off, washed with a hot 5 percent solution of ammonium nitrate, ignited and weighed as $AlPO_4$.

Iron: One gram of finely ground soil is fused as for total silicon. After evaporation and filtering off SiO_2, iron is precipitated from the filtrate with ammonium hydroxid; the precipitated iron is filtered, washed 6 times with hot water and transferred from filter paper into precipitating beaker by means of a jet of hot water. After dissolving in hydrochloric acid, iron is determined with N-100 potassium bichromate solution following the usual procedure.

Calcium: One gram of the finely ground soil is fused as directed under the method for total silicon. The filtrate from the separated silica is treated as follows: The volume being about 150 cc. (2 cc. of a 10 percent solution of ferric chloride may be added)* a slight excess of ammonium hydroxid is added to the solution; after heating to boiling, the precipitated iron and aluminum hydroxides are filtered off on 11 cm. filter paper and washed 4 times with hot water. The precipitate is washed from the filter paper back into the beaker in which the precipitation was made. A slight excess of hydrochloric acid is added and heated until solution is complete. A second precipitation of iron and aluminum is made, the filtrate being received in beaker containing the first filtrate. The solution is evaporated to about 250 cc., made alkaline with ammonium hydroxid and allowed to cool. Sufficient bromine water (approximately 20 cc.) is added to precipitate the manganese; after heating to boiling the manganese is filtered off and washed. The volume of the filtrate being about 200 cc., calcium is precipitated as oxalate by the addition of ammonium hydroxid and a small excess of a saturated solution of ammonium oxalate to the hot solution; heat to boiling for fifteen minutes, allow to stand on steam bath for two hours or if more convenient over night. The precipitated calcium oxalate is filtered on asbestos mat in filter tube, using suction, and washed with hot 2 percent ammonium hydroxid solution. The precipitate and asbestos mat are transferred to precipitating beaker; 100 cc. of distilled water and 25 cc. of concentrated sulphuric acid added. Mixture of acid and water will generate sufficient heat for titration. Calcium is determined volumetrically with N-20 potassium permanganate solution.

Magnesium: The filtrate from the precipitation of calcium oxalate is evaporated in a 400 cc. beaker to about 100 cc.; after cooling, 20 cc. concentrated nitric acid are added, the beaker covered and evaporated to dryness on hot plate to remove ammonium salts; 10 cc. of hydrochloric acid are added and the solution evaporated nearly to dryness. The residue is dissolved in hot water and a small amount of hydrochloric acid; if necessary the solution is filtered, and the filter paper washed with about 100 cc. of hot water. The volume of the solution being about 100 cc., the magnesium is precipitated as magnesium ammonium phosphate by the addition of 3 cc. of a 10 percent solution of ammonium phosphate and sufficient ammonium

*To facilitate filtering and washing.

hydroxid to make the solution slightly alkaline; stir vigorously; allow to stand fifteen minutes and add 15 cc. of ammonium hydroxid and allow precipitation to proceed over night. Precipitate is filtered off on a 9 cm. filter paper and washed with a 2 percent ammonium hydroxid solution; placed in porcelain crucible, dried and ignited in electric muffle furnace.

Manganese: One gram of soil is fused as previously directed for total silicon. When the sample is thoroughly disintegrated add an excess of nitric acid; evaporate to dryness on steam bath; take up residue with 50 cc. 1-1 nitric acid; heat to effect solution and filter. Evaporate solution to a volume of 50 cc. and add .5 gram of sodium bismuthate, agitating solution for 15 minutes; then add 50 cc. of 3 percent nitric acid; filter through asbestos mat into a 300 cc. Erlenmeyer flask, using suction; wash with 50 to 100 cc. of 3 percent nitric acid. Run into filtered solution a measured excess of ferrous ammonium sulphate solution and titrate to a faint pink color with standard permanganate. For further details of the method see Blair's Chemical Analysis of Iron, 7th edition, pp. 121-122; or The Journal of Am. Chem. Soc., Vol. XXV, p. 793. The first treatment with sodium bismuthate is omitted because all oxidizable substances, organic matter and hydrocarbons have been destroyed by fusion.

Phosphorus: The magnesium nitrate method is used for the determination of total phosphorus.* Weigh into a 50 cc. porcelain dish 5 grams of soil, moisten with 5 to 7 cc. of magnesium nitrate solution (Bureau of Chem., Bulletin 107, Rev., p. 2, Sec. g.), bring to dryness on steam bath and burn off organic matter at low redness; when cool break up with a heavy glass rod and moisten slightly with water; add 5 cc. of concentrated hydrochloric acid and 3 cc. of concentrated nitric acid; digest for 2 hours on steam bath, keeping dish covered and stir 2 or 3 times during digestion. Transfer into 250 cc. flask having excess of hydrochloric acid present; make up to a volume of 250 cc. Mix well and throw on a dry folded filter, pouring back on the filter until the solution runs through clear. Make the determination on aliquots corresponding to 2 or 4 grams of soil, depending upon the amount of phosphorus present; bring to dryness on steam bath and take up with 4 cc. concentrated nitric acid and water; evaporate to dryness the second time, taking up with 2 cc. nitric acid and hot water. Filtrate and washing should not exceed 50 cc. Add gradually while stirring 5 to 15 cc. of molybdate solution (Bureau of Chemistry, Bull. 107, Rev., p. 2); allow to stand a minute or two and add 5 grams of dry ammonium nitrate, stirring thoroughly. Heat the solution at a temperature of 40 to 50° for one hour and allow to

*Proceedings of the Association of Official Agricultural Chemists, Bureau of Chemistry, Circular 43 stand over night at room temperature. Filter on asbestos pad placed in filtering tube; wash well with cold water or a .25 percent solution of potassium nitrate. Transfer filtering pad and precipitate to precipitating beaker using as little wash water as possible. Determine phosphorus volumetrically, using standard potassium hydroxid and nitric acid.

Potassium: The fusion for total potassium is made according to the Lawrence Smith method for total alkalies. After the alkalies are dissolved out of the fusion several modifications of the usual procedure for the determination of potassium are used. Grind very thoroughly in agate mortar 0.5 gram of soil with 0.5 gram of ammonium chloride; when finely ground add 4 grams of calcium carbonate and grind until well mixed. Place a little calcium carbonate in the bottom of a clean, dry, Smith crucible, then charge the crucible with the contents of mortar, and finally rinse mortar with about 0.5 gram of calcium carbonate, which add to crucible together with the brushings from paper on which mortar has stood while grinding. Tap well to settle; place in asbestos cylinder and heat at low temperature until ammonium fumes no longer escape. Move crucible frequently so as to heat all parts of mixture alike. Avoid heating hot enough to cause escape of ammonium chloride. Next turn up burner and heat for 45 minutes at the highest temperature to be secured with a good Bunsen; this will be at a bright red but a little short of whiteness. A piece of wire gauze over the top of the cylinder will prevent the burner from being easily extinguished by drafts. Turn the crucible often. Let cool, rinse cover of crucible into a 4-inch porcelain dish; loosen fusion from crucible with the aid of glass rod if necessary and transfer to dish; fill crucible with hot water, let stand a few minutes, rinse into dish; cover with large watch glass and let stand until fusion slakes thoroughly; this slaking usually takes place readily enough, but with some samples not. This, however, makes little difference. The fusion should stand thus over night, at least, although heating on the steam bath will hasten disintegration. When ready to filter, grease lip of dish, stir up contents with rod, and decant onto 11 cm. filter; receive filtrate in 400 cc. Jena beaker. Grind residue in dish with pestle, add some boiling water, stir up and decant; repeat a couple of times. Grind residue again and transfer all to filter. Rinse dish twice with hot water onto filter. Wash eight times on filter with boiling water. This will usually fill the beaker and is amply sufficient. It is useless to attempt washing free from chlorine.

To the filtrate in beaker add 10 cc. concentrated hydrochloric acid, chemically pure, and evaporate, first, on hot plate, almost to dryness, then on steam bath, to dryness, or as nearly as possible

Filter with suction into 150 cc. beaker covered with perforated watch glass; filtrate will almost fill beaker. This filtration removes a slimy material which appears to be derived from the action of the caustic lime upon the filter during the first filtration, and a considerable amount of silica which would render the final filtration extremely slow. Add 1 cc. concentrated hydrochloric acid and 5 cc. platinic chlorid solution of such strength that 1 cc. equals 1 percent K_2O on 0.5 gram sample; evaporate on steam bath until solid; let cool; add 15 to 20 cc. acidulated alcohol and let stand until calcium chloride is dissolved. (Acidulated alcohol is made as follows: To 1500 cc. of 95 percent alcohol add 1139.9 cc. hydrochioric acid, sp. gr. 1.20, and pass enough hydrochloric acid gas into solution to make it 2.25—normal hydrochloric acid.) Filter in special potassium filter tube,[1] transfer all precipitate from beaker to filter, using 80 percent alcohol. Wash several times with Gladding wash, finally about 6 times with 80 percent alcohol. Dry filter tube, wash with hot water into weighed platinum dish, evaporate on steam bath to dryness, place dish covered with watch glass in drying oven and heat for 1 hour at 120° C.; weigh as K_2PtCl_6.

Carbonates: The method used is a modification of the method devised by Marr[2], using the apparatus devised by Gaither[3]. The procedure is as follows: From 2 to 20 grams of soil (depending upon the carbonate content) and 80 cc. of distilled water free from carbon dioxide are put into 250 cc. Jena reagent bottle; after thoroughly mixing the bottle is connected to apparatus and vacuum pump started. When a vacuum of 65 to 70 cm. is obtained 20 cc. of hydrochloric acid solution (2 cc. hydrochloric acid, 1.19 sp. gr. to 18 cc. of water) are run from separatory funnel into the bottle in which carbon dioxid in the soil is liberated. Boil for 30 minutes, keeping bottom of bottle about three-fourths inch above gauze, protecting it from the free flame; if liquid is thrown up into condenser, the flame should be lowered. The evolved carbon dioxid is absorbed in sodium hydroxid solution using NaOH made from metallic sodium, (25 cc. of 4 percent solution of sodium hydroxid and sufficient carbon dioxid free water to cover solid beads in absorption tower). After boiling 30 minutes, vacuum is relieved and liquid drawn out of absorption tower into 250 cc. beaker or flask. The tower is washed out with 250 cc. carbon dioxid free water. Add 1 cc. phenolphthalein and run normal hydrochloric acid into solution until red color begins to fade; finish titration with N-20 hydrochloric acid. When end point with phenolphthalein is reached add 2 drops of methyl orange

[1]Jour. Ind. Eng. Chem., 4. p. 436.
[2]Jour. Agr. Sci., Vol. 3, Pt. 2, pp. 155-160.
[3]Jour. Ind. & Eng. Chem., Vol. 4, p. 611.

solution, (1 gram to 1000 cc.) and titrate with N-20 hydrochloric acid. Continue the addition of acid until the lemon color of the alkaline methyl orange just darkens to a slight orange color. No account is taken of the cc.'s of acid used in titrating to end point with phenolphthalein. From the cc.'s of N-20 hydrochloric acid used subtract blank which will be approximately 4 cc. 1 cc. N-20 hydrochloric acid—0.0022 gram CO_2; equivalent to 0.0028 gram CaO or 0.005 gram $CaCO_3$.

Organic carbon: The combustion of the organic matter in soil is effected in a Parr calorimeter bomb by means of sodium peroxid and metallic magnesium as described by Pettit[1]. The carbon dioxid from the resulting sodium carbonate is determined volumetrically by the double titration method described under carbonates. The apparatus for carbonates in soils is used for the decomposition of the sodium carbonate and absorption of carbon dioxid liberated.

Nitrogen: Nitrogen in soils is determined by the Kjeldahl method completing the oxidation with potassium permanganate. Either 10 or 20 grams of soil are used, depending upon the organic content of the soil. Instead of transferring digested soil and solution from the 500 cc. glass digestion flask to copper distilling flask as is the usual practice, the digestion and distillation are made in the same flask. This is made possible by adding 2 grams of coarse aluminum to the flask when the distillation is started. The aluminum prevents bumping and the distillation proceeds quietly.

Organic matter soluble in 4 percent ammonium hydroxid solution: This portion of the soil organic matter which is ordinarily designated as "humus" is determined as follows: Five grams of soil with 250 cc. of 1 percent hydrochloric acid are placed in a liter bottle and agitated in shaking machine for 2 hours. The solution is filtered off through alundum extraction tube (33 mm. diameter at open end and 95 mm. long) which is fitted into glass cylinder connected with filtering flask. The acid extracted soil is washed with cold water to remove material dissolved by the acid treatment. The filtering tube is reversed and the soil washed out with 500 cc. of 4 percent ammonium hydroxid into original bottle, using suction. The bottle is placed in shaking machine and shaken for 5 hours. After standing over night to allow the coarse material to settle out, 300 cc. of solution are decanted into a 500 cc. stoppered cylinder. Sufficient dry ammonium carbonate is added to coagulate the clay particles. After standing a sufficient time the ammonium hydroxid solution is filtered through alundum extraction tubes. An aliquot of the solution free from clay is evaporated in tared platinum

[1]Jour. Am. Chem. Soc., Vol. 26, p. 295.

dish and the determination completed as usual. This method has been used in this laboratory for the past seven years and gives satisfactory results.

METHODS FOR N-5 NITRIC ACID SOLUBLE CONSTITUENTS

Preliminary digestion: Weigh 10 grams of soil into an Erlenmeyer flask; add 100 cc. N-5 nitric acid and allow to stand 5 hours at room temperature, shaking at intervals of 30 minutes; filter through a folded filter into a dry flask, rejecting the first 25 cc. of filtrate. Pipette off 20 cc. (equal to 2 grams of soil) and titrate with N-5 potassium hydroxid solution, using phenolphthalein as indicator. Subtract the cc.'s of potassium hydroxid used from the 20 cc.'s of N-5 nitric acid required to neutralize the bacidity of the soil; this added to original 20 cc. will give the amount of acid necessary to have very nearly N-5 nitric acid when digestion is complete.

Final digestion: Weigh 200 grams of soil into a 2500 cc. Winchester bottle and add 2200 cc. of nitric acid of such a strength that will give N-5 nitric acid at end of digestion. Shake until well mixed and digest at room temperature for 5 hours, shaking at intervals of 30 minutes. When digestion is complete, shake contents of bottle and pour into 32 cm. folded filter reenforced with 15 cm. round filter receiving the first 150 cc. in beaker and returning same to the filter paper. When the filtrate runs through clear it is received in dry Winchester bottles.

Silicon: Of the clear filtered solution 200 cc. are evaporated to dryness; taken up with 10 cc. concentrated hydrochloric acid and again evaporated to dryness, keeping beaker covered to prevent spattering of solution caused by the action of hydrochloric acid on nitrates. When thoroughly dry the residue is taken up with 5 cc. of hydrochloric acid and hot water; heated a few minutes and filtered through 9 cm. filters, washed 4 times with 1-6 hydrochloric acid and then with hot water until free from chlorides, then ignited and weighed.

Calcium: To the filtrate from silicon determination 2 cc. of 10 percent ferric chlorid solution and a slight excess of ammonium hydroxid are added. The precipitated iron and aluminum hydroxides are filtered and washed a few times with hot water. Transfer precipitate from filter to precipitating beakers; dissolve in hydrochloric acid and reprecipitate. The second filtration is made on the same filter and the filtrate received in the beaker containing the first filtrate. After evaporating to 100 cc. the solution is cooled then made alkaline with ammonium hydroxid, adding 1 cc. excess; 25 cc. of bromine water are added, allowed to stand without heating for a few minutes and covered with watch glasses and heated to boiling until the precipitated manganese settles out. A slight excess of acetic acid is added and the precipitate filtered and washed. Calcium is determined in the filtrate as outlined under the determination of total calcium.

Magnesium: Evaporate filtrate from calcium oxalate precipitate to about 100 cc.; add 30 cc. concentrated nitric acid; cover beaker with watch glass and evaporate to dryness on hot plate to expell all ammonium salts. Take up with 10 cc. hydrochloric acid and evaporate to dryness on steam bath; add 3 cc. hydrochloric acid and hot water; make alkaline with ammonium hydroxid and filter off any insoluble matter. Filtrate is slightly acidified with hydrochloric acid and magnesium is determined as under total magnesium.

Iron: Pipette 100 cc. of nitric acid solution into a beaker; add slight excess of ammonium hydroxid and heat nearly to boiling for 10 minutes; filter and wash 5 times with hot water. Wash precipitate from filter to precipitating beakers with a jet of water; dissolve with hydrochloric acid and determine iron with N-200 standard dichromate solution in the usual manner.

Aluminum: Aluminum is determined in 100 cc. of nitric acid solution, using the methods given under determination of total constituents.

Manganese: Measure off 100 cc. of soil solution into 400 cc. Erlenmeyer flask; add 15 cc. concentrated nitric acid and boil until volume of solution is approximately 50 cc.; allow to cool and add .5 gram sodium bismuthate and boil until dissolved. A few drops of 10 percent solution of sodium thio-sulphate are added until the color is destroyed. Boil off nitrous fumes; cool to 20°; add .5 gram of sodium bismuthate and finish determination as outlined for total manganese.

Phosphorus: 400 cc. of nitric acid solution (equal to 40 grams of soil) are evaporated to dryness and baked on steam bath for one-half hour. The residue is taken up with 5 cc. concentrated nitric acid and hot water; digest on steam bath until solution is complete. Filter off insoluble matter and wash; neutralize filtrate, which should have a volume of 75 cc., with ammonium hydroxid, adding a slight excess; make acid with nitric acid, adding ½ cc. excess. Add sufficient molybdate solution to precipitate the phosphorus (from 3 to 10 cc.) stirring vigorously; allow to stand for 5 minutes; add 5 grams solid ammonium nitrate and continue determination as under total phosphorus.

Potassium: Evaporate 200 cc. of nitric acid soil solution to about 50 cc. on hot plate; add 10 cc. hydrochloric acid and evaporate to dryness on steam bath, keeping beaker covered to prevent spattering. Add 5 cc. of hydrochloric acid and evaporate to dryness a second time; take up with 1 cc. of hydrochloric acid and 25 cc. of hot water; filter off separated silica on 9 cm. filter and wash thoroughly with hot water; the filtrate should have a volume of about 50 cc. Add a sufficient amount of platinic chloride solution and continue the procedure as outlined for total potassium.